UNITED STATES BANKRUPTCY COURT
SOUTHERN DISTRICT OF NEW YORK

IN RE;	**Chapter 11 Case No.:**
MOTORS LIQUIDATION COMPANY, et al., f/k/a General Motors Corp., et al.	**09-50026 (REG)**
	Claim No.:69683
Debtors.	

INDEX OF APPEAL

SHERIF R. KODSY
PRO'SE/APPELLANT
15968 LAUREL OAK CIRCLE
DELRAY BEACH, FLORIDA 33484
561-666-0237

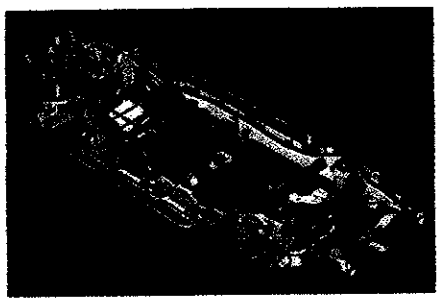
[Type text]

TABLE OF CONENTS

A

H2 CHASSIS TUNED TO OPTIMAL BLEND OF ON-ROAD COMFORT AND OFF-ROAD PROWESS

The chassis of the HUMMER H2 was painstakingly designed and engineered to provide a solid foundation for best-in-class off-road performance, while maintaining a refined, comfortable ride on pavement. Not only was the chassis specially tuned for superior off-road performance, it was designed to optimize the off-road balance between rock crawling and desert racing. Special attention was paid in areas of obstacle clearance, suspension articulation, wheel control and underbody protection.

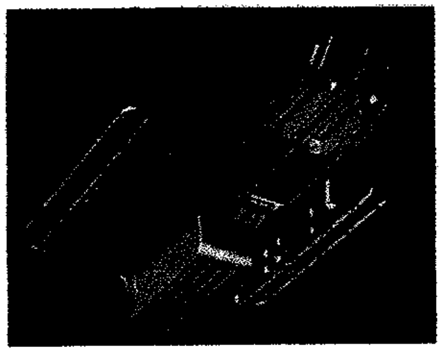


From the start of development of H2's frame design, all components were packaged flush with or above the frame rails. This provides better protection during underbody impacts. It also allows the vehicle to slide over obstacles more easily on the frame rail or rocker protection-H2 is not as likely as other vehicles to get hung up on any low-hanging components.

H2 was created with a long wheelbase, wide tread and short overhangs to provide superior control for the driver in varying types of road or terrain conditions. The short overhangs provide high approach and departure angles, allowing the H2 to drive right into a hole and out again, for example, without getting hung up in front or rear.

With its standard LT315/70R17 tires and air leveling suspension, the H2 has a 43.6-degree approach angle and 39.7-degree departure angle.

Special underbody protection, including large skid plates, helps define the H2's rugged character and enhance its performance characteristics. A thick (4mm) stamped aluminum front engine shield runs from right beneath the front bumper back to the transmission. It angles prominently up at the front, with the H2 logo pressed into the shield just below the bumper. A one-inch diameter tubular steel, ladder-type shield protects the transmission and the exhaust system's two catalytic converters. It is strong enough, when necessary, to briefly support the load of the vehicle sitting on a rock that it is passing over. A third, high-tensile strength, galvanized steel shield protects the transfer case. It has a special cantilevered design, which allows it to flex or spring back after coming into contact with a rock. The shield is designed so that the weight of the truck can move it up when traveling over a rock. But, once the truck has passed over a rock and the shield has done its job of protecting the transfer case, it springs right back to its previous position.



Unique rocker protectors bolt through the frame. Large, standard, black-painted steel tubes, running along each side of the vehicle, protect its lower body and door panels against rocks and stumps. The high-strength structural pieces bolt right into the frame with heavy brackets and are designed to withstand off-road impacts from beneath or from side angles. The rocker protectors are so strong they can be used to pivot the entire vehicle on a rock. The fuel tank also has its own heavy plastic shield, designed to absorb abrasions and hits that would otherwise contact the tank.

Such protective features greatly enhance the H2's performance capabilities because they allow it go places competitors cannot go.

Also providing superior off-road control is H2's solid rear axle setup. It helps optimize suspension articulation and gross motion control, giving the driver a precise sense of vehicle control in the tightest of situations.

CHASSIS CONSTRUCTION: THREE-PIECE, FULLY WELDED FRAME

A fully welded ladder-type frame, with a modular, three-piece design that incorporates a number of hydroformed components, provides outstanding strength, stiffness and dimensional accuracy for H2's chassis. The hydroformed front section helps create the H2's high approach angle. To improve the frontal crush zone, GM engineers added reinforcements in key box sections of the frame, enhancing its ability to absorb energy, crush and collapse.

Uncommonly flat crossmembers are used around the transmission mounting area to preclude any possible hang-up points. The tolerances for powertrain mount positions have also been tightened to reduce potential noise, vibration and harshness (NVH).

Because of H2's full-time 4WD system, GM engineers also took great care to minimize the NVH transmitted by the front axle to the frame, devising a special three-point mounting system to isolate it. Two forward mounts vertically connect the axle to the frame, while the rear mount attaches it to a crossmember that fits between the two lower control arm brackets in the frame.

The front frame section incorporates a GM-first standard winch receiver. It is designed to handle an impressive 9,000-pound capacity winch for freeing a vehicle that's helplessly grounded. An extension for the receiver could also be used for adding such accessories as a bicycle rack. The receiver itself has the same diameter as the standard integrated rear trailer hitch receiver. Therefore, the front receiver could also be fitted with a hitch that would allow pushing a boat into the water, for example. The winch platform, including the receiver and a bracket, is built right into a thick front crossmember as an integral part of the vehicle's design. Paired tow loops up front complement the distinctive HUMMER-style rear pivoting tow loops.

The mid-frame has a stamped-steel box section design, with common inner and outer sections and a clamshell-welded configuration. Its strength and stiffness help minimize ride and body vibrations, contributing to a smooth ride on-road and providing the strength and stiffness required to handle severe bumps and jolts. As in other GM SUVs, the composite fuel tank (with large, 33-gallon capacity) is mounted inside the left frame rail, ahead of the rear axle, for maximum protection.

The hydroformed, short rear-frame section helps create a high departure angle. It is heavily reinforced in key areas for H2's 8,600-pound GVWR capacity. The rear section incorporates a standard, integral trailer hitch receiver. Unlike with most SUVs (whose hitch receiver is added on), the H2's is built right into the last crossmember of the frame rail and developed into the bumper. A Class 3 trailer hitch is standard.

UNIQUE SUSPENSION INCLUDES NEW SELF-LEVELING REAR AIR SPRING SYSTEM

The H2's standard independent front torsion bar and five-link coil spring rear suspension provides excellent on-pavement ride comfort and control and a high degree of strength, control and rear-axle articulation off-road. An optional self-leveling air spring suspension for the rear takes comfort, control and off-road axle articulation to an even higher level.

FRONT SUSPENSION

The independent front torsion bar has 46mm monotube gas-charged shock absorbers, a large 35.9mm diameter tubular front stabilizer bar and unique tuning. The axle has a 4,000-pound capacity.

The front shocks contain unique features for off-road performance. They have a large, high-strength 40mm center tube and a secondary integral bump stop feature, which allows them to absorb jolts at two junctures. Full-size trucks typically have only one urethane front jounce bumper. When severe bumps push the suspension toward the frame, it acts like a final cushion to protect the suspension from hitting the frame. The H2 also has a secondary jounce bumper built into the shock. So, rather than taking all the load at the bump stop attached to the frame rail, it takes some of the load with the shock's built-in bump stop, slowing the suspension's travel before it hits its final cushion. The design is ideal for absorbing the extreme forces exerted on the jounce bumper during high-speed desert racing.

REAR SUSPENSIONS

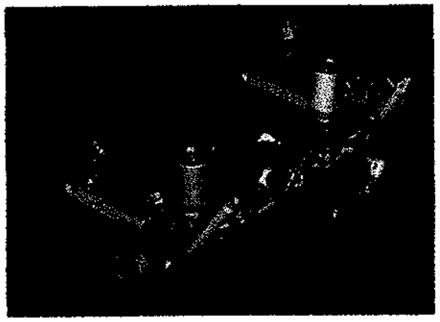
There are two suspensions available for the rear: a standard five-link trailing arm coil spring suspension and optional self-leveling air spring suspension, available with the off-road package. The package also includes an air compressor and tire inflation accessory.

The standard five-link coil spring suspension's basic linkages include two forged-steel upper control arms and two stamped-steel lower control arms with bushings on each side for better isolation. These components control the solid rear axle's fore-aft and vertical position; a track bar controls the axle's lateral position. This suspension is inherently much smoother than a leaf-spring system. H2's suspension also features brand new variable-rate coil springs, longer shock absorbers and different linkage positioning-all designed to provide more articulation for the rear axle during off-road operation.

The new variable-rate coil springs have a dual stage design for on-/off-road comfort and increased suspension articulation under demanding off-road conditions. On-road (or under lightly loaded conditions), their low or soft spring rate optimizes comfort. Off-road, the springs adjust themselves to varying road conditions. If a driver starts running through undulating terrain or speeding over rocks, the spring rate will progressively stiffen to help prevent high input forces at the rear from being transmitted to body and to keep the suspension from bottoming out. The springs actually progress from a low rate to a transitional and then a high rate. Aside from their excellent ride characteristics, they also provide good handling because, due to their progressive nature, they don't transfer weight to the same degree as conventional coil springs, thereby minimizing vehicle roll.

A specifically tuned, 30mm diameter rear stabilizer bar helps enhance off-road control. It has a tubular design, with a 5mm wall thickness, designed to provide high strength in a lightweight design. Like the stabilizer bar used with the air spring suspension, it is also specially contoured to help protect the more delicate drop links.

The optional, self-leveling air spring suspension system is brand new for GM. The system is available with the off-road suspension package. Targeted to dedicated off-road enthusiasts, it includes a high-capacity air compressor and inflation accessory. Rim protection, a reinforcement of the tire design that extends the durable rubber over the rim of the wheel, and triple sidewalls are standard as well. Rim protection adds extra protection to the tires and prevents them from slipping off the wheels when aired down.



The air spring suspension system's numerous benefits include:

· A smooth on-road ride. The air springs provide a 4.3-Hz rating (natural frequency), compared to the 4.5-Hz rating of the standard coil spring suspension.

· A longer suspension stroke for off-road operation. Longer, 719mm length shocks are used to provide an additional 20mm of rebound travel over that of the coil spring suspension. This improves traction by helping to maintain wheel contact with the ground over undulating terrain. The shock absorbers, although having the same 46mm diameter as those with the coil spring suspension, also feature a larger-diameter-size rod for increased durability.

· Automatic load leveling. If a customer loads up the rear of an H2, for example, the automatic load leveling suspension system will detect the drop in ride height and pump more air into the springs to restore a level condition. It has height sensors attached to the suspension links, which monitor and determine deviations from the standard height, and the system adjusts accordingly. The system includes an air dryer, which removes all the moisture from the air to prevent it from contaminating or degrading the springs. Because it's a closed system, once the springs are charged, they won't lose pressure.

· A driver-selectable rear suspension height elevation ("extended ride height") provides extra ground clearance at the rear and improves the vehicle's departure angle. Off-road, if the truck is in the "4 LO" transfer case mode, the driver can raise the rear suspension by 50mm (about two inches) using a ride height switch on the instrument panel. This increases the H2's rear departure angle from 35.9 degrees to 41 degrees. Once the vehicle's wheels are freed and driver leaves the rock, the system can be returned back to normal. Anytime the vehicle exceeds 20 mph, the system automatically restores the rear suspension to its standard height. Also, at freeway speeds (beginning around 50 mph), it will lower the rear end slightly to further improve the vehicle's stability.

B

HUMMER

LIKE NOTHING ELSE.™

2008 HUMMER H2 S

STANDARD EQUIPMENT

ITEMS FEATURED BELOW ARE INCLUDED AT NO EXTRA CHARGE IN THE STANDARD VEHICLE PRICE SHOWN

•5 YEAR / 100,000 MILE POWERTRAIN LIMITED WARRANTY SEE DEALER FOR DETAILS

CHASSIS / SUSPENSION

•ENGINE, 6.2L V8 VORTEC, 393 HP
•TRANSMISSION, 6 SPD AUTOMATIC
•3-PIECE LADDER-TYPE FRAME
•INDEP FRONT SUSPENSION W/TORSION BARS
•COIL SPRING REAR SUSPENSION
•TRANSFER CASE, ELECTRONIC
•ELEC LOCKING REAR DIFFERENTIAL
•FRONT & REAR RECOVERY LOOPS
•UNDERBODY PROTECTION
•ROCKER PANEL PROTECTION
•8600 LB GVW RATING
•REAR AXLE - 3.73

SAFETY & SECURITY

•STABILITRAK-STABILITY CONTROL
•AIRBAGS, DUAL FRONTAL, PASSENGER SIDE DEACTIVATION
•HEAD CURTAIN SIDE AIRBAGS, FRONT/REAR
•REMOTE VEHICLE START
•REMOTE KEYLESS ENTRY
•ANTILOCK BRAKE SYSTEM, HYDRAULIC POWER 4 WHEEL DISC
•TRACTION CONTROL SYSTEM
•DAYTIME RUNNING LAMPS
•AUTO HEADLAMPS
•THEFT DETERRENT SYSTEM
•BATTERY RUNDOWN PROTECTION
•1 YR ONSTAR DIRECTIONS W/TURN-BY-TURN NAVIGATION (ASK DEALER ABOUT GEOGRAPHIC COVERAGE)

INTERIOR FEATURES

•SEATS, FRONT BUCKET, FULL LEATHER DRIVER & FRONT PASSENGER HEATED SEATS
•PWR SEAT ADJUST, DRIVER, FRONT PASSENGER 8 WAY POWER LUMBAR, DRIVER, FRONT PASSENGER
•FOLD-FLAT REAR HEATED SEATS
•CRUISE CONTROL
•AUTO DUAL ZONE CLIMATE CONTROL
•CLIMATE CONTROL, REAR SEAT
•ILLUMINATED CENTER CONSOLE
•GLOBAL EXPRESS DOWN POWER WINDOWS
•REAR WINDOW DEFOGGER
•DRIVER INFORMATION CENTER
•LEATHER WRAP STEERING WHEEL W/ REDUNDANT CONTROLS
•MAP POCKETS IN FRT & RR DOORS
•AM/FM STEREO, 6 DISC CD CHANGER, W/ AUX. INPUT JACK
•AUDIO SYSTEM, BOSE PREMIUM SOUND, 9 SPEAKERS
•XM SATELLITE RADIO - SERVICE FEE EXTRA. 1ST 3 MOS. INCL.

EXTERIOR FEATURES

•REAR SPARE TIRE CARRIER
•CHROME DOOR HANDLES

EPA Fuel Economy Estimates

These estimates reflect new EPA methods beginning with 2008 models.

CITY MPG

Expected range for most drivers
XX to **XX** MPG

NOT APPLICABLE TO THIS VEHICLE

HIGHWAY MPG

Expected range for most drivers
XX to **XX** MPG

Your actual mileage will vary depending on how you drive and maintain your vehicle.

ZZZ

See the FREE Fuel Economy Guide at dealers or www.fueleconomy.gov

This veh
for front

Source:
Adminis

EXTERIOR: SLATE BLUE METALLIC
INTERIOR: EBONY

ENGINE, 6.2L V8 VORTEC
TRANSMISSION, 6 SPD AUTOMATIC

Visit us at www.HUMMER.com

HROME FUEL FILLER DOOR
OWER FOLDING HEATED OUTSIDE
RRORS
RONT WINCH RECEIVER
ASS III TRAILER HITCH
CEIVER
7" ALUMINUM WHEELS
RES, LT315/70R17
/OFF ROAD, BLACKWALL

TIONS & PRICING

MANUFACTURER'S SUGGESTED RETAIL PRICE

TANDARD VEHICLE PRICE $56,690.00

ONS INSTALLED BY THE MANUFACTURER (MAY REPLACE
DARD EQUIPMENT SHOWN)

VENTURE PACKAGE INCL:	1,555.00
SUSPENSION PACKAGE INCL:	
R COMPRESSOR	
R SPRINGS	
GUARD	
AID/SUPERTOOL/FLASHLIGHT	

THIRD ROW SEAT	860.00
(DELETES REAR CARGO MAT)	
UNIVERSAL HOME REMOTE	105.00
TOTAL OPTIONS	$2,520.00
TOTAL VEHICLE & OPTIONS	$59,210.00
DESTINATION CHARGE	900.00
TOTAL VEHICLE PRICE*	**$60,110.00**

RNMENT SAFETY RATINGS

not been rated by the government
, side crash or rollover risk.

l Highway Traffic Safety
(NHTSA).

fercar.gov or 1-888-327-4236

This label has been applied pursuant to Federal law - Do not remove prior to delivery to the ultimate purchaser. *Includes Manufacturer's Recommended Pre-Delivery Service. Does not include dealer installed options and accessories not listed above, local taxes or license fees.

ORDER NO MNRNK1 SALES CODE E
SALES MODEL CODE RN25706
DEALER NO 31035
FINAL ASSEMBLY MISHAWAKA, IN U.S.A.

VIN 5GRGN23878H107653

DEALER TO WHOM DELIVERED
GENERAL MOTORS CORPORATION
100 RENAISSANCE CTR/482-A25-C48
DETROIT, MI 48265-1000

RO
1GA0807580

TRANS ID 55307817 TITLE NUMBER 10130802

CERTIFICATE OF ORIGIN FOR A VEHICLE

32
17-35

80

4768

RBLPD019
INVOICE NO.

DATE
01/30/08

HID00288159

VEHICLE IDENTIFICATION NO.	YEAR	MAKE
5GRGN23878H107653	2008	HUMMER

BODY TYPE
HUMMER 4-DOOR SUV

SHIPPING WEIGHT
6550

H.P. (S.A.E.)	G.V.W.R.	NO. CYLS.	SERIES OR MODEL
52.0	8600	08	RN25706

N.T.R.
3/4

I, the undersigned authorized representative of the company, firm or corporation named below, hereby certify that the new vehicle described above is the property of the said company, firm or corporation and is transferred on the above date and under the Invoice Number indicated to the following distributor or dealer.

NAME OF DISTRIBUTOR, DEALER, ETC.

31035 MNRNK1

GENERAL MOTORS CORPORATION
100 RENAISSANCE CTR/SE/482-A25-C48
DETROIT MI 48265-1000

It is further certified that this was the first transfer of such new vehicle in ordinary trade and commerce.

```
***************
* THIS VEHICLE*
*    HAS A    *
*  50-STATE   *
*  EMISSION   *
*   SYSTEM    *
***************
```

GENERAL MOTORS CORPORATION
& SUBSIDIARIES

BY: [signature]
(SIGNATURE OF AUTHORIZED REPRESENTATIVE) (AGENT)

G52109543

DETROIT MI 48243-1114
CITY - STATE

GM 521 REV. 10-05

55I 97031 Atlanta 6

Needs auth

D

USTOMER #: 105741 540280

INVOICE

CORAL CADILLAC
The Dealer Is In

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
NTON BEACH, FL 33437
ME:561-758-9858 CONT:N/A
US: CELL:

PAGE 1

NOBODY OUT CADILLACS CORAL CADILLAC

GM Parts

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		5224/5228	T3816

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 22OCT08			CASH	23OCT08

R.O. OPENED	READY	OPTIONS:
6:19 20OCT08	16:06 23OCT08	STK:P08372 DLR:21038 1)DD CHECKED

```
INE OPCODE TECH TYPE HOURS                               LIST      NET     TOTAL
 CUSTOMER STATES ENGINE WON'T STAY RUNNING
AUSE: MAS AIR FLOW SENSOR SHORTED OUT SET PO172 P0175 RICK CODES
    J5670 MASS AIRFLOW SENSOR REPLACEMENT
          47  WH2                                                          (N/C)
      1 15904068 SENSOR AS                                                 (N/C)
       FC: 6G
       PART#: 15904068
       COUNT: 1
       CLAIM TYPE:
       AUTH CODE:    E
       OJ
    J6354 POWERTRAIN CONTROL MODULE ENGINE
       REPROGRAMMING WITH SPS
          47  WH2                                                          (N/C)
       FC: 96 PART#: COUNT: 0
       CLAIM TYPE:
       AUTH CODE:    B
       MA

ARTS:      0.00  LABOR:      0.00  OTHER:      0.00  TOTAL LINE A:         0.00

5228 MAS AIR FLOW SENSOR SHORTED OUT SET PO172 P0175 RICK CODES
REPLACED MAS AIR FLOW SENSOR AND CLEARED AND REPROGRAMMED ECM WITH
UPDATED WCC 111AD FOR ECM R/R SPARK PLUGS AND CLEAN FROM MAS AIR FLOW
FAULED OKOLH FOR PROGRAM AND R/R SPARK PLUGS 1.1 OK 18618318 OK #18
     ***************************************************
 08080 SERVICE UPDATE INVENTORY ONLY - TRANS CONTROL MODULE REPGM
AUSE: TCM UPDTAED PROGRAM WCC 18F45
    V1741 Reprogram Transmission Control Module (TCM)
          47  WH2                                                          (N/C)
       FC: 93 PART#: COUNT: 0
       CLAIM TYPE:
       AUTH CODE:
```

ISCLAIMER OF WARRANTIES:
he seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any nplied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes or authorizes any other person to assume for it any liability in connection with the sale of the vehicle or roduct.
P.L. 93-637).
UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL IAGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY CTION."
OMER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE HEREOF.

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER COPY

1

CUSTOMER #: 105741 540280

INVOICE

PAGE 2

CORAL CADILLAC
The Dealer Is In

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

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GM Parts

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
NTON BEACH, FL 33437
HOME:561-758-9858 CONT:N/A
BUS: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
BLUE	08	HUMMER H2	5GRGN23878H107653		5224/5228	T3816

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
19AUG08 DD		11JUN2012	17:00 22OCT08			CASH	23OCT08

R.O. OPENED	READY	OPTIONS:
16:19 20OCT08	16:06 23OCT08	STK:P08372 DLR:21038 1)DD CHECKED

LINE OPCODE TECH TYPE HOURS LIST NET TOTAL

MA

PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B: 0.00

5228 TCM UPDTAED PROGRAM WCC 18F45 REPROGRAMMED TCM AND CLEARED ALL CODES

****

C COURTESY SERVICE WASH
ISW COURTESY SERVICE WASH
837 ISH (N/C)
PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE C: 0.00

5224 ISW DONE

****

D** CUSTOMER STATES CD PLAYER INOP
CAUSE: RADIO SHORTED OUT WON,T PLAY ANY CDS
R0760 RADIO, REMOVE AND REPLACE
47 WH2 (N/C)
1 EX RADIO (N/C)
FC: 80C00
PART#:
COUNT: 0
CLAIM TYPE:
AUTH CODE:
OJ

PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE D: 0.00

5228 RADIO SHORTED OUT WON,T PLAY ANY CDS REPLACED RADIO AND PROGRAMMED WCC 80C00 AND SET AS NEEDED

****

E** CUSTOMER STATES EXCESSIVE RUST UNDER FRONT OF VEHICLE

DISCLAIMER OF WARRANTIES:
The seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any implied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes nor authorizes any other person to assume for it any liability in connection with the sale of the vehicle or product.
(P.L. 93-637).
"I UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL MAGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY INSPECTION."
CUSTOMER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE HEREOF.

X ______________________
CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

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(2)

CUSTOMER #: 105741 540280

INVOICE

PAGE 3

CORAL CADILLAC
The Dealer Is In!
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BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS CORAL CADILLAC

GM Parts

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93 LAUREL GREEN DRIVE
NTON BEACH, FL 33437
HOME:561-758-9858 CONT:N/A
BUS: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

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19AUG08 DD		11JUN2012	17:00 22OCT08			CASH	23OCT08

R.O. OPENED	READY	OPTIONS:
16:19 20OCT08	16:06 23OCT08	STK:P08372 DLR:21038 1)DD CHECKED

LINE OPCODE TECH TYPE HOURS LIST NET TOTAL

CAUSE: R/R BOTH FRONT AXLE AND TIE ROD ENDS RUSTING
E8040 TIE ROD, INNER RIGHT ~~REPLACE~~ R+R (10) 10/23
47 WH2 (N/C)
1 12345327 PAINT (N/C)
FC: 5W PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE:
VD
E8041 TIE ROD, INNER LEFT ~~REPLACE~~ R+R (10) 10/23
47 WH2 (N/C)
FC: 5W PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE: B
VD

PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE E: 0.00

5228 R/R BOTH FRONT AXLE AND TIE ROD ENDS RUSTING R/R BOTH FRONT AXLES AND COATED WITH POR 15 RUST #PIT3749B: Underbody Corrosion AND COATED TIE ROD ENDS AS WELL

****

** FOUND DURING REPAIR, BEFORE RADIO WAS REPLACED, L/CENTER A/C DEFLECTOR IS COMING APART
CAUSE: LEFT CENT A/C VENT LOOSE AND WON,T HOLD POSTION
C2313 INSTRUMENT PANEL CLUSTER TRIM PLATE BEZEL REPLACEMENT
47 WH2 (N/C)
1 25954826 BEZEL (N/C)
FC: 4N
PART#: 25954826
COUNT: 1
CLAIM TYPE:
AUTH CODE:

DISCLAIMER OF WARRANTIES:
The seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any implied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes or authorizes any other person to assume for it any liability in connection with the sale of the vehicle or product.
P.L. 93-637).
I UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL MAGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY ECTION."
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CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER COPY (3)

USTOMER #: 105741 540280

INVOICE

PAGE 4

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS CORAL CADILLAC

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
NTON BEACH, FL 33437
IOME:561-758-9858 CONT:N/A
US: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		5224/5228	T3816

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 22OCT08			CASH	23OCT08

R.O. OPENED	READY	OPTIONS:
6:19 20OCT08	16:06 23OCT08	STK:P08372 DLR:21038 1)DD CHECKED

INE OPCODE TECH TYPE HOURS LIST NET TOTAL
VK

ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE F: 0.00

5228 LEFT CENT A/C VENT LOOSE AND WON,T HOLD POSTION REPLACED
COMPLETE RADIO BEZEL ASSEMBLY WITH BOTH A/C VENTS
****
** CUSTOMER CAME BACK TO DEALERSHIP AND STATED L/F SEAT HEATER IS INOP
AT TIMES AND WILL GOFF OFF AFTER BEING ON FOR 5 MINUTES
2000 VEHICLE IS OPERATING TO SPECIFICATIONS AT
THIS TIME.
47 ISH (N/C)
TS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE G: 0.00

5224 WORK AS DESIGN AT THIS TIME NO BULLTIENS NO UPDATED PROGRAMS
FOR HEATER MODULE
****
** REPAIR DINGS ON L/R DOOR AND R/F DOOR ANS PER JACK GARDNER
3050 SUBLET REPAIRS
309 SUBLET TECH LIC#: 256
IUCI (N/C)
UBL PO#168998,PAINTLESS DENT REPAIR,REPAIR DENTS
PO#540280
IUCI (N/C)
ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE H: 0.00
****

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER COPY

:USTOMER #: 105741 540280

INVOICE

PAGE 5

CORAL CADILLAC

The Dealer Is In

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS CORAL CADILLAC

GM Parts

...ERIF RAFIK KODSY
...393 LAUREL GREEN DRIVE
...NTON BEACH, FL 33437
...IOME:561-758-9858 CONT:N/A
...US: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
...LUE	08	HUMMER H2	5GRGN23878H107653		5224/5228	T3816

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
...9AUG08 DD		11JUN2012	17:00 22OCT08			CASH	23OCT08

R.O. OPENED	READY	OPTIONS:
...6:19 20OCT08	16:06 23OCT08	STK:P08372 DLR:21038 1)DD CHECKED

...INE OPCODE TECH TYPE HOURS LIST NET TOTAL

REPAIR 2 DOOR DINGS PER GET
READY PER JACK G

***** STATE OF FLA. REG. # MV-00488 *********
OUR GOAL IS 100% CUSTOMER SATISFACTION. IF YOU HAVE ANY QUESTIONS I CAN BE REACHED AT (954) 426-1800 ext 389 JOE BARDILL SERVICE DIRECTOR. **PARTS MARKED W/"W" ARE COVERED BY A LIFE TIME WARRANTY.
*********** www.coralcadillac.com ***********

...ISCLAIMER OF WARRANTIES:
...he seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any ...nplied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes ...or authorizes any other person to assume for it any liability in connection with the sale of the vehicle or ...roduct.
...P.L. 93-637).
...I UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL ...AGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** ...THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY ...ECTION."
...OMER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE ...HEREOF.

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	0.00
PARTS AMOUNT	0.00
GAS, OIL, LUBE	0.00
SUBLET AMOUNT	0.00
MISC. CHARGES	0.00
TOTAL CHARGES	0.00
LESS INSURANCE	0.00
SALES TAX	0.00
PLEASE PAY THIS AMOUNT	0.00

CUSTOMER COPY

(5)

USTOMER #: 105741

541007

INVOICE

PAGE 1

CORAL CADILLAC
The Dealer Is It

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS *CORAL CADILLAC*

GM Parts

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
NTON BEACH, FL 33437
E:561-758-9858 CONT:N/A
US: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		6526/6553	T3913

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 05NOV08			CASH	12NOV08

R.O. OPENED	READY	OPTIONS:
2:51 05NOV08	14:46 12NOV08	STK:P08372 DLR:21038 1)DD CHECKED

INE OPCODE TECH TYPE HOURS LIST NET TOTAL

CUSTOMER STATES BRAKES SQUEEL WHEN BRAKING AT HWY SPEEDS
AUSE: NO PARTS ON BACK ORDER
2050 SPECIAL ORDER PART ON BACK ORDER
26 GILROY,TREVOR LIC#: 256
IP (N/C)
1 25924485 PAD KIT (N/C)
1 63501 QUIET/BRAKE (N/C)
ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE A: 0.00

6526 NO PARTS ON BACK ORDER NO PARTS AVAILABLE AT THIS TIME
****

CUSTOMER STATES ENGINE RUNS ROUGH AND BUZZES THRU IPC, SEE JOE B
USE: EXHAUST VIBRATION
L2004 EXHAUST SYSTEM ALIGN
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
1 10199232 DAMPNER A (N/C)
1 10199232 DAMPNER A (N/C)
2 PO#169202 CLAMPS (N/C)
FC: 2E
PART#: 10199232
COUNT: 4
CLAIM TYPE:
AUTH CODE: E
PQ

ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B: 0.00

5553 EXHAUST VIBRATION ENGINE FIRING PULSES TRANSFERING INTO
VEHICLE. INSTALL EXHAUST WEIGHT TO PIPE ,NECESSARY FOR VIBRATION IN
INTERIOR. 1.8 OLH FOR DIAGNOSTIC TIME PER #18. 18319318
****
BASIC 6,000 MILE SERVICE. CHG ENG OIL & FILTER, CHECK FLUIDS, INSPT

SCLAIMER OF WARRANTIES:
e seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any plied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes r authorizes any other person to assume for it any liability in connection with the sale of the vehicle or oduct.
.L. 93-637).
UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL AGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY ECTION."
TOMER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE HEREOF.

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER SIGNATURE

CUSTOMER COPY

(6)

ISTOMER #: 105741

541007

INVOICE

PAGE 2

CORAL CADILLAC
The Dealer Is In

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS
CORAL CADILLAC

GM Parts

ERIF RAFIK KODSY
93 LAUREL GREEN DRIVE
TON BEACH, FL 33437
ME:561-758-9858 CONT:N/A
S: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
UE	08	HUMMER H2	5GRGN23878H107653		6526/6553	T3913

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
AUG08 DD		11JUN2012	17:00 05NOV08			CASH	12NOV08

R.O. OPENED	READY	OPTIONS:
:51 05NOV08	14:46 12NOV08	STK:P08372 DLR:21038 1)DD CHECKED

NE OPCODE TECH TYPE HOURS LIST NET TOTAL

TIRES & PRESS, MULTI PNT INSPT, ROTATE 4 TIRES, INSTL WASHER
FLUID
USE: MAINTENANCE
6KH3 BASIC 6,000 MILE SERV, CHG ENG OIL & FILTER.
CHK & FILL ALL FLUIDS, MULTI PNT INSPT,
INSPT TIRES & FILL TO PROPER PRESSURE,
ROTATE 4 TIRES, INSTALL WASHER FLUID
26 GILROY,TREVOR LIC#: 256
CMH2 56.15 56.15
1 89017524 FILTER 14.67 6.60 6.60
BE OIL
CMH2 19.20 19.20
RTS: 6.60 LABOR: 56.15 OTHER: 19.20 TOTAL LINE C: 81.95

8 MAINTENANCE PERFORM 6K SERVICE MAINTENANCE
****
COURTESY RENTAL TRANSPORTAION
USE: .
Z7901 1 DAYS RENTAL; GOLD KEY COURTESY
TRANSPORTATION
309 SUBLET TECH LIC#: 256
WH2 (N/C)
FC: 98 PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE:
MJ

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE D: 0.00

****
CUSTOMER STATES TRANS WON'T SHIFT WHEN ACCELERATING AT HWY SPEEDS,
ATTN: JOE B
USE: TRANSMISSION CONTROL MODULE

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER COPY

(7)

ISTOMER #: 105741 541007

INVOICE

PAGE 3

CORAL CADILLAC
The Dealer Is In

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 428-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS CORAL CADILLAC

ERIF RAFIK KODSY
93 LAUREL GREEN DRIVE
YTON BEACH, FL 33437
E:561-758-9858 CONT:N/A
IS: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
UE	08	HUMMER H2	5GRGN23878H107653		6526/6553	T3913

DEL DATE	PROD DATE	WARR EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
AUG08 DD		11JUN2012	17:00 05NOV08			CASH	12NOV08

R.O. OPENED	READY	OPTIONS:
:51 05NOV08	14:46 12NOV08	STK:P08372 DLR:21038 1)DD CHECKED

NE OPCODE TECH TYPE HOURS LIST NET TOTAL

K6562 CONTROL SOLENOID VALVE AND TRANSMISSION
CONTROL MODULE ASSEMBLY REPLACEMENT
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
1 24241890 VALVE (N/C)
1 500FRT CHARGES (N/C)
1 24243897 F-SEAL KIT (N/C)
FC: 6C
PART#: 24241890
COUNT: 2
CLAIM TYPE:
AUTH CODE: E
U OV

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE E: 0.00

553 TRANSMISSION CONTROL MODULE T.A.C CASE #10583778 11/12/08 .
ERFORM DIAG SYS CHECK, INSTALL TECH2 AND ROAD TEST TRUCK,COMMAND ALL
HIFT WHILE DRIVING ,OK, PART THROTTLE DOWN SHIFT TO 4th GEAR ENGINE
LAIR/UP & DOES NOT INCREASE SPEED ON HIGHWAY , NO CODES C, CHECK TRANS
LUID LEVEL OK,ATTEMPT TO RECALIBRATE MODULE HAS CURRENT UPDATE. R & I
AN,NECESSARY TO REPLACE TRANS MODULE , AFTER TRANS MODULE REPLACE TECH
OULD NOT REPROGRAM NEW MODULE , CODE #U0101 LOOS COMMUNICATIONCALL
ECH LINE , FOR INFO. CLAIM CODE #18F45 11/12/08. MULTIPLE ATTEMPT
BEFORE MODULE TAKES PROGRAM. 1.9 OLH FOR DIAGNOSIS AND TIME TO PROGRAM
ER #18 . 18319319

****

L/WIPER STREAKS
AUSE: WORN INSERT
B1783 WINDSHIELD WIPER BLADE REPLACEMENT
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
1 88944326 INSERT (N/C)

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

(8)

CUSTOMER COPY

STOMER #: 105741 541007

INVOICE

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

ERIF RAFIK KODSY
93 LAUREL GREEN DRIVE
TON BEACH, FL 33437
:561-758-9858 CONT:N/A
S: CELL:

PAGE 4

NOBODY OUT CADILLACS CORAL CADILLAC

GM Parts

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
UE	08	HUMMER H2	5GRGN23878H107653		6526/6553	T3913

EL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
AUG08 DD		11JUN2012	17:00 05NOV08			CASH	12NOV08

R.O. OPENED	READY	OPTIONS:
:51 05NOV08	14:46 12NOV08	STK:P08372 DLR:21038 1)DD CHECKED

NE OPCODE TECH TYPE HOURS LIST NET TOTAL

FC: 4X
PART#: 88944326
COUNT: 1
CLAIM TYPE:
AUTH CODE:
OJ

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE F: 0.00

553 WORN INSERT REPLACE LS WIPER INSERT
****

COURTESY SERVICE WASH
ISW COURTESY SERVICE WASH
612 EDWARD,TRAVIS LIC#: 0
ISH (N/C)
RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE G: 0.00

553 isw done
****

***** STATE OF FLA. REG. # MV-00488 *********
OUR GOAL IS 100% CUSTOMER SATISFACTION. IF YOU HAVE ANY QUESTIONS I CAN BE REACHED AT (954) 426-1800 ext 389 JOE BARDILL SERVICE DIRECTOR. **PARTS MARKED W/"W" ARE COVERED BY A LIFE TIME WARRANTY.
*********** www.coralcadillac.com ***********

CLAIMER OF WARRANTIES:
seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any lied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes authorizes any other person to assume for it any liability in connection with the sale of the vehicle or duct.
.. 93-637).
UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL GNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY PECTION."
MER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE EREOF.

DESCRIPTION	TOTALS
LABOR AMOUNT	56.15
PARTS AMOUNT	6.60
GAS, OIL, LUBE	19.20
SUBLET AMOUNT	0.00
MISC. CHARGES	3.14
TOTAL CHARGES	85.09
LESS INSURANCE	0.00
SALES TAX	5.11
PLEASE PAY THIS AMOUNT	90.20

CUSTOMER SIGNATURE

CUSTOMER COPY

(9)

STOMER #: 105741 541391

CORAL CADILLAC

ACCOUNTING

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

ERIF RAFIK KODSY
LAUREL GREEN DRIVE
ON BEACH, FL 33437
ME:561-758-9858 CONT:N/A
CELL:

PAGE 1

NOBODY OUT CADILLACS
CORAL CADILLAC

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
E	08	HUMMER H2	5GRGN23878H107653		6608/6656	T3967

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
AUG08 DD		11JUN2012	17:00 13NOV08			CASH	24NOV08

R.O. OPENED	READY	OPTIONS:
08 12NOV08	13:40 21NOV08	STK:P08372 DLR:21038 1)DD CHECKED

E OPCODE TECH TYPE A/HRS S/HRS COST SALE COMP LIST NET TOTAL

USTOMER STATES ENGINE HAS CONSTANT VIBRATION DURING ACCELERATION AND
DECCELERATION,
USE: NOISE VIBRATION AT IPC
D9737 08-01-39-002 Reposition A/C Compressor
Discharge Line
26 GILROY,TREVOR LIC#: 256
WH2 0.00 0.30 810 3300 33.00 33.00
FC: 93 PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE:
MH
0 0 TPARTS
810 3300 TLABOR
: 0.00 LABOR: 33.00 OTHER: 0.00 TOTAL LINE A: 33.00

ERSION 1 (EMP# 26,19NOV08 12:10): 6656 NOISE VIBRATION AT IPC
9737 0.93 PERFORM DOC#2049909 OPERATION RELOCATE A/C HIGH PRESURE HOSE
ROM WHEEL WELL AREA
ERSION 2 (EMP# 18,20NOV08 12:00): 6656 NOISE VIBRATION AT IPC
9737 0.93 PERFORM DOC#2049909 OPERATION RELOCATE A/C HIGH PRESURE HOSE
ROM WHEEL WELL AREA
ERSION 3 (EMP# 18,20NOV08 12:21): 6656 NOISE VIBRATION AT IPC
9737 0.93 PERFORM DOC#2049909 OPERATION RELOCATE A/C HIGH PRESURE HOSE
ROM WHEEL WELL AREA. AFTER ABOVE REPAIR STILL HAD SOME VIBRATION IN
EERING WHEEL AND SEAT. COMPARED WITH LIKE VEHICLE HAD SAME VIBRATION.
LED REPORT WITH BOB MARTIN H2 BQM.
ERSION 4 (EMP# 26,21NOV08 12:10): 6656 NOISE VIBRATION AT IPC
9737 0.90 PERFORM DOC#2049909 OPERATION RELOCATE A/C HIGH PRESURE HOSE
ROM WHEEL WELL AREA. AFTER ABOVE REPAIR STILL HAD SOME VIBRATION IN
TEERING WHEEL AND SEAT. COMPARED WITH LIKE VEHICLE HAD SAME VIBRATION.
LED REPORT WITH BOB MARTIN H2 BQM. R & I STARTER AS PER BOB MARTIN
EMOVE FLYWHEEL BOLTS AND RESTART ENGINE TO ISULATE VIBRATION, STILL
AS VIBRATION WITH FLY WHEEL DISCONNECTED , 1.6 OLH FOR DIAGNOSTIC TIME
ER #18. 18769316

USTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

ACCOUNTING COPY

(10)

USTOMER #: 105741 541391

CORAL CADILLAC
The Dealer Is In

INVOICE

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
NTON BEACH, FL 33437
E:561-758-9858 CONT:N/A
US: CELL:

PAGE 1

NOBODY OUT CADILLACS
CORAL CADILLAC

GM Parts

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		6608/6656	T3967

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 13NOV08			CASH	24NOV08

R.O. OPENED	READY	OPTIONS:
7:08 12NOV08	13:40 21NOV08	STK:P08372 DLR:21038 1)DD CHECKED

INE OPCODE TECH TYPE HOURS LIST NET TOTAL

CUSTOMER STATES ENGINE HAS CONSTANT VIBRATION DURING ACCELERATION AND
DECCELERATION,
AUSE: NOISE VIBRATION AT IPC
D9737 08-01-39-002 Reposition A/C Compressor
Discharge Line
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
FC: 93 PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE:
MH

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE A: 0.00

6656 NOISE VIBRATION AT IPC D9737 0.90 PERFORM DOC#2049909
OPERATION RELOCATE A/C HIGH PRESURE HOSE FROM WHEEL WELL AREA. AFTER
ABOVE REPAIR STILL HAD SOME VIBRATION IN STEERING WHEEL AND SEAT.
COMPARED WITH LIKE VEHICLE HAD SAME VIBRATION. FILED REPORT WITH BOB
MARTIN H2 BQM. R & I STARTER AS PER BOB MARTIN REMOVE FLYWHEEL BOLTS
AND RESTART ENGINE TO ISULATE VIBRATION, STILL HAS VIBRATION WITH FLY
WHEEL DISCONNECTED , 1.6 OLH FOR DIAGNOSTIC TIME PER #18. 18769316
****

CUSTOMER STATES VEHICLE RIDES ROUGH AT ALL SPPEDS OVER 50 MPH
AUSE: NO FAULT FOUND
2000 VEHICLE IS OPERATING TO SPECIFICATIONS AT
THIS TIME.
26 GILROY,TREVOR LIC#: 256
ISH (N/C)
ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B: 0.00

6656 NO FAULT FOUND PERFORM ROAD TEST , COULD NOT DUPLICATE
CONDITION AT THIS TIME, NORMAL CHARACTERISTIC OPERATION OF TRUCK,
COMPARE TO ANOTHER "H2" SAME CONDITION.

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

(11)

CUSTOMER COPY

USTOMER #: 105741

541391

INVOICE

PAGE 2

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS *CORAL CADILLAC*

GM Parts

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
TON BEACH, FL 33437
OME:561-758-9858 CONT:N/A
US: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		6608/6656	T3967

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 13NOV08			CASH	24NOV08

R.O. OPENED	READY	OPTIONS:
7:08 12NOV08	13:40 21NOV08	STK:P08372 DLR:21038 1)DD CHECKED

INE OPCODE TECH TYPE HOURS LIST NET TOTAL

CUSTOMER STATES TRANS KICKS ON ACCEL AFTER COAST
AUSE: REPROGRAM E.C.M
J6354 POWERTRAIN CONTROL MODULE ENGINE
REPROGRAMMING WITH SPS
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
FC: 111AD
PART#:
COUNT: 0
CLAIM TYPE:
AUTH CODE:
OJ

.S: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE C: 0.00

5656 REPROGRAM E.C.M PERFORM E.C.M TO COLLABORATE WITH TRANS MODULE
CLAIM CODE #111AD 11/18/08
****

CUSTOMER STATES NOISE FROM DASH AREA AT HWY SPEEDS
AUSE: WIND NOISE "A"PILLOR MOLDINGS
B7570 MOLDING, WINDSHIELD SIDE PILLAR REVEAL
RIGHT R&R OR REPLACE
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
1 25869091 MOLDING (N/C)
FC: 4N
PART#: 25869091
COUNT: 1
CLAIM TYPE:
AUTH CODE:
N3
B7571 MOLDING, WINDSHIELD SIDE PILLAR REVEAL LEFT
R&R OR REPLACE

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER COPY

(17)

STOMER #: 105741 541391

INVOICE

ERIF RAFIK KODSY
LAUREL GREEN DRIVE
'ON BEACH, FL 33437
ME:561-758-9858 CONT:N/A
S: CELL:

PAGE 3

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS
CORAL CADILLAC

GM Parts

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
UE	08	HUMMER H2	5GRGN23878H107653		6608/6656	T3967

EL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
AUG08 DD		11JUN2012	17:00 13NOV08			CASH	24NOV08

R.O. OPENED	READY	OPTIONS:
:08 12NOV08	13:40 21NOV08	STK:P08372 DLR:21038 1)DD CHECKED

NE OPCODE TECH TYPE HOURS LIST NET TOTAL
26 GILROY,TREVOR LIC#: 256
WH2 (N/C)
1 25869092 MOLDING (N/C)
FC: 4N
PART#: 25869092
COUNT: 1
CLAIM TYPE:
AUTH CODE:
N3

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE D: 0.00

WIND NOISE "A"PILLOR MOLDINGS REPLACE BOTH "A"PILLOR MOLDINGS
NOISE TAG #101803 11/19/08
****
COURTESY RENTAL TRANSPORTAION
USE: .
Z7901 1 DAYS RENTAL; GOLD KEY COURTESY
TRANSPORTATION
309 SUBLET TECH LIC#: 256
WH2 (N/C)
FC: 98 PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE:
MJ

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE E: 0.00

****
COURTESY SERVICE WASH
ISW COURTESY SERVICE WASH
613 ISH (N/C)

CLAIMER OF WARRANTIES:
seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any ed warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes authorizes any other person to assume for it any liability in connection with the sale of the vehicle or uct.
93-637).
NDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL NUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** HE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY ON."
ER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE EREOF.

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

USTOMER SIGNATURE

CUSTOMER COPY

(12)

JSTOMER #: 105741 541391

INVOICE

PAGE 4

CORAL CADILLAC
The Dealer Is In

5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS CORAL CADILLAC

GM Parts

ERIF RAFIK KODSY
393 LAUREL GREEN DRIVE
TON BEACH, FL 33437
OME:561-758-9858 CONT:N/A
JS: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		6608/6656	T3967

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 13NOV08			CASH	24NOV08

R.O. OPENED	READY	OPTIONS:
7:08 12NOV08	13:40 21NOV08	STK:P08372 DLR:21038 1)DD CHECKED

INE OPCODE TECH TYPE HOURS LIST NET TOTAL
ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE F: 0.00

5656 isw done

****

***** STATE OF FLA. REG. # MV-00488 *********
OUR GOAL IS 100% CUSTOMER SATISFACTION. IF
YOU HAVE ANY QUESTIONS I CAN BE REACHED AT
(954) 426-1800 ext 389 JOE BARDILL
SERVICE DIRECTOR. **PARTS MARKED W/"W" ARE
COVERED BY A LIFE TIME WARRANTY.
*********** www.coralcadillac.com ***********

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	0.00
PARTS AMOUNT	0.00
GAS, OIL, LUBE	0.00
SUBLET AMOUNT	0.00
MISC. CHARGES	0.00
TOTAL CHARGES	0.00
LESS INSURANCE	0.00
SALES TAX	0.00
PLEASE PAY THIS AMOUNT	0.00

(14)

CUSTOMER COPY

USTOMER #: 240290

443188

INVOICE

SCHUMACHER

3001-3031 Okeechobee Blvd.
West Palm Beach, FL 33409
www.SchumacherAuto.com

Schumacher Buick-Pontiac	(561) 615-3270
Schumacher Saab	(561) 615-3298
Schumacher Volkswagen	(561) 615-3345
Hummer of the Palm Beaches	(561) 656-5010

Registration No. MV-15866 MV-39987 MV-53731

ERIF KODSY
5968 LAUREL OAK CIRCLE
RAY BEACH, FL 33484
OME:561-737-8998 CONT:N/A
US: CELL:

PAGE 1

SERVICE ADVISOR: 940396 DOUG BRADY

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN / OUT	TAG
	08	HUMMER H2	5GRGN23878H107653		7198/7214	TH931

DEL. DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
1JUN08 DD			10:45 01DEC08			CASH	03DEC08

R.O. OPENED	READY	OPTIONS:
0:42 01DEC08	12:48 03DEC08	ENG:6.2_Liter_MPFI_OHV

INE OPCODE TECH TYPE HOURS LIST NET TOTAL

AT HWY SPEEDS THERE IS A ROARING AND HOPING FELT AT NEARLY ALL SPEEDS
AUSE: ROAD TESTED TIRE VIBRATION 45MPH & UP
E0435 TIRE, B F GOODRICH REPLACE
1001 WSH
3 89031270 BF3157017 (N/C)
3 9591585 F-WT-.75OZ (N/C)
3 TWASTE EPA DISPOSAL (N/C)
OLH RODE FORCE (N/C)
1001 WSH
ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE A: (N/C) 0.00

7214 ROAD TESTED TIRE VIBRATION 45MPH & UP ROAD TESTED TIRE
IBRATION 45MPH & UP 13HZ .09G'S CHECK RIMS, HUB BEARINGS BALANCE &
AD FORCE LF18 RF 31 RR40 LR37 INDEX 3 TIRES 30 36 35 ORDER 3 B F
DRICH TIRES MOUT 3 TIRES BALANCE & DO ROAD FORCE LF 11 RF7 RR17 LR18
****
HUMMER SERVICE WASH
HUMMERSERVWASH HUMMER SERVICE WASH
97217 IHW
RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B: (N/C) 0.00
****
RENTAL VEHICLE C/P
USE: F
RENTAL RENTAL VEHICLE C/P
8888 WSH
FC: PART#: COUNT: (N/C)
CLAIM TYPE:
AUTH CODE:

BL HERTZ
WSH (N/C)

PARTS ARE NEW UNLESS IDENTIFIED BY: LKQ USED; OR NPN IN THE PART NUMBER OR DESCRIPTION. GENUINE ORIGINAL EQUIPMENT REPLACEMENT PARTS ARE COVERED BY A MANUFACTURER RRANTY OF 12 MONTHS OR 12,000 MILES, WHICHEVER COMES FIRST.

STATEMENT OF DISCLAIMER

factory warranty constitutes all of the warranties with respect to the sale of this item\items. Seller hereby expressly disclaims all warranties either express or implied, including any implied rranty of merchantability or fitness for a particular purpose. Seller neither assumes nor horizes any other person to assume for it any liability in connection with the sale of this ms.

TOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

CUSTOMER COPY

(15)

ISTOMER #: 240290

443510

INVOICE

DUPLICATE 1
PAGE 1

SCHUMACHER

3001-3031 Okeechobee Blvd.
West Palm Beach, FL 33409
www.SchumacherAuto.com

Schumacher Buick-Pontiac	(561) 615-3270
Schumacher Saab	(561) 615-3298
Schumacher Volkswagen	(561) 615-3345
Hummer of the Palm Beaches	(561) 656-5010

Registration No. MV-15866 MV-39987 MV-53731

RIF KODSY
68 LAUREL OAK CIRCLE
AY BEACH, FL 33484
E:561-737-8998 CONT:N/A
IS: CELL:

SERVICE ADVISOR: 940396 DOUG BRADY

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN / OUT	TAG
	08	HUMMER H2	5GRGN23878H107653		7245/7245	TH981

DEL. DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
JUN08 DD			17:30 05DEC08			CASH	05DEC08

R.O. OPENED	READY	OPTIONS:
:34 05DEC08	17:16 05DEC08	ENG:6.2_Liter_MPFI_OHV

NE OPCODE TECH TYPE HOURS LIST NET TOTAL

AT IDLE THERE IS A VIBRATION FELT THROUGH THE TRUCK
USE: NPF
S111 MISC BODY
97263 CSH 0.00 0.00
RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE A: 0.00

245 NPF NO DTC OR BULLETINS TO UPDATE .
****
RENTAL VEHICLE C/P
USE: F
RENTAL RENTAL VEHICLE C/P
8888 WSH
FC: PART#: COUNT: 0 (N/C)
CLAIM TYPE:
AUTH CODE:

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B: 0.00

****
* C/S THERE IS STILL A HOPP AS DRIVING OVER 25 MPH
USE: NPF
S111 MISC BODY
8888 CSH 0.00 0.00
RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE C: 0.00

245 NPF C/S STILL A HOP AFTER NEW TIRES NO CURRENT BULLETIN FOR
HIS ITEM.
****

PARTS ARE NEW UNLESS IDENTIFIED BY: LKQ USED; OR NPN IN THE PART NUMBER OR DESCRIPTION. GENUINE ORIGINAL EQUIPMENT REPLACEMENT PARTS ARE COVERED BY A MANUFACTURER RRANTY OF 12 MONTHS OR 12,000 MILES, WHICHEVER COMES FIRST.

STATEMENT OF DISCLAIMER

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TOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	0.00
PARTS AMOUNT	0.00
GAS, OIL, LUBE	0.00
SUBLET AMOUNT	0.00
MISC. CHARGES	0.00
TOTAL CHARGES	0.00
LESS INSURANCE	0.00
SALES TAX	0.00
PLEASE PAY THIS AMOUNT	0.00

(17)

SCHUMACHER

3001-3031 Okeechobee Blvd.
West Palm Beach, FL 33409
www.SchumacherAuto.com

Schumacher Buick-Pontiac	(561) 615-3270
Schumacher Saab	(561) 615-3298
Schumacher Volkswagen	(561) 615-3345
Hummer of the Palm Beaches	(561) 656-5010

Registration No. MV-15866 MV-39987 MV-63731

USTOMER #: 240290

443188

INVOICE

ERIF KODSY
5968 LAUREL OAK CIRCLE
RAY BEACH, FL 33484
OME:561-737-8998 CONT:N/A
US: CELL:

PAGE 2

SERVICE ADVISOR: 940396 DOUG BRADY

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN / OUT	TAG
	08	HUMMER H2	5GRGN23878H107653		7198/7214	TH931

DEL. DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
1JUN08 DD			10:45 01DEC08			CASH	03DEC08

R.O. OPENED	READY	OPTIONS:
0:42 01DEC08	12:48 03DEC08	ENG:6.2_Liter_MPFI_OHV

INE OPCODE TECH TYPE HOURS LIST NET TOTAL
ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE C: 0.00

****

L PARTS ARE NEW UNLESS IDENTIFIED BY: LKQ USED; OR NPN IN THE PART NUMBER OR DESCRIPTION.
L GENUINE ORIGINAL EQUIPMENT REPLACEMENT PARTS ARE COVERED BY A MANUFACTURER ARRANTY OF 12 MONTHS OR 12,000 MILES, WHICHEVER COMES FIRST.

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STOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	0.00
PARTS AMOUNT	0.00
GAS, OIL, LUBE	0.00
SUBLET AMOUNT	0.00
MISC. CHARGES	0.00
TOTAL CHARGES	0.00
LESS INSURANCE	0.00
SALES TAX	0.00
PLEASE PAY THIS AMOUNT	0.00

CUSTOMER COPY

(16)

CUSTOMER #: 105741 543204 INVOICE PAGE 1

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 3306
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS
CORAL CADILLAC

GM Parts

ERIF RAFIK KODSY
968 LAUREL OAK CIR
RAY BEACH, FL 33484-5539
HOME:561-758-9858 CONT:N/A
BUS: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
BLUE	08	HUMMER H2	5GRGN23878H107653		9016/9022	T3184

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
19AUG08 DD		11JUN2012	17:00 23DEC08			CASH	23DEC08

R.O. OPENED	READY	OPTIONS:
09:21 22DEC08	13:25 23DEC08	STK:P08372 DLR:21038 1)DD CHECKED

LINE OPCODE TECH TYPE HOURS LIST NET TOTAL

A CUSTOMER STATES VIBRATION AT HWY SPEEDS 45-55
2000 VEHICLE IS OPERATING TO SPECIFICATIONS AT
THIS TIME.
517 ISH (N/C)
PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE A: 0.00

9022 ROAD TESTED O.K. VEHICLE EXHIBITS SOME RAIL SHAKE
CHRACTERISTIC OF SUV'S.
****

B CUSTOMER STATES BRAKES SQUEEL
CAUSE: front brakes squeel
H0042 PADS, DISC BRAKE FRONT R&R OR REPLACE
517 WH2 (N/C)
1 25924485 PAD KIT (N/C)
FC: 02R03
PART#: 25924485
COUNT: 1
CLAIM TYPE:
AUTH CODE:
NV

PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B: 0.00

9016 front brakes squeel nec to replace front pads see doc 2128875.
labor op h0042
****

C CUSTOMER STATES ENGINE IDLES ROUGH
2000 ROAD TESTED 6 MILES. VEHICLE EXHIBITS NORMAL
IDLE QUALITY FOR 6.2 LITRE ENGINE.
PREVIOUSLY COMPARED WITH LIKE VEHICLE.
517 ISH (N/C)
PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE C: 0.00

DISCLAIMER OF WARRANTIES:
The seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any implied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes nor authorizes any other person to assume for it any liability in connection with the sale of the vehicle or product.
(P.L. 93-637).
"I UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL MAGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** BY THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY INSPECTION."
CUSTOMER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE COPY HEREOF.

X ______________________
CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

(19)

CUSTOMER COPY

JSTOMER #: 105741 543204

INVOICE

PAGE 2

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS CORAL CADILLAC

GM Parts

ERIF RAFIK KODSY
968 LAUREL OAK CIR
AY BEACH, FL 33484-5539
:561-758-9858 CONT:N/A
JS: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
UE	08	HUMMER H2	5GRGN23878H107653		9016/9022	T3184

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
AUG08 DD		11JUN2012	17:00 23DEC08			CASH	23DEC08

R.O. OPENED	READY	OPTIONS:
:21 22DEC08	13:25 23DEC08	STK:P08372 DLR:21038 1)DD CHECKED

NE OPCODE TECH TYPE HOURS LIST NET TOTAL

022 ROAD TESTED 6 MILES. VEHICLE EXHIBITS NORMAL IDLE QUALITY FOR
.2 LITRE ENGINE. PREVIOUSLY COMPARED WITH LIKE VEHICLE.
****

COURTESY RENTAL TRANSPORTAION
USE:
Z7901 1 DAYS RENTAL; GOLD KEY COURTESY
TRANSPORTATION
309 SUBLET TECH LIC#: 256
WH2 (N/C)
FC: 98 PART#: COUNT: 0
CLAIM TYPE:
AUTH CODE:
MJ

RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE D: 0.00

****

CUSTOMER STATES TRANS HESITATES/SHIFTS HARSH ON REACCEL, SEE JOE
2000 VEHICLE IS OPERATING TO SPECIFICATIONS AT
THIS TIME.
517 ISH (N/C)
RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE E: 0.00

022 ROAD TESTED O.K. PREVIOUSLY REPROGRAMMED W/SOFTWARE UPDATE.
****

* COURTESY SERVICE WASH
ISW COURTESY SERVICE WASH
837 ISH (N/C)
RTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE F: 0.00

022 isw done
****

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	
PARTS AMOUNT	
GAS, OIL, LUBE	
SUBLET AMOUNT	
MISC. CHARGES	
TOTAL CHARGES	
LESS INSURANCE	
SALES TAX	
PLEASE PAY THIS AMOUNT	

(19)

CUSTOMER COPY

USTOMER #: 105741

543204

INVOICE

PAGE 3

CORAL CADILLAC
The Dealer Is In
5101 NORTH FEDERAL HIGHWAY POMPANO BEACH, FL 33064
BROWARD: 426-1800 TOLL FREE: 930-2672

NOBODY OUT CADILLACS *CORAL CADILLAC*

GM Parts

ERIF RAFIK KODSY
68 LAUREL OAK CIR
RAY BEACH, FL 33484-5539
OME:561-758-9858 CONT:N/A
US: CELL:

SERVICE ADVISOR: 207 MICHAEL STANWYCK

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/OUT	TAG
LUE	08	HUMMER H2	5GRGN23878H107653		9016/9022	T3184

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
9AUG08 DD		11JUN2012	17:00 23DEC08			CASH	23DEC08

R.O. OPENED	READY	OPTIONS:
9:21 22DEC08	13:25 23DEC08	STK:P08372 DLR:21038 1)DD CHECKED

LINE OPCODE TECH TYPE HOURS LIST NET TOTAL

***** STATE OF FLA. REG. # MV-00488 *********
OUR GOAL IS 100% CUSTOMER SATISFACTION. IF
YOU HAVE ANY QUESTIONS I CAN BE REACHED AT
(954) 426-1800 ext 389 JOE BARDILL
SERVICE DIRECTOR. **PARTS MARKED W/"W" ARE
COVERED BY A LIFE TIME WARRANTY.
*********** www.coralcadillac.com ***********

SCLAIMER OF WARRANTIES:
e seller, CORAL CADILLAC, hereby expressly disclaims all warranties, either express or implied, including any plied warranty of merchantability or fitness for a particular purpose, and CORAL CADILLAC, neither assumes r authorizes any other person to assume for it any liability in connection with the sale of the vehicle or oduct.
.L. 93-637).
UNDERSTAND THAT ALL PARTS AND ACCESSORIES SOLD OR USED ARE SUBJECT TO THE FEDERAL AGNUSON MOSS ACT AND THE CONSUMER MERCHANDISE PURCHASED IS UNDER **LIMITED WARRANTY** THE MANUFACTURER AND THE WRITTEN TERMS AND CONDITIONS THEREOF ARE AVAILABLE FOR MY SPECTION."
MER HEREBY ACKNOWLEDGES RECEIPT OF ABOVE MENTIONED VEHICLE, AND RECEIPT OF INVOICE HEREOF.

CUSTOMER SIGNATURE

DESCRIPTION	TOTALS
LABOR AMOUNT	0.00
PARTS AMOUNT	0.00
GAS, OIL, LUBE	0.00
SUBLET AMOUNT	0.00
MISC. CHARGES	0.00
TOTAL CHARGES	0.00
LESS INSURANCE	0.00
SALES TAX	0.00
PLEASE PAY THIS AMOUNT	0.00

(20)

CUSTOMER COPY

E

HAGEN RANCH TEXACO
7450 West Boynton Beach Blvd
Boynton Beach, FL 33437-0000
Shop Phone: (561) 732-1323

Invoice
5232
Estimate Ref #5,571
Date Printed: 01/02/2009
Printed Time: 12:28 pm
MV 52815

Ref:
THANK YOU FOR CHOOSING HAGEN RANCH TEXACO
IDSY, SHERIF
Time Promised:
2008 HUMMER H2 V8 6.2L 6199CC 378CID FI GAS N 8 L92
VIN: 5GRGN23878H107653
License:
ne: Work:
:
Unit #:
DOM:
Mileage In: 9,101
Mileage Out: 9,101
Date Written: 01/02/2009
Written By:
Save Old Parts: No

) #1
or Rate 1

BILLY Work Requested - CHECK CAR&TEST DRIVE ,CAR HAS VIBRATION	0.00	82.00	0.00
		Job Total:	*0.00*

HANK YOU FOR YOUR CONTINUED BUSINESS!!

RRANTY 1 YEAR PARTS 90 DAYS LABOR. EXCLUDING ELECTRICAL PARTS

EDS TO BRING BACK TO DEALER FOR FURTHER REPAIR &WARRANTY

Parts:	$0.00
Labor:	$0.00
Sublet:	$0.00
Misc:	$0.00
Hazmat:*	$0.00
Supplies:*	$0.00
Tax:	$0.00
Total:	**$0.00**
Less Paid:	0.00
Balance Due:	**$0.00**

BOCA RATON TIRE CENTER

10 NW 28TH ST
BOCA RATON, FL 33431
(561)391-6666, FL REG# MV58766

GOODYEAR
Gemini

"VOICE
)689

: 01

03/13/09 03/13/09
04:23 PM 04:50 PM
TERR: 1634
NONSIG: 164561

TO: ALL RESTORATION SERVICES
SHERIF
15968 LAUREL OAK CR
DELRAY BEACH, FL 33484

IE 1....... (561)737-8998
IE 2.......
: PROMISED 03/13/09
: PROMISED
IRN PARTS.. NO
SMAN...... 034 / 034

VEH YEAR/MAKE. 08 HUMMER
VEHICLE MODEL. H2
VEHICLE COLOR.
LICENSE/STATE.
ODOMETR IN/OUT 11658 / 11658
PRIOR INVOICE. 028688

IT #	COB	TC	CUST#	TYPE/STATE		AUTHORIZATION	CREDIT CARD NO.	
)051	M	01	05968	0	FL	159238	HDC	3886

TECH	PRODUCT CODE	BC	QTY	DESCRIPTION	PARTS	LBR/EXCISE	LINE TOTAL
019	093-608	R	1	DIAGNOSTIC CHECK	.00	86.00	86.00
019	048-170	R	1	ESTIMATE/WORK ORDER PREPARATION	.00	.00	.00
019	093-002	R	1	ADDITIONAL REPAIRS RECOMMENDED	.00	.00	.00
019	047-100	R	1	SCANNED VEHICLE NO CODES AT THIS TIME. WE	.00	.00	.00
	047-100	R	1	DO FEEL A ROUGH IDLE & ENGINE VIBRATION.	.00	.00	.00
019	047-100	R	1	VEHICLE SHIFTS HARD INTERMITTENLY.WE DID	.00	.00	.00
019	047-100	R	1	FIND A TSB FOR CLEANING OUT INJECTORS.	.00	.00	.00
019	047-100	R	1	ALSO CHECKED OUT BRAKES FOR NOISE.	.00	.00	.00
019	047-100	R	1	NOTICED SCUFF MARKS ON ROTORS.	.00	.00	.00
019	047-100	R	1	WE RECOMMEND TAKING BACK TO THE DEALER	.00	.00	.00
019	047-100	R	1	FOR FURTHER INSPECTION & WARRANTY REPAIRS	.00	.00	.00

CALL SCOTT, SIDNEY,OR MIKE FOR ALL OF YOUR AUTOMOTIVE NEEDS.IF YOU EVER HAVE ANY QUESTIONS ABOUT OUR SERVICES. WE WILL GLADLY ANSWER THEM FOR YOU !!
THANK YOU FOR YOUR BUSINESS & YOUR CONTINUED PATRONGE.

RSTAND THAT ALL CUSTOM WHEEL LUG NUTS MUST BE RE-TORQUED AFTER 25 MILES AND CHECKED PERIODICALLY. ____________ (signature)

		PARTS TOTAL.........	.00
		LABOR TOTAL.........	86.00
CHARGED AMOUNT	86.00	SUB TOTAL..........	86.00
TAXABLE AMOUNT	.00	SALES TAX..........	.00

TOMER AUTHORIZATION FOR TOTAL

INVOICE TOTAL $86.00

ALL PARTS LISTED ARE NEW, UNLESS OTHERWISE STATED

'EE REVERSE SIDE FOR IMPORTANT SAFETY WARNING AND WARRANTY INFORMATION

HAVE A QUESTION OR PROBLEM?
Please tell our store manager. We value your opinion as much as your business. Should you need additional assistance, call our
CUSTOMER ASSISTANCE LINE 1-800-321-2136

401 NE 6th Avenue (Federal Hwy.)
DELRAY BEACH, FLORIDA 33483
(561) 272-0644
Fax (561) 272-7522

FW REE UNDER WARRANTY

RW - REDUCED COST UNDER WARRANTY

DATE IN: 05/04/09 — DATE PROMISED: A.M. P.M.
ESTIMATE DATE: A.M. P.M. — ORDER WRITTEN BY:

NAME: Sherif Rafik Kodsy
ADDRESS: 15968 Laurel Oak Cir
CITY: STATE: ZIP:
BUS. PHONE: (561) 738-9858 EXT.
HOME PHONE: (561) 737-8998 — MILEAGE IN: 13572
LICENSE NO: — MILEAGE OUT:
YEAR, MAKE AND MODEL: 08 Hummer H2
SERIAL NO./V.I.N.: 5GRGN23878H107653
CALL WHEN READY: ☐ YES ☐ NO — MECHANIC/TECHNICIAN:
TERMS:

Scan cc computer system
Note: block learn out of spec
fuel ratio out of spec

Cause of this problem
comes from timing chain
installed wrong

fuel & timing problem / internal
engine problem

(Note:) engine should be replaced
under factory warr. 100,000 miles

SERVICES REQUESTED/DESCRIPTION OF WORK	AMOUNT
① Inspect for vibration/miss	
② ck for vibration on acceleration	

WATSEN FRANCOIS
Notary Public - State of Florida
My Commission Expires Feb 8, 2011
Commission # DD 629854
Bonded Through National Notary Assn.

FL DL# M000-793-64-459-0 DOB 12/19/1964

TOTAL PARTS

This charge represents costs and profits to the motor vehicle repair facility for MISCELLANEOUS SHOP SUPPLIES OR WASTE DISPOSAL.

(s.403.7185) BATTERY DISPOSAL FEE ______ (s.403.718) TIRE DISPOSAL FEE ______

TOTAL SHOP CHARGES EPA / WASTE DISPOSAL

PLEASE READ CAREFULLY, CHECK ONE OF THE STATEMENTS BELOW, AND SIGN: I UNDERSTAND, THAT UNDER STATE LAW, I AM ENTITLED TO A WRITTEN ESTIMATE IF MY FINAL BILL WILL EXCEED $100.

☐ I REQUEST A WRITTEN ESTIMATE.

☑ I DO NOT REQUEST A WRITTEN ESTIMATE AS LONG AS THE REPAIR COSTS DO NOT EXCEED $ 180.00. THE SHOP MAY NOT EXCEED THIS AMOUNT WITHOUT MY WRITTEN OR ORAL APPROVAL.

☐ I DO NOT REQUEST A WRITTEN ESTIMATE.

SIGNED [signature] DATE 05/04/2009

I hereby authorize the above repair work to be done along with the necessary materials. You and your employees may operate vehicle for purposes of testing, inspection, or delivery at my risk. It is understood that you will not be held responsible for loss or damage to vehicle or articles left in vehicle in case of fire, theft or any other cause beyond your control.

SIGNATURE [signature] DATE

SAVE OLD PARTS ☐ YES ☐ NO

ALTERNATE WORK AUTHORIZER (If Any) — PHONE
GUARANTEED ITEMS — ESTIMATED COSTS OF REPAIRS
PERIOD OF TIME OR MILEAGE
TIME ______ MILES ______ — X
BASIS FOR CHARGE
☐ FLAT RATE ☐ HOURLY RATE ☒ BOTH
$ ______ (Per Above)
CHARGE FOR ESTIMATE $ ______
REASSEMBLY IF REPAIRS CANCELLED $ ______
OTHER CHARGES $ ______

REVISED ESTIMATE / ADDITIONAL WORK

PARTS	LABOR	TOTAL
AUTHORIZED BY	ADDITIONAL AUTHORIZED AMOUNT	☐ IN PERSON ☐ BY PHONE

DESCRIPTION OF ADDITIONAL WORK AUTHORIZED

DATE	TIME	CALLED BY	PHONE

A daily storage charge will begin (3) working days after notification of completion of repairs. $______ /day

TOTAL LABOR	
☒ CASH ☐ CHECK ☐ CREDIT CARD	
TYPE ______ EXP. ______	
CC NUMBER	
TOTAL LABOR	
TOTAL PARTS	
GAS, OIL AND GREASE	
STORAGE	
TOTAL SHOP CHARGES EPA / WASTE DISPOSAL	
TAX	
TOTAL	180.00

OMER #: 4754077

447738

INVOICE

PAGE 1

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MON-FRI 7AM-7PM · SAT: 8AM-5PM · SUN: 9AM-5PM
www.maroone.com

HERIF KODSY
5968 LAUREL OAK CIRCLE
AY BEACH, FL 33484
ONE:561-737-8998 CONT:N/A
US: CELL:

SERVICE ADVISOR: 9228 STEVEN BRENIS

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN / OUT	TAG
	08	HUMMER H2	5GRGN23878H107653		18540/18540	

DEL. DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
5JUN08 IS 5JUN08 DD			19:00 12NOV09		0.00	CASH	12NOV09

R.O. OPENED	READY	OPTIONS:
2:58 12NOV09	13:01 12NOV09	DLR:26200 ENG:6.2_Liter_MPFI_OHV

INE OPCODE TECH TYPE HOURS LIST NET TOTAL

C/S VIBRATION AT IDLE AND ON ACCLERATION-VISIBLE VIBRATION FROM ENGINE

06 DID NOT ADDRESS FURTHER WITH DIAG AT THIS TIME

1417 C 0.00 0.00

ARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE A: 0.00

****

Open Sundays starting November 1st

EASE SEE THE LIMITED WARRANTY ON THE REVERSE SIDE OF THIS PAIR INVOICE.

IOR SUPPLIES AND HAZARDOUS MATERIALS CHARGES: We have added charge equal to 12% of the cost of parts & labor up to a maximum of 9.75. "This charge represents costs and profits to the motor repair facility r miscellaneous shop supplies or waste disposal." (s.559.905 (l) (h))

e State of Florida requires a $1.00 fee to be collected for each new tire ld in the state [s.403.718], and a $1.50 fee to be collected for each new nufactured battery sold in the state, (s.403.7185].

CUSTOMER SIGNATURE

PAYMENT METHOD

CASH — AMERICAN EXPRESS
CHECK — VISA
DISCOVER — MASTERCARD
INTERNAL — OTHER

STATE OF FLORIDA REGISTRATION NUMBER #MV - 33283

DESCRIPTION	TOTALS
LABOR AMOUNT	0.00
PARTS AMOUNT	0.00
GAS, OIL, LUBE	0.00
SUBLET AMOUNT	0.00
MISC. CHARGES	0.00
TOTAL CHARGES	0.00
LESS INSURANCE	0.00
SALES TAX	0.00
PLEASE PAY THIS AMOUNT	0.00

ALL PARTS INSTALLED ARE NEW UNLESS OTHERWISE INDICATED

CUSTOMER COPY

Connect

JARROD PILONE
November 2 2010

Update My Profile
Logout

Global Warranty Management: Main > Interface With Customer > View Vehicle Summary

INTERFACE WITH CUSTOMER | ANALYZE WARRANTY | MANAGEMENT PLANNING | PREPARE PARTS RETURN | USER OPTIONS

View Vehicle Summary

This screen allows GMVIS users to view the Summary of Vehicle Information, Field Actions, Service Information, Applicable Warranties, Transaction History, Service Contract(s) if applicable, Warranty Block, Branded Title information and OnStar and XM Radio information (if applicable)

For this vehicle:
- View Vehicle Summary
  - Service Contract
  - Branded Title
  - Warranty Block
- View Vehicle Build
- View Vehicle Component Summary
- View Vehicle Transaction History Detail
- View Vehicle Delivery Information
- Investigate Major Assembly History

Vehicle Information

VIN: 5GRGN23878H107653
Model: RN25706-2008 HUMMER H2 SUV
Service Contract: No Branded Title: No Warranty Block: No PDI Status: No
Order Type: 81 - DEALER USED CAR (CVMS USE)
Field Actions: 0 Open [redacted]

Required Field Actions

Open field actions are highlighted

Type	Number	Original Nbr	Description	Release Date	Status
Service Update Bulletins	N080080	08080	SERVICE UPDATE INVENTORY ONLY - TRANS CONTROL MODULE REPGM - *EXP. 3/31/09*	03/04/2008	Closed

Branded Title

*The VIN information contained herein and information derived therefrom is the proprietary property of The Polk Company and is to be used only for the purpose of warranty verification and shall not be used for any other purpose whatsoever

Vehicle has no current record of branded titles.

Warranty Block

Vehicle has no current record of warranty block.

Service Information

Vehicle has no current record of outstanding service information.

OnStar and XM Satellite Radio Information

Refer to Help page for details. For OnStar contact 888.ON.STAR1 (888.667.8271) and for XM Radio contact 877.GET.XMST (877.438.9677).

OnStar Equipped: Y OnStar Status: Inactive
XM Equipped: Y XM Radio ID: WUPCY0CB XM Status: Inactive
OnStar Vehicle Diagnostics: N DMN Enabled: N

Applicable Warranties

Valid warranties are highlighted

Valid	Description	Start Date	Effective Odometer	End Date	End Odometer
	Emission Select Component Ltd Wty	06/11/2008	0 MI	06/11/2016	80,000 MI
	Powertrain Limited Warranty	06/11/2008	0 MI	06/11/2013	100,000 MI

Bumper to Bumper Limited Warranty	06/11/2008	0 MI	06/11/2012	50,000 MI
Corrosion Limited Warranty	06/11/2008	0 MI	06/11/2014	Unlimited
Emission Limited Warranty	06/11/2008	0 MI	06/11/2013	50,000 MI

Service Contract

Vehicle has no current record of service contracts.

Transaction History

View Details

Job Card Date	Job Card Number	Transaction Type	Transaction Adjustment	Labour Operation	Odometer Reading
12/22/2008	543204	ZREG---Regular Vehicle Transaction		Z7200 - CORPORATE PARTS RETURN REIMBURSEMENT	9,016 MI
12/22/2008	543204	ZREG---Regular Vehicle Transaction		H0042 - Pads, Disc Brake - Front - R&R Or Replace	9,016 MI
12/22/2008	543204	ZREG---Regular Vehicle Transaction		Z7902 - 2-DAY COURTESY TRANSPORTATION	9,016 MI
12/01/2008	443188	ZREG---Regular Vehicle Transaction		E0435 - B F Goodrich Tire Replacement	7,198 MI
12/01/2008	443188	ZREG---Regular Vehicle Transaction		Z7902 - 2-DAY COURTESY TRANSPORTATION	7,198 MI
11/12/2008	541391	ZREG---Regular Vehicle Transaction		D9737 - Reposition A/C Compressor Discharge Line	6,608 MI
11/12/2008	541391	ZREG---Regular Vehicle Transaction		J6354 - Powertrain Control Module Engine Reprogramming with SPS	6,608 MI
11/12/2008	541391	ZREG---Regular Vehicle Transaction		B7570 - Windshield Side Reveal Molding Replacement	6,608 MI
11/12/2008	541391	ZREG---Regular Vehicle Transaction		B7571 - Molding, Windshield Side Pillar Reveal - Left - R&R Or Replace	6,608 MI
11/12/2008	541391	ZREG---Regular Vehicle Transaction		Z7920 - Incidental Expense Reimbursement	6,608 MI
11/05/2008	541007	ZREG---Regular Vehicle Transaction		L2020 - Hanger And/Or Clamp, Exhaust System - Replace	6,526 MI
11/05/2008	541007	ZREG---Regular Vehicle Transaction		Z7920 - Incidental Expense Reimbursement	6,526 MI
11/05/2008	541007	ZREG---Regular Vehicle Transaction		K6562 - Control Solenoid Valve and Transmission Control Module Assembly Replacement	6,526 MI
11/05/2008	541007	ZREG---Regular Vehicle Transaction	Full Debit	B1783 - Windshield Wiper Blade Replacement	6,500 MI
11/05/2008	541007	ZREG---Regular Vehicle Transaction		B1783 - Windshield Wiper Blade Replacement	6,500 MI
11/05/2008	541007	ZREG---Regular Vehicle Transaction		Z7200 - CORPORATE PARTS RETURN REIMBURSEMENT	6,526 MI
10/24/2008	540468	ZREG---Regular Vehicle Transaction		Z7920 - Incidental Expense Reimbursement	5,224 MI
10/21/2008	540280	ZREG---Regular Vehicle Transaction		R0754 - RADIO RECEIVER-RETURN TO AC/DELCO ESC	5,224 MI
10/20/2008	540280	ZREG---Regular Vehicle Transaction		Z7200 - CORPORATE PARTS RETURN REIMBURSEMENT	5,224 MI

10/20/2008	540280	ZREG----Regular Vehicle Transaction	J6354 - Powertrain Control Module Engine Reprogramming with SPS	5,224 MI
10/20/2008	540280	ZREG----Regular Vehicle Transaction	C2328 - Instrument Panel Cluster Trim Plate Replacement	5,224 MI
10/20/2008	540280	ZREG----Regular Vehicle Transaction	J5670 - Mass Airflow Sensor Replacement	5,224 MI
10/20/2008	540280	ZFAT----Field Action Recall	V1741 - 08080 - Reprogram Transmission Control Module (TCM)	5,224 MI
10/20/2008	540280	ZREG----Regular Vehicle Transaction	R0760 - Radio, Remove and Replace	5,224 MI
10/20/2008	540280	ZREG----Regular Vehicle Transaction	E8040 - Tie Rod, Inner - Right - Replace	5,224 MI
10/20/2008	540280	ZREG----Regular Vehicle Transaction	E8041 - Tie Rod, Inner - Left - Replace	5,224 MI

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PAGE 3

USTOMER #:4754077

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5968 LAUREL OAK CIRCLE
RAY BEACH, FL 33484
E:561 737-8998 CONT:561-737-8998
US: CELL:

SERVICE ADVISOR: 3235 PILONE,JARROD

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
	08	HUMMER H2	5GRGN23878H107653		18586/	T3166

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
6JUN08 IS 6JUN08 DD			18:00 02NOV10			CASH	

R.O. OPENED	READY	OPTIONS: DLR:26200 ENG:6.2_Liter_MPFI_OHV
2NOV2010 14:47		

INE	OP CODE	TECH.	TYPE	DESCRIPTIONS/INSTRUCTIONS
F	*11		WCT	INTERMITTENTLY, WILL ONLY BLOW HOT ON ONE SIDE WHEN THE OTHER IS BLOWING COLD AC AIR
G	*22		WCT	C/S BRAKES SQUEAK WHEN BRAKES HEATED UP, PLEASE CHECK AND ADVISE
H	*MULTI-N			ICEPS MULTI POINT INSPECTION NOT PERFORMED ON THIS VISIT.

OMMENTS SHUTTLE CC created 2010-11-02 02:11:00pm taken by DME BDC

LIENT LABOR CHARGES ARE BASED ON FLAT RATE AND HOURLY UNLESS OTHERWISE INDICATED.
ou will be notified upon completion of any diagnostic work necessary to estimate the cost of repair or if he actual charges will exceed the written estimate, including any additional authorized charges, by $10 or 0%, whichever is greater, not to exceed $50.00
dditional person authorized to approve performance of repairs, if customer desires to designate uch person________ Phone:________ Date:________

ADDITIONAL REPAIRS AUTHORIZED: I ACKNOWLEDGE NOTICE AND ORAL APPROVAL OF AN INCREASE IN THE ORIGINAL ESTIMATED PRICE.

ESTIMATE $________ TIME ________
ADDITIONAL $________ DATE ________
TOTAL $________ OK'D ________
CUSTOMER SIGNATURE X ________

PLEASE READ CAREFULLY, CHECK ONE OF THE STATEMENTS BELOW AND SIGN: I UNDERSTAND THAT UNDER STATE LAW, I AM ENTITLED TO A WRITTEN ESTIMATE, IF MY FINAL BILL WILL EXCEED $100.00.

☐ I REQUEST A WRITTEN ESTIMATE.

☐ I DO NOT REQUEST A WRITTEN ESTIMATE *AS LONG AS THE REPAIR COSTS DO NOT EXCEED $______. THE SHOP MAY NOT EXCEED THIS AMOUNT WITHOUT MY WRITTEN OR ORAL APPROVAL.*

☐ I DO NOT REQUEST A WRITTEN ESTIMATE.

SIGNED: ________ DATE: ________

ALL PARTS ARE NEW UNLESS OTHERWISED INDICATED. Dealer will dispose of replaced parts, unless subject to a manufacturer's warranty, core charge or otherwise specified. ______ (Customer Initials) Please save old parts for inspection or return. There may be a additional charge for the return of old parts.

MISCELLANEOUS SHOP SUPPLIES AND WASTE DISPOSAL CHARGES: This charge represents costs ar profits to the motor vehicle repair facility for miscellaneous shop supplies or waste disposal. The state of Florida requires a $1.00 fee to be collected for each new tire sold in the state (s.403.718), and $1.50 fee to be collected for each new or remanufactured battery sold in the state (s.403.7185).

DIAGNOSTIC WORK/PARTIALLY COMPLETED REPAIRS: In the event that you authorize diagnostic work estimate the cost of repair or commencement of repairs, but do not authorize completion of a repair or servic a charge will be imposed for disassembly, reassembly or partially completed work. The vehicle shall reassembled to a condition reasonably similiar as when received, unless you waive reassembly or t reassembled vehicle would be unsafe. Any charges will be directly related to the actual amount of labor parts involved in the inspection, repair or service.

STORAGE CHARGES: *Storage charges will be assessed and shall accrue daily if you fail to pick up your vehi within 3 working days from the date you are notified that the work on your vehicle has been completed. T daily charge for the storage of your vehicle will be $50.00 per day.*

LIMITED WARRANTY: *PLEASE SEE THE REVERSE SIDE OF THIS REPAIR ORDER FOR WARRANTY INFORMATION*

I hereby authorize the Dealer to perform the above-described repair work and agree to pay for the repairs, along with the necessary materials, in Cash upon completion of the repairs, unless the Dealer agrees to other payment arrangements in advance. An express mechanic's lien is hereby acknowledged on the above vehicle to secure the cost of repairs and materials. I further agree that the Dealer is not responsible for any delays caused by unavailability of parts or shipping by the supplier or transporter. I hereby grant the Dealer permission to operate the vehicle on streets, highways or public roadways for the purpose of testing and/or inspecting the vehicle. I acknowledge that the Dealer is not responsible for loss of or damage to the vehicle or articles left in the vehicle in case of fire, theft or any other cause beyond its control.

CUSTOMER SIGNATURE X ______

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US: CELL:

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SERVICE ADVISOR: 3235 PILONE,JARROD

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN/ OUT	TAG
	08	HUMMER H2	5GRGN23878H107653		18586/	T3166

DEL DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
6JUN08 IS 6JUN08 DD			18:00 02NOV10			CASH	

R.O. OPENED	READY	OPTIONS: DLR:26200 ENG:6.2_Liter_MPFI_OHV
2NOV2010 14:47		

INE	OP CODE	TECH.	TYPE	DESCRIPTIONS/INSTRUCTIONS
A	05		WCT	C/S ENGINE IS TRANSLATING A VIBRATION TO THE STEERING WHEEL/INTERIOR WHILE IDLING IN GEAR, HAS BEEN GETTING PROGRESSIVELY WORSE
B	13		WCT	THERE IS A CLUNK IN THE DRIVETRAIN WHEN COASTING AND THEN REACCELERATING
C	05		CCCR	THERE IS A VIBRATION IN THE VEHICLE WHILE AT HIGHWAY SPEEDS, PLEASE INSPECT AND ADVISE, FRONT TIRES ARE CHOPPING
D	01		WCT	C/S VEHICLE'S RIDE QUALITY IS POOR, IS ROUGHER THAN WHAT IT'S SUPPOSED TO BE, WANDERS, LOOSENESS, AND BUMPY RIDE EXPERIENCED
E	11		WCT	INTERMITTENTLY, ONLY BLOWS HOT AIR OUT DASH VENTS (LIKE HEAT IS ON)

IENT LABOR CHARGES ARE BASED ON FLAT RATE AND HOURLY UNLESS OTHERWISE INDICATED.
u will be notified upon completion of any diagnostic work necessary to estimate the cost of repair or if e actual charges will exceed the written estimate, including any additional authorized charges, by $10 or 0%, whichever is greater, not to exceed $50.00
lditional person authorized to approve performance of repairs, if customer desires to designate
ch person__________ Phone:__________ Date:__________

ADDITIONAL REPAIRS AUTHORIZED: I ACKNOWLEDGE NOTICE AND ORAL APPROVAL OF AN INCREASE IN THE ORIGINAL ESTIMATED PRICE.
ESTIMATE $__________ TIME __________
ADDITIONAL $__________ DATE __________
TOTAL $__________ OK'D __________
CUSTOMER SIGNATURE X __________

LEASE READ CAREFULLY, CHECK ONE OF THE TATEMENTS BELOW AND SIGN: I NDERSTAND THAT UNDER STATE LAW, I AM NTITLED TO A WRITTEN ESTIMATE, IF MY INAL BILL WILL EXCEED $100.00.
☐ I REQUEST A WRITTEN ESTIMATE.
☐ I DO NOT REQUEST A WRITTEN ESTIMATE LONG AS THE REPAIR COSTS DO NOT .CEED $________. THE SHOP MAY NOT XCEED THIS AMOUNT WITHOUT MY WRITTEN R ORAL APPROVAL.
☐ I DO NOT REQUEST A WRITTEN ESTIMATE.

IGNED: __________ DATE: __________

ALL PARTS ARE NEW UNLESS OTHERWISED INDICATED.
Dealer will dispose of replaced parts, unless subject to a manufacturer's warranty, core charge or otherwise specified.
________ (Customer Initials) Please save old parts for inspection or return. There may be an additional charge for the return of old parts.

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STORAGE CHARGES: Storage charges will be assessed and shall accrue daily if you fail to pick up your vehicle within 3 working days from the date you are notified that the work on your vehicle has been completed. The daily charge for the storage of your vehicle will be $50.00 per day.

LIMITED WARRANTY: PLEASE SEE THE REVERSE SIDE OF THIS REPAIR ORDER FOR WARRANTY INFORMATION.

I hereby authorize the Dealer to perform the above-described repair work and agree to pay for the repairs, along with the necessary materials, in Cash upon completion of the repairs, unless the Dealer agrees to other payment arrangements in advance. An express mechanic's lien is hereby acknowledged on the above vehicle to secure the cost of repairs and materials. I further agree that the Dealer is not responsible for any delays caused by unavailability of parts or shipping by the supplier or transporter. I hereby grant the Dealer permission to operate the vehicle on streets, highways or public roadways for the purpose of testing and/or inspecting the vehicle. I acknowledge that the Dealer is not responsible for loss of or damage to the vehicle or articles left in the vehicle in case of fire, theft or any other cause beyond its control.

CUSTOMER SIGNATURE X __________

F

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	Sherif Kodsy	Inspection Date:	1/21/2009
Vehicle Brand:	2008 Hummer	Model:	H2
File #	71-693377188	VIN:	5GRGN23878H107652

Mileage at Inspection: **10,808**

Inspection Location: **Schumacher Buick Hummer West Palm Bch, FL 33409**

Inspector's phone number: **954-749-3637**

Inspected By: **Jim Daugherty EAA**

Section 1 **INSPECTION SUMMARY**

BRIEFLY Describe the customer's ALLEGATION below:

Owner stated that the vehicle ride was jerky and rough. He also stated that the engine did not idle smoothly.

Following the inspection, summarize the facts and observations: *(Additional cmts may be 33409placed in section 9)*

Inspected the vehicle undercarriage and tires and wheels. Checked tires pressure for over inflation and damage to wheels or tires. None was noted. Road tested vehicle for several miles with the dealer service director. Vehicle did not appear to ride improperly for this type of chassis and tire combination. Selected another vehicle form stock with identical engine, tires, and wheel combination. Road test indicated that ride was similar to owner's vehicle. Engine idle appeared normal with only a slight quiver in the tachometer needle as the fuel injection made minor adjustment to the fuel/air mixture. Second vehicle idled similarly.

Section 2 **INTERVIEW - INCIDENT DETAILS**

Obtain all of the information for this section from the Driver/Claimant

Provide a complete description of the incident according to the DRIVER / CLAIMANT

Interview mode: ☐ By Telephone X In Person

Incident Date and Time: **Not applicable**

Interview date: **1/21/2009**

No accident involved.

Driver/other occupant's physical description (include name, gender, height, weight, & disabilities):
Sherif Kodsy 5' 8" tall, 190lbs, DOB 4/27/1964, No disabilities

If there was a collision:

Describe extent of any injuries to the Driver: **States that rough ride increases his medical problems**

Describe where other occupants were seated & extent of any injuries: **N/A**

What was the exact location of the incident. N/A

Driving conditions at the time of the incident:

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	Sherif Kodsy	Inspection Date:	1/21/2009
Vehicle Brand:	2008 Hummer	Model:	H2
File #	71-693377188	VIN:	5GRGN23878H107652

Weather conditions & Visibility: **N/A** Approximate Temp (°F): {

Road Surface: ☐ Concrete ☐ Asphalt ☐ Gravel ☐ Crushed rock ☐ Dirt
Road Condition: ☐ Dry ☐ Wet ☐ Icy ☐ Other: {
Shoulder ☐ Curb ☐: ☐ Concrete ☐ Asphalt ☐ Gravel ☐ Crushed rock ☐ Dirt
Shoulder/Curb Condition: ☐ Dry ☐ Wet ☐ Icy ☐ Other: {
Posted Speed Limit {
Any objects in the road? (rocks, scrap metal, pothole, speed bump, etc.)_ **Normal asphalt pavement**

Length of Drive Prior to incident:

Total Time (hrs. & mins.):_**N/A** Distance (miles):_{
Estimate of vehicle speed:_{ mph Source of est. {
Estimated vehicle speed at impact:_{ mph Source of est._{
(Do Not report speed information from the Vetronix data here)

If the driver/claimant description of the vehicle operation prior to and during the incident does not include the following information, please obtain it.

Steering	**Normal** X	**Other** ☐	**Describe** {
Suspension	**Normal** ☐	**Other** X	**Describe** **Rough and overly firm**
Brakes	**Normal** X	**Other** ☐	**Describe** {
Engine	**Normal** ☐	**Other** X	**Describe** **Idles rough and tach needle drops to 0**
Electrical	**Normal** X	**Other** ☐	**Describe** {

Were any warning lights illuminated or driver information center messages displayed? ☐ Yes X No If "Yes", get the details and describe the event(s).

Has the vehicle behavior noted during this incident ever been noted prior to this incident? X Yes ☐ No If "Yes", get the details and describe the event(s). Operated this was since new

Also, determine whether there were any warning lights illuminated, messages on driver information panel, unusual noises, smoke or steam observed. **None noted**

Describe any evasive action: ☐ Turning ☐ Braking ☐ Accelerating ☐ Other:
{_**N/A**

Describe cargo (in the vehicle interior, trunk and/or trailer (if any):_**None noted**
Estimated total weight of cargo:_{ Estimated weight of the trailer, if any. {

If a trailer was being towed, photograph the hitch structure, both on the trailer and towing vehicle.

Did the vehicle leave the roadway?: ☐ Yes X No Describe: {
Objects Impacted: {
{
{
{

Section 3	INTERVIEW - VEHICLE HISTORY

Source of information (name, address, phone number, & relationship), if other than claimant:
{

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	**Sherif Kodsy**	Inspection Date:	**1/21/2009**
Vehicle Brand:	**2008 Hummer**	Model:	**H2**
File #	**71-693377188**	VIN:	**5GRGN23878H107652**

Comments: *(Additional cmts may be placed in section 9)*
Dealer service dieector stated that they had recently replaced three of the vehicle tires and installed the spare as a fourth tire to try to satisfy the owner. No appreciable change was seen in the vehicle ride.

Did the owner purchase the vehicle new? X Yes ☐ No Date 6/11/2008 Used? ☐ Yes ☐ No Date_____

VEHICLE MODIFICATIONS / ALTERATIONS
Are any vehicle modifications or alterations present, and has any after-market equipment been installed? (e.g., objects attached to the steering wheel or instrument panel, controls for disabled persons, shock absorbers, springs, modified body, electrical components, powertrain, wheels or tires, after-market seats, etc..) Describe:
None noted

VEHICLE REPAIR / SERVICE HISTORY
Prior electrical system service? X No ☐ Yes If yes, describe:

Prior collision repair? X No ☐ Yes If yes, describe:

Repaired by whom? (name, address, phone)

Prior chassis system service, repair, or replacement? ☐ No XYes If yes, describe what was done:
3 new tires

Prior electrical system components serviced, repaired, or replaced by whom? (name, address, phone number)

Any other pertinent vehicle history information (from interview, GM warranty or dealership history files)? X No ☐ Yes
If yes, describe:

Section 4	VEHICLE INSPECTION – VISUAL/PHOTO

THE VEHICLE VISUAL INSPECTION DOCUMENTS THE PHYSICAL EVIDENCE USING PHOTOS AND WRITTEN OBSERVATIONS. RECORD YOUR OBSERVATIONS IN THE APPROPRIATE SECTION.
PHOTOGRAPH THE EXTERIOR OF THE VEHICLE AS FOLLOWS: VIN PLATE, QUARTER VIEWS FROM LEFT FRONT, RIGHT REAR ARE REQUIRED, AND DOCUMENT FURTHER EXTERIOR DAMAGE WITH MANY PHOTOS.

DESCRIBE ANY DAMAGE TO THE VEHICLE BODY:
None

UNDERBODY / FRAME / CHASSIS AREA: Describe any damage to the underside of the vehicle. Note the condition of the bumpers, frame, suspension, tires, wheels, brake and fuel lines & engine mount(s)/crossmember. Photograph and comment on any contact between vehicle components and the underbody. Photograph if damage is present.
None

CORNER ASSEMBLIES

Struts/shocks	Ball joints	Tire/wheel assemblies
Springs	Steering knuckles	
Control arms	Axle assemblies	

Comments: **No damage noted**

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	**Sherif Kodsy**	Inspection Date:	**1/21/2009**
Vehicle Brand:	**2008 Hummer**	Model:	**H2**
File #	**71-693377188**	VIN:	**5GRGN23878H107652**

UNDERHOOD

Engine compartment
Brake fluid level and condition
Power steering lines, hoses, clamps and connections
Power steering fluid level and condition

Comments:
None noted

GENERAL OBSERVATIONS

Photograph and comment on any aftermarket equipment found, vehicle modifications or items that are unusual or out of place.

Comments:
None noted

Section 5	**VEHICLE INSPECTION - PASSENGER COMPARTMENT**

INTERIOR

Instrument panel
Controls
Overall view of seat position
Photo of options label-glove box/trunk
Personal items/cargo
Odometer
Steering wheel and column
Driver and passenger seat back angle (inclinometer measurement)
Sunvisors and headliner

INTERIOR INSPECTION (Describe any damage and photograph)
None

Section 6	**STEERING, SUSPENSION, TIRE AND WHEEL SYSTEM INSPECTION**

Use the following table to identify what you did and what you found during the inspection. Identify the tests and test results for the applicable items. Describe anything relevant to the allegation that is not in normal working condition, does not function properly or is a non production part. Take appropriate photographs.

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	**Sherif Kodsy**	Inspection Date:	**1/21/2009**
Vehicle Brand:	**2008 Hummer**	Model:	**H2**
File #	**71-693377188**	VIN:	**5GRGN23878H107652**

ITEM	OBSERVATIONS/TEST RESULTS
Steering system-Are all components in place and connected in a normal manner? Can the steering wheel be rotated lock to lock with appropriate movement of the front wheels. Is there any binding, sticking or uneven feel?	**Normal appearance and operation**
Steering linkage-Is the linkage free from cracks, bends, fractures, etc. Are there any scrapes, abrasions, signs of contact with any of the linkage?	**Normal appearance and operation**
Gear/rack and pinion-Any sign of leakage, damage to boots on the rack, contact by foreign objects?	**Normal appearance**
Steering column, ignition switch, intermediate shaft. Does the column unlock with the ignition key "on"? Is the steering column properly fastened to the dash?	**Normal operation**
Steering pump, drive, hoses, connections, flow, pressure. If possible, start the engine and rotate the steering wheel lock to lock. Is power assist normal? If not, it may be necessary to check pressure and flow.	**Belt tight – Normal operation**
PS fluid level and condition-Color, contamination, odor	**Reservoir full – fluid clear – no odor-**
Steering knuckle-All attachments secure and proper?	**Normal appearance**
Suspension components – LF Strut attachments, springs intact; control arms properly attached, deformed, broken, scraped, etc. Sway bars properly attached.	**Normal appearance**
Strut attachments, springs intact; control arms properly attached, deformed, broken, scraped, etc. RF	**Normal appearance**
Strut attachments, springs intact; control arms properly attached, deformed, broken, scraped, etc Rear sway bars,	**Normal appearance**

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	**Sherif Kodsy**	Inspection Date:	**1/21/2009**
Vehicle Brand:	**2008 Hummer**	Model:	**H2**
File #	**71-693377188**	VIN:	**5GRGN23878H107652**

trailing arms properly attached and undamaged. LR	
Strut attachments, springs intact; control arms properly attached, deformed, broken, scraped, etc. RR	**Normal appearance**
Rear axle assembly-deformed, signs of impact, properly located, etc.	**No damage noted**
Deformation to the frame	**No damage noted**
Describe and photograph evidence of axle/ suspension/ tire contact with frame, body or components	**None noted**
Describe and photograph contact of the under- carriage with the road surface (road, shoulder, curb, or grass)	**None noted**
Stability Enhancement system/components-check for codes with Tech II	**None stored**
Engine (normal, other)-Obtain codes using a Tech II.	**Normal operation – no codes stored**
Electrical (normal, other)	**Normal operation**
Warning lights/messages displayed? Describe and obtain codes using a Tech II	**None**
Anything components missing?	**None noted**
Other	

If the vehicle is driveable, conduct a road test to evaluate the concern expressed by the customer. Describe the results of the road test. If the concern is observed during the road test, it would be desirable to get a Tech II "snapshot".
See previous comments

If the vehicle is equipped with an ABS/Traction Control/Stability Enhancement System, use a Tech II to obtain any codes stored as current and/or history. Document via photos and include the code description. Follow the procedures in the service manual to determine the cause of each stored code which relates to the allegation. State which procedures were followed, record results of each test and state the root cause of each code. Consult with the CRM or Team Manager of the PAR group if this process leads to a disassembly of components. Follow the procedure in the General Guidelines for parts that need to be assembled for evaluation.

Inspect the system wiring, connections and components for damage. Note if the damage was the result of the incident

TIRE AND WHEEL INSPECTION

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	**Sherif Kodsy**	Inspection Date:	**1/21/2009**
Vehicle Brand:	**2008 Hummer**	Model:	**H2**
File #	**71-693377188**	VIN:	**5GRGN23878H107652**

1. IDENTIFICATION:

	TIRE BRAND (Goodyear)	TIRE TYPE (Eagle GA)	TIRE SIZE (P205/70R15)	PRESSURE (psi)	AVE. TREAD DEPTH 32nds of inch	DOT Numbers
LF	**B F Goodrich**	**All Terrian**	**315/70 R17**	**44**	**17**	
RF	"	"	"	**44**	**17**	
LR	"	"	"	**44**	**17**	
RR	"	"	"	**44**	**15**	

Note: DOT numbers may be found on the inside of each tire adjacent to the rim.

Describe and photograph any damage to tires and wheels, such as scrapes, marks due to impact, cuts, tread separation, flat spots, bead separation, embedded grass/dirt, etc. Photographs should include inner and outer views of the damaged tire/wheel assemblies with chalk marks on each assembly to denote position on vehicle (RF, LF. RR and LR).

LF
None

RF
None

LR
None

RR
None

2. TIRE PLACARD DATA:
Record the following data: (located on driver's door edge or inside the decklid)

	SIZE	PRESSURE (psi)	PRESSURE AT MAXIMUM LOAD(psi)
TIRES	**315/70 R 17**	**45**	
SPARE TIRE	**Not recorded**		

Section 7	SITE INSPECTION

SITE INSPECTION - PERFORM THE FOLLOWING IF ADDITIONAL INFORMATION MAY BE FOUND:

- Check the incident scene for tire marks, gouges in the pavement, debris, or any other marks. Measure location and photograph.
-

PRODUCT ALLEGATION RESOLUTION
PRELIMINARY INSPECTION
STEERING, SUSPENSION, AXLE, TIRE AND WHEEL SYSTEMS

Customer's Name:	Sherif Kodsy	Inspection Date:	1/21/2009
Vehicle Brand:	2008 Hummer	Model:	H2
File #	71-693377188	VIN:	5GRGN23878H107652

Identify evidence of whether the vehicle left the road prior to, during, or after the incident. Document all locations, distances, stationary objects (guard rails, telephone poles, fences,buildings,etc), nearest posted speed limit signs in the direction of travel, etc...

- Identify evidence & photograph any object struck by the vehicle on or off the road prior to, during or after incident.
- Inspect roadway & shoulder surfaces in the area of the incident site for telltale signs of loss of control, excessive speed, severe braking, etc.

Photograph the scene and property if involved.

Comments:

{
{
{
{
{

Section 8	COMMENT OVERFLOW

Please use this page if needed for additional comments from the inspection form. Please note the section and area the comments are continued from prior to each comment.

{
{
{
{
{

Section 9	OTHER REPORT INFORMATION

☐ **Check here if there was evidence of a "Fire-Related" event.**
According to NHTSA, "fire" means combustion or burning of material in or from a vehicle as evidenced by flame. The term also includes, but is not limited to, thermal events and fire-related phenomena such as smoke, sparks or smoldering, but does not include events and phenomena associated with a normally functioning vehicle, such as combustion of fuel within an engine or exhaust from an engine.

Attachments: (Check all that apply)
X **Photographs** X **Data Downloads** ☐ **Other Records**

G

SAE International www.sae.org

Noise and Vibration Control Measures in the Powertrain of Passenger Cars

Document Number: 911053

Date Published: May 1991

Author(s):
Peter Schwibinger - Freudenberg-NOK
David Hendrick - Freudenberg-NOK
Wei Wu - Freudenberg-NOK
Yasuhiro Imanishi - Freudenberg-NOK

Abstract:
The paper describes a theoretical and experimental approach to solve vibration and noise problems in the powertrain with vibration control products on an elastomer basis.

Crankshaft dampers can reduce the torsional, and, if properly tuned and designed~also the bending vibrations. The paper compares the crankshaft vibrations for different damper designs which shows the potential for further vibration and noise reductions.

Shafts in the drivetrain are excited to torsional and bending vibrations by the inertia and gas forces of the engine, cardan joints and gear mesh. For the following two problems vibrations and noise are investigated: 1) a torsional resonance of a driveshaft; and 2) a bending resonance of a halfshaft.

Measurements show that noise and vibrations from the drivetrain can also be reduced significantly with tuned elastomer dampers.

File Size: 289K
Product Status: In Stock

See other papers presented at

A New Method for Engine Design Using Dynamic Optimization and Substructure Synthesis Method

Document Number: 911065

Date Published: May 1991

Author(s):
Masanori Ishikawa - Isuzu Motors Ltd.
Mitsuo Iwahara - Isuzu Advanced Engineering Center, Ltd.
Akio Nagamatsu - Tokyo Institute of Technology

Abstract:
This paper describes a new method for engine design using dynamic optimization and substructure synthesis method. A very important theme in engine design is how to shift the peak of the natural frequency of the vibration mode that causes some noise and vibration problems. This must be resolved by effective modification of structural design.

In order to carry out effectively vibration analysis of a large scaled structure like engine assembly and conduct dynamic optimization with many iterative calculations, we have used substructure synthesis method that devides a whole structure into a number of substructures and solves each substructure.

Vibration analysis of engine assembly (cylinder block, crankshaft, bearing caps and flywheel systems) was carried out by using this substructure synthesis method. And, on the basis of the sensitivity of eigenvalue of the residual structure that is to be modified (cylinder block and bearing caps this time), the optimization program using pseudo least square method has been successfully applied to shift the peak of a given natural frequency to a designated frequency range.

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A Development Process to Improve Vehicle Sound Quality

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Document Number: 911079

Date Published: May 1991

Author(s):
Robert S. Thomas - Ford Motor Co.
Paul J. Stanecki - Ford Motor Co.
H. Peter Creutz - Ford Motor Co.

Abstract:
Vehicle sound quality has become an important basic performance requirement. Traditionally, automobile noise studies were focused on quietness. It is now necessary for the automobile to be more than quiet. The sound must be pleasing.

This paper describes a development process to improve both vehicle noise level and sound quality. Formal experimental design techniques were utilized to quantify various hardware effects. A-weighted sound pressure level, speech intelligibility, and composite rating of preference were the three descriptors used to characterize the vehicle's sound quality. Engineering knowledge augmented with graphical and statistical techniques were utilized during data analysis.

The individual component contributions to each of the sound quality descriptors were also quantified in this study. This paper discusses the importance of measurement studies to ensure desired experimental precision, the use of regression analysis to overcome the effect of engine rpm during experimentation, and normal probability plots as an initial empirical model building technique

File Size: 460K
Product Status: In Stock

See other papers presented at Noise

H

EXERPTS, from trial transcript, direct questioning of defendants' corporate agent , mr. Tom Thornton.

Q But you don't actually do any mechanical work?

A I am not a mechanic, no.

Q What about those tires on that vehicle, do you know what kind of tires they are?

A BF Goodrich All Terrain T/A's.

Q What does that mean?

A The brand is BF Goodrich. The model is All Terrain T/A.

Q So they're not off road tires?

A Actually they're a street legal, all terrain tire. As a matter of fact, I do have some experience with those tires in my own personal background using them in off road applications.

They are designed to be used off road.

They have an aggressive tread, very deep tread. The lugs are spaced far enough apart to allow dirt, debris, sand, water to pass through the tread so that the vehicle can maintain traction in off road conditions. They're an aggressive tire.

Q But they're street legal tires, they're made for on road?

A They are street legal tires.

0149

Q The truck is a street legal vehicle, it's not an off road vehicle unless you take it off road, correct?

A The truck is designed to be used on and off road. It's designed with off road capabilities.

Q I'm saying in this city, there is no off road driving. So, when that truck is driven in the city, it is not to be driven off roads, it's to be driven on pavement, a flat road, correct?

A The use of the vehicle is up to the driver.

Q You've got to drive in the city, you're driving on a flat road, there is no dirt roads that you're going to drive on, correct?

A Honestly, that depends on the city.

Q Okay. My point is, if those tires are off road tires and you're driving in the city, is it supposed to have that off road feeling when you're driving in the city?

A The tires are stiff, aggressive off road tires. They will feel stiffer than a comparable street application.

Q Is it true that BF Goodrich stopped making those tires?

A That is not true.

0150

Q Well, they did.

Wasn't this your statement saying the Hummer brand is targeted towards the outdoor enthusiast, it's an off road vehicle?

A That's correct.

Q What about on road, isn't it meant to be on road as well?

A As I already answered, it is a street legal vehicle.

Q But it's not supposed to feel like it is on road as it is off road, it's supposed to cushion the off road to feel like it's on road, and when you drive the on road, it's supposed to feel like a normal vehicle?

A I believe that's your speculation.

Q Okay. So you're saying those tires are all terrain?

A Correct.

Q They're supposed to be what, a smoother ride 'cause they're all terrain?

A The design of those tires is for traction. The ride is going to be a subjective feel by the driver.

Q Subjective feel by the driver.

Don't you have standards?

0151

A Of course we have standards.

Q What's your standard on that?

A With respect to which dimension?

Q The subjective feel of the driver, what's that mean?

A Mr. Kodsy, you're asking for how the tires are supposed to drive on pavement.

Q Right.

A They're designed to be an all terrain tire.

Q What's the specs on them?

A Your experience with all terrain tires -- they're much different than a street oriented tire. These tires are designed to be stiff, heavy, aggressive tires.
Q So, they're stiff and aggressive?
A They're a not a road tire you would find on a passenger car.
Q Okay. They're stiff and aggressive tires?
A By design.
Q By design, okay.
And whose fault is that?
A I don't think it's anything I assign fault for. It's design. It's intentional.
Q It's intentional?

0152

A For an aggressive tire.
Q Okay. And you're supposed to feel those tires when you drive?

A Can you express your question a little differently? I'm not sure I understand what you're asking.

Q Okay. I mean, you're telling me it's a stiff and aggressive ride -- or aggressive tire. So, how is that supposed to feel when you drive? You're supposed to feel it?

A I'm going to answer what I think you're asking. The Hummer H2 is a very large, very heavy truck. The BF Goodrich All Terrain T/A's are very large, very heavy, all terrain tires. It is not going to ride smoothly on the road like a passenger car will. It's going to ride as it's designed, like a heavy, off road capable, powerful truck.

Q Off road capable, powerful truck, okay.

Isn't it supposed to be compared to the Escalade with a 6.2 liter engine, 393 horsepower?

You got the Escalade with the same engine qualities, same everything, and you're telling me that this truck's supposed to be different?

A It's actually a poor comparison because the two vehicles are radically different. The

0153

Escalade is designed for on road comfort. It's not an off road vehicle. The Escalade has street oriented tires and a completely different drive train from what the Hummer H2 has. The frame is different, the suspension is different. The entire ride of the vehicle is designed completely different.

Q So it's supposed to be better?

A It has a different purpose.

Q You're not just saying that, right?

THE COURT: Sir, you have to ask an actual question.

BY MR. KODSY:

Q Well, you're telling me that the Hummer's supposed to have a heavier, more supported suspension than an Escalade so it wouldn't have a rail shake, correct?
A I wouldn't -- I wouldn't go that direction with it. The way I would describe the difference in the suspension between an Escalade and a Hummer -- first of all, we're looking at apples and oranges. The Escalade, other than size, is a street truck. It's a street vehicle. It's designed to be a luxury vehicle. The suspension is tuned for a street application.

0154

The Hummer is intended to be an off road capable vehicle. The suspension is tuned for an off road application by design.
Q Off road capable, I understand. That means when you take it off road, it's capable. But

on road is what I don't understand.

You're telling me on road -- you're telling everybody here that on road this truck is aggressive and it's got a stiff ride. So, that just -- it doesn't explain it to me, it just causes a lot of doubt.

THE COURT: You have to have a ask question. It's strictly question and answer.

BY MR. KODSY:

Q So, you're saying this truck's supposed to drive like a beast?

A The truck is kind of a beast. It's a big, heavy and powerful, capable off road vehicle.

I

TESTIMONY BY JOE BARDILL, THE GM AUTHORIZED MECHANIC FROM CORAL CADILLAC INC..

JOE BARDILL,
called as a witness by the Defendant, having been first duly sworn by the Clerk, in answer to questions propounded, was examined and testified as follows:

0542

THE WITNESS: I do.
THE COURT: Okay. Have a seat. Do you mind just telling the jury your name?
THE WITNESS: I'm Joe Bardill.
THE COURT: Okay. And how do you spell your last name, sir?
THE WITNESS: B-a-r-d-i-l-l.
THE COURT: Thanks a lot. Okay.

DIRECT EXAMINATION

BY MR. KLEIN:
Q Morning, Mr. Bardill.
A Morning.
Q Could you please tell the jury where you're currently employed?
A Coral Cadillac.
Q And what is your title at Coral Cadillac?
A I'm the service manager.
Q Can you tell the jury how long you've been at Coral Cadillac?
A I've been there 28 years, 15 as a technician, 10 as a shop foreman, and since 2006 I've been the service manager.
Q All right. Mr. Bardill, for me back here it's a little -- you're a little soft spoken. Just speak up some.

0543

A Okay.
THE COURT: What you need to do is point the microphone right at you because it's a directional microphone. There you go.

BY MR. KLEIN:
Q So you've been the service manager for Carl Cadillac since 2006?
A Yes.
Q Can you describe for the jury your automotive training and experience?
A I'm an ASE master technician. I've got over 400 -- I believe 438 GM courses that I completed. And that's pretty much it.
Q What is ASE?
A ASE is the National Institute for Automotive Service Excellence. It was a nonprofit organization. It started in 1972 basically because there was no yard stick to measure competent technicians versus incompetent. It's become very large.
It's required in Broward and Dade County. To have a technician's license you're required to have your ASE. It's also required in GM training for your training path to have the ASE certification.
0544
Q And what does it mean to have the ASE master certification?
A That means you have all eight.
Q All eight --
A All eight categories. There's approximately 4,000 automobile masters in the United States.
Q And --
A I'm sorry, 400,000. I'm sorry.
Q And ASE has certain categories they will certify you in individually?
A Yes.
Q To have your master's you have to have all eight categories?
A Yes. I also carried the L1 for 10 years, which is advanced engine performance. I don't carry it currently.
Q Now, as the service manager for Coral

Cadillac, are you familiar with the repair work and service orders that have been done with Mr. Kodsy's 2008 Hummer?
A Yes, sir.
Q I'm going to show you what's already in evidence as Plaintiff's Exhibit 2.
Mr. Bardill, Exhibit 2 are the repair
0545
orders that have been admitted in evidence already. Several of them are from Coral Cadillac.
When did Mr. Kodsy first bring the vehicle to Coral Cadillac?
A I believe this is the first -- the first repair attempt, first time in for a repair and service.
Q And that is what date?
A It's October 20th.
Q 2008?
A 2008, yes.
Q And what were Mr. Kodsy's complaints at that time?
A The vehicle would not stay running.
Q And what did the dealership do for that complaint?
A We replaced a mass air flow sensor.
Q Can you explain to the jury what the mass flow air sensor is?
A The mass air flow sensor meters the air that comes into the engine, and that's pretty much how the computer knows how much fuel to add. It's a speed density system. But basically what it's doing is it's telling the computer how much fuel to add.
Q And did you do anything else in addition
0546
to replacing the mass air flow sensor for that --
A Yes, I think we did a -- there was actually a service inventory update for the transmission control module reprogram. That was for a -- I believe a down shift. It was strictly customer satisfaction bulletin.

And then I believe he added on a couple
lines of a CD player was in-op. We did replace the
radio. And rusting, I believe this line was also
added, rust on the suspension parts, which we
painted with 415.
Q And what is 415?
A It's a rust inhibitor. Basically the
thing with the Hummers, it's so high that people see
the under -- the chassis and underside. Down here
in this environment, every chassis gets some rust,
discoloration. But it actually was a PI that Terry
Nicholson -- we worked on with and he came up with
the 415 to paint the suspension parts with that.
Q What is a PI?
A It's a preliminary -- it's before it
becomes a bulletin. It's preliminary, but it hasn't
gone through legal. Sometimes they never go through
legal because it's not that important or they find
another route that they want to go. So, this one
0547
never became a service bulletin.
Q And so it's to assist dealerships if the
customer has a particular concern?
A It's a preliminary -- like a preliminary
bulletin that General Motors makes available to us,
but it never becomes -- don't get me wrong,
sometimes they do become a bulletin, but then it
loses the PI number and it becomes a bulletin
number.
Q And -- but with regard to the concern
about the engine not staying running, did you also
reprogram the engine control module?
A Yes, we did. There apparently was an
updated program for it, that's why that was done.
Q In addition, you mentioned he came back
and some things were added?
A Yes.
Q One of them is the seat heater, is that
right?
A Yes, also the seat heater. We found

nothing wrong with that. And there was some door dings that were repaired at no charge.
Q The door dings that were repaired, was that due to defects in GM's workmanship?
A No. I don't know -- I don't know if it

0548

was done for -- obviously it was done for customer satisfaction. I don't know if they were claimed to have been dinged on our lot or what, but I don't know the specifics there.
Q But Mr. Kodsy wasn't charged for the dings?
A No.
Q Now, were you actually personally involved with the vehicle the first time it came in?
A No, I was not.
Q Did you personally become involved with Mr. Kodsy's vehicle?
A I believe it was the next time -- yes.
Q And the next time it came in was --
A The next time it came in would be, yes, the brake squeal. That was November 5th, 2008.
Q And that's page six of Exhibit 2?
A Yes.
Q And what did you find with regard to the brake squeal?
A The brake squeal, there was a bulletin. We special ordered a new design pad that they had come out with.
Q Was the pad available at that time?
A It was not.

0549

Q So, Mr. Kodsy would have to come back to have the pads installed?
A That's true.
Q What else did you find with the vehicle?
A Well, I road tested -- at this time I had spent about probably 45 minutes with Mr. Kodsy. We took the vehicle up on 95. He was complaining -- he claimed the vehicle was missing. It was not

missing. There was a vibration in the steering wheel that was basically engine firing impulses.

All combustion engine's have a firing frequency and what -- that's why we have motor mounts and that to try and lessen that frequency coming into the vehicle, and that's what I felt and I felt that we could improve upon.

I felt nothing on the highway as far as vibration. And that's why we did put the dampeners on the exhaust system.

Q Before you put the dampeners on the exhaust system, how did the vibration feel? Did it feel substantial at all?

A It felt -- it felt different than a 2007 H2. And this is where I got egg on my face because this is the first time I got involved with the customer with a 2008. I went for a road test with

0550

him and I totally forgot that we replaced the six liter engine with a 6.2 in 2008.

Q And why would that make a difference between a six liter and the 6.2?

A Well, the 6.2 has 20 percent more horsepower. That's about 70 more horsepower in that engine than there was in the six liter. It was in the Escalade, and had I been driving an Escalade I would have said, this is normal, they all idle like this. But because I was in a Hummer H2, it just didn't click that this is a 2008 and not a 2007.

Q But even what you felt when you rode in Mr. Kodsy's before the dampeners were put on, would you feel that that was a defect or something substantial?

A No, not a defect. Just as I told him, we were sitting at the railroad tracks on Dixie and 48th Street and I said -- I explained to him what it was because he kept insisting that it was a misfire. I said, I can improve upon this, I'll never make it all go away, but I can improve on it.

Q And you couldn't make it go away why?

A Because it's normal basically. We're trying to improve upon a normal concern.
Q How did you improve upon the concern?
0551
A Well, we're trying to isolate the firing frequency from getting into the vehicle, and I felt that the exhaust system was getting excited from the frequency. It's basically like a guitar string, when you strum a guitar string. By putting the -- basically lead on the exhaust system, it's like putting your finger on a guitar string and it deadens the vibration or the -- you know, basically the excitement of that exhaust system.
Q How much weight did the weights weigh?
A They're three pounds. I believe we used two.
Q And --
A Actually, yes, there's two billed out on the ticket. So, we used two.
Q Sorry, I thought you were still looking at the document.
Now, on that same repair order from November 5th, Mr. Kodsy also had a concern about the transmission shifting, is that correct?
A Yes. And I did feel that on the road test. When we were merging into traffic we were -- we were in, say, sixth gear and I hit the throttle quite hard and the engine flared and it didn't down shift. So, we got technical assistance involved in
0552
that repair and we put a valve body and a TCM in the vehicle.
Q And a TCM is what?
A The transmission control module.
Q Can you explain to the jury what technical assistance is?
A That's -- basically it's -- they're out of Detroit. They're engineers who we call when we need help fixing a vehicle.
Q And they're GM engineers?

A GM engineers.
Q Is that common for a dealership to contact technical assistance if they have questions?
A Well, it basically -- if there's not a written document and service information that is going to assist you like a bulletin or just the service manual itself and you get to a point where you really don't know what to do, that's when we call them.
Q And what date and time was the vehicle ready for Mr. Kodsy to pick up?
A I believe on this particular repair he left and came right back and we opened his ticket back up. So, let me see. This doesn't have time stamps on it.
0553
Q Mr. Bardill, on page eight -- actually, I guess, we should go to the first page of the invoice. That would be page -- page six of Exhibit 2.
At the top where it says ready, does it have a date and time?
A Yeah, that was November 12.
Q At what time?
A 2:46.
Q P.m.?
A Yes.
Q And then the next repair order begins on page 10 of Exhibit 2, is that correct?
A Oh, yes, yes. Okay. That's right.
Q And what time was that repair order opened?
A That was opened at 5:08.
Q On November 12th?
A On November 12th, yes.
Q So, Mr. Kodsy came back. What did you decide to do then?
A Well, he was very upset. I may or may not have gone on the road test with him. I don't believe I did. I do believe I sat in the vehicle

with him and we had a buzz through the IPC.

0554

Q I'm sorry, what's the IPC?

A That's the instrument panel. The dash basically.

Q Okay.

A And, you know, it's pretty common. What happens is a line might be too close to something, whether it be the fire wall, the fender, something, and it will touch it and that -- it will make a buzzing noise that comes in through the IPC. It was pretty much a nothing repair other than finding the source of the buzz.

Q And just relocating the line?

A And just relocating the line.

Q What did you do after that?

A He was also at that time complaining of it running rough over 50. We found nothing wrong with that. Oh, we did -- actually, yeah, at that point I contacted Bob Martin because he was still -- he was still complaining that it was idling rough.

Bob Martin is the brand quality manager, or was the brand quality manager for the H2 at the time, and he told us to go ahead and disconnect the engine from the transmission and see if the vibration was still there, which we did. The vibration was still there.

0555

I spoke to Bob again and that's when I had the egg on my face. He's like, Joe, you got to remember, this is a 6.2 liter engine in there, there's some trade off for that horsepower. And at that point I was like, yeah.

We happened to have another 2008 that was sitting right next to Mr. Kodsy's in the parking lot. Myself and my foreman got in both vehicles and they both idled identically.

Q That's another 2008 Hummer H2?

A Yes.

Q And with regard to Mr. Kodsy's concern

that the vehicle rides rough at all speeds over 50, did you find any problems?
A I never duplicated that, no.
Q And does the repair order note it's a normal characteristic of the truck?
A Just it says no fault found. Oh, yes, it does actually. Could not duplicate condition, at this time normal characteristic operation of truck compared to another H2 same condition.
Q And I'm going to direct your attention to the next repair order. Mr. Kodsy said the transmission still kicks on acceleration after coasting, is that right?
0556
A Correct.
Q What did you all do there?
A We reprogrammed the ECM, which is the engine control module. There was another calibration in there and we found that we needed to match that to the transmission control module when we update the transmission control module.
Q So, it's a continuation of the previous replacement?
A Yes.
Q What about Mr. Kodsy's last concern on the repair order about the noise in the dash area at highway speeds? What did you all find?
A That was A-pillar moldings. They're plastic moldings on the outside of the windshield. They're double side taped to the windshield. Air gets underneath there, loosens up the tape and they vibrate on the windshield. It's a pretty -- pretty common problem. Minor problem, but very common.
Q And so you went ahead and replaced those moldings, is that right?
A Yes, we did replace them. The one on his -- usually we just put double sided tape on, but we actually replaced the left side on his.
Q In Exhibit 2 there's some invoices from
0557

Schumacher. I'm going to ask you to skip over those and go to the next one from Coral Cadillac, and that's at page 18.
A Okay.
Q Now, this December 22nd repair visit, do you know what this was scheduled in response to?
A Well, we got the brake pads in and he was still complaining about a vibration between 45 and 55.
Q And do you know whether or not GM scheduled this as part of its inspection and repair opportunity in response to a notice from Mr. Kodsy under the Lemon Law?
A I believe it possibly was because there's no other one that was here.
Q And were you involved in that repair visit?
A Yes.
Q Can you tell the jury what you did and what you found?
A Well, we didn't find anything really with the shake. It's -- I don't know if any of you drive pickup trucks, but if you go on down a road like Federal Highway or an uneven road, you get about 45, you get a little waddle in the street. Pretty
0558
common. I believe every truck -- my truck does it when I drive on an uneven road. We call it rail shake. So, that's how we closed it out. No problem, found it's a normal condition of an SUV.
We did put the brake pads on it. And he was still complaining of a rough idle and we didn't do anything. We just -- actually I think at that time I could be -- I could be incorrect because I don't know if Jorge was involved with me or not at this time, but I know Jorge came down and we sat in about five different vehicles. And I don't -- he did not do that at Schumacher. So, it probably is this repair, but I can't say for certain.
Q So, during that time you met with somebody

from GM --
A Yes.
Q -- and sat in some other Hummers?
A Yes.
Q Did you feel any difference between those Hummer H2's?
A No. Actually Jorge's words were that Mr. Kodsy's is the best of the five we sat in. But we did have the weights on there and that's probably why it was better than the other five or four.
Q What about Mr. Kodsy, was he still

0559

complaining about the transmission shifting?
A I don't recall. Let me look. Yes, he was. Trans shift hesitates, shifts harsh on re-accell and road tested okay.
This is -- see, this is a six speed transmission. So, it is shift busy if you're used to a four speed transmission. We seen it -- it first went into the Escalade and when customers came out of their 2005 Escalade and went into like a 2007, they went from the four speed to that six speed transmission and they weren't real happy with it until they got used to it.
Q And why would that be, because it's got more gears?
A Because it's got more gears. Think of, I guess, a three speed bicycle versus a 10 speed bicycle kind of thing, you know.
Q And you personally road tested this vehicle?
A Yes.
Q And at the end of this repair visit did you find anything that was abnormal remaining?
A No, we didn't find anything. We did put the brake -- the new brake pads on.
Q In addition to the times you talked about

0560

driving Mr. Kodsy's vehicle during the repair visit to Coral Cadillac, did you also ride in it on March

the 2nd, 2009?
A At Schumacher? That would be at Schumacher, right?
Q Right.
A Yes, I did.
Q Okay. And who was with you at that inspection?
A That was Tom Thornton and Jorge Lopez and Mr. Kodsy.
Q And when you rode in the vehicle, did you feel any abnormal vibration at that time?
A No, not at all.
Q And, Mr. Bardill, just for the record, so the court reporter can get down both of us, just wait for me to finish my question.
A I'm sorry.
Q That's all right.
Have you ever testified in court in trial like this before?
A No.
Q Okay. Based on your experience with Mr. Kodsy's vehicle, are there any defects in GM's workmanship or materials that have not been

repaired?
A No.
Q You talked about doing some things with customer satisfaction. Can you explain what that is?
A Well, there's a lot of times that -- that a vehicle is operating as designed, but it has something that the customer's not happy with. If I feel we can improve upon it, we will try, you know, even though there's -- it's really characteristic of the vehicle. But if I can make it better, I'm gonna make it better.
Q And in terms of trying to satisfy customers, will your dealership spend time really looking at vehicles?
A Certainly.

Q When you guys -- when you have a customer that has repeat concerns, does that change how you look at a vehicle?
A Yes, definitely.
Q Explain to the jury what that -- what you would do.
A We have a repeat repair log. So, if a customer comes back with the same concern, the repair order gets stamped and it goes into -- the
0562
service advisor puts it into the computer and it goes into a repeat repair log.
That makes me aware of it. I will get involved personally in the vehicle, my shop foreman will get involved with the vehicle and -- because General Motors looks very closely obviously at repeat repairs. And we do too because we don't want customers coming back.
Q Mr. Bardill, there's been some testimony about the possibility that the timing in the Hummer H2 may be incorrect. Is that consistent with what you found in driving the vehicle?
A No. Are you talking valve timing, I would assume?
Q I believe that's correct.
If the timing -- if there was a timing problem with the Hummer H2, would there be any indication?
A Well, first of all, there is no adjustment for timing. So, it would have to have been perhaps a mis-built engine. The service engine soon light would be on all the time.
Q If there was a problem with the way the engine was built?
A Yes.
0563
Q It would -- why would the service engine soon light come on?
A Well, it has crank sensors and cam sensors. So, it's going to see an uncorrelation

between the two, as well as it's going to effect the fuel line. So, you're going to get fuel trim codes. You would get several different ETC's.

Q So, if there was an internal problem with the engine that might be causing some timing problem, it would set a trouble code?

A Yes, it would.

Q And the check engine light would come on?

A Yes. And I can say I've never seen that ever from the factory in the 28 years. Perhaps we've seen it when we've repaired -- done engine repair and we're off with the cam timing slightly. That's how I know that it will turn a light on.

Q And when the mass air flow sensor had failed that first repair visit, I see on page one of Exhibit 2 there's a number. It says set P0172 and P0175 codes?

A Yes.

Q Are those the trouble codes you're talking about?

A Yes, those -- those are field trim codes.

0564

Q And so if those codes had been set, would the check engine light have come on as well?

A Yes, they would have.

Q Are those trouble codes stored in the computer?

A Yes.

Q What is the purpose of those trouble codes?

A Well, the purpose is to diagnose, for us to diagnose it. It's just the most technician friendly thing that ever happened. We don't have to go by the seat of our pants anymore. The computer in the vehicle says, this vehicle's running too rich. 20 years ago you had to sit in the vehicle and say, okay, this vehicle's running rich, you know.

Q And now you have the ability through diagnostic equipment to look at that?

A Yes.
Q And know for a fact whether or not it is running rich?
A Yes.
Q And again, so if there was an internal problem with the engine causing the timing issues, there would always be a diagnostic trouble code?
0565
A Yes.
Q Would there be multiple diagnostic trouble codes?
A Yes, most likely.
Q Did you find any after the mass air flow sensor was repaired?
A No, no.
MR. KLEIN: If I may have a minute, your Honor?
THE COURT: Sure.
MR. KLEIN: Your Honor, I don't have any further questions of Mr. Bardill at this time.
THE COURT: Okay. Thanks.
Okay. Do you have any questions you'd like to ask?
MR. KODSY: Yes, I do, your Honor.
THE COURT: Okay.
MR. KODSY: Thank you.
CROSS-EXAMINATION
BY MR. KODSY:
Q How you doing, Joe?
A Hi.
Q Mr. Bardill, what happened?
A Trimming my tree, fell off a ladder.
Q Excuse me?
0566
A Fell off a ladder trimming a tree.
Q You got to be more careful. Sorry it happened.
Back to this Hummer H2, you said when you got a customer that keeps coming back with the same problem you call that a repeat repair?

A Yes, sir.
Q Okay. And what does that actually tell you? Once it's been denied before, does that mean you're excused for that alleged repair?
The nonconformity, is it always going to be denied because you already noted it that it was similar to another vehicle, as in this case?
A I guess are you asking would I still be involved and still look at the vehicle?
Q Would you repair the vehicle if you've already got documented similar to another?
A There would be nothing to repair.
Q Okay. So, you deny any further repairs alleged similar to previously?
A Yes, there would be nothing -- nothing to repair.
Q Okay. That's my point.
So, you would deny those repairs, you would not do anything else, is that correct?
0567
A Yes.
Q Okay. As far as your testimony said you -- this was your first 2008 Hummer?
A The first one that I drove with this concern. I believe I actually even told you that as we were driving.
Q Okay. So, it was your first 2008 Hummer with a 6.2 liter?
A No, the first one I drove for this concern. I'm not saying it's the first one I ever drove for any reason. I don't know. I can't tell you yes or no, but yours was the first one I ever drove for that concern. And I think I even commented to you about the six speed transmission, you know, coming from the Escalade to the H2.
Q Obviously, you know, I'm a consumer. So if I went out and bought --
THE COURT: Okay. Let's just ask questions, sir, no commenting.
BY MR. KODSY:

Q So, you had never experienced that with a 6.2 liter engine before, is that correct --
A In a --
Q -- for vibration?
A In a Hummer H2. Certainly in the
0568
Escalades because the Escalades had it previous.
Q The Escalade had what?
A The 6.2 liter before the Hummer did.
Q What, that was since 2007, correct?
A Yes.
Q Okay. And this is 2008. So, it's the same engine, is that correct?
A Yes. But we did have customers with Escalades complaining of the vibration at idle until they got used to it.
Q So it's an inherent defect, is that correct?
A No, it's the trade off for the horsepower. It's got that little vibration.
Q So, from the manufacturer because it's got increased horsepower it's got a vibration, is that correct?
A Well, if -- if it was a defect, as you're saying a defect, we've got a lot of cars out there that nobody's complaining of it.
Q Right. I mean, it's not obvious to everybody.
But you're telling everybody here that because we got a 6.2 liter engine with 20 horsepower more than 2006, then you have that vibration, is
0569
that correct?
A No, what I'm saying is in the 6.2 liter there's a 20 percent increase in horsepower, which is approximately 70 horsepower, and that the vibration is a characteristic of that engine.
Q Have you ever had any other Chevy vehicles with a 6.2 liter engine?
A Yes.

Q Okay. Are they also having that vibration problem?
A I've never had a customer complain, but we are not a Chevrolet dealership.
Q But you have run across it before in a 6.2 Cadillac Escalade, is that correct?
A Yes.
Q So, allegedly your testimony states that it's normal, is that correct?
A Yes.
Q Okay. Why did you take the vehicle apart and do all these repairs trying to eliminate this vibration that is normal?
A Well, like I said, first of all, we did not take the vehicle apart.
Q You didn't?
A We put -- we put weights on the exhaust
0570
system. That engine was never disassembled.
Q What about disconnecting the fly wheel from the engine.
A Okay. I do apologize. Yes, Bob Martin asked us to do that, yes.
Q Who's Bob Martin, sir?
A He's the brand quality -- he was the brand quality manager for Hummer at the time.
Q He's not now?
A No, he's no longer there.
Q Why is that?
THE COURT: Sorry, sir, I've already ruled on it. Let's go ahead.
BY MR. KODSY:
Q Okay. So, you actually did take -- disconnect the engine from the fly wheel, which is the transmission, is that correct?
A Correct.
Q So, you did disconnect that?
A Basically at that -- what we're doing there is we're just isolating the engine.
Q Okay.

A So that the only thing -- the only thing that could be emitting the vibration would be the engine.

0571

Q Correct. So, if it was normal you wouldn't do that though?
A Well, we -- at this point, remember, I didn't put the -- I was still not thinking about it being a 6.2 liter.
Q But your 2007 Escalades have had similar problems and they have that 6.2 liter?
A Yes.
Q So you're already aware of this?
A Right, it's a normal --
Q And you still took this engine apart?
THE COURT: Wait, wait, let him talk.
THE WITNESS: It's a normal characteristic of a 6.2. But, again, I was not thinking that your vehicle had a 6.2. The six liter did not idle the same as the 6.2.
BY MR. KODSY:
Q And -- all right. Never the less, you did dismantle some major components on that vehicle and --
THE COURT: Listen, this is repetitive. You already said it. So, let's go on to something else, something new.
MR. KODSY: I'm just highlighting, your Honor.

0572

BY MR. KODSY:
Q Tell us about those weights that you put in. Is that a factory option?
A No. Actually -- obviously it is a GM part number. It was an application and a PI for a different vehicle used years ago, but the same -- it's the same theory. But there is nothing in the service information that suggests we try that on your vehicle. That's something I took upon myself to do.

Q Because of the vibration?
A Yes. Again, remember, I'm thinking that it's a six liter and, again, I didn't know what the firing frequencies of the engine were.
Q So -- all right. Then you got -- how did you figure out that the vibration is normal?
I mean, did you do any biomechanical testing? What kind of actual testing did you do to make that determination?
A Well, unfortunately the vibration is not severe enough to even be registered on the EVA, which is the Electronic Vibration Analyzer.
Q What is it?
A Electronic Vibration Analyzer. It would not -- we tried that on your vehicle just to give us
0573
some basis to score by to see if we're making an improvement. Because when you're just sitting in a car you may think you made an improvement, but if you're already tune to that vibration, you make an improvement, you're like is it better or is it not.
So, we hooked up the EVA to your steering column and it was not even measurable. The vibration was not even measurable by the Electronic Vibration Analyzer. So, there was not a number we could put on to see if we improved upon it or not basically. So, at that point we just compared it to the other 2008 and then further down the road with four -- four other vehicles.
Q All right. Tell me about that instrument that you use, sir, because I'm not familiar with it. I don't think any of us is.
THE COURT: Just ask your questions. No talking to the jury, please. Just ask questions and leave it at that. Thank you.
BY MR. KODSY:
Q Tell us about that.
A It's a required tool by General Motors that we use to diagnose vibration concerns.
Q Okay. And how does that register?

A It has a sensor that we put depending on
0574
the type of vibration.
Q Where do you put it?
A Again, it depends on the vibration. If you're talking about vibration at highway speeds, you're gonna probably put it on a seat frame.
In your case, you were concerned with the vibration through the steering column. So, we put it on the column and it would not measure it.
Q What's the capacity of it? From one to a thousand?
A No.
Q What's the capacity?
A It reads in G force. It will read .003 G's.
Q What does that mean?
A Well, one -- a G force -- one G force is the weight of your body applied one time. It's reading .003. It wasn't even registering .003. Basically we are not supposed to even attempt a repair on a vehicle if it reads less than -- more than -- unless it reads more than .006 G's.
Q Are you familiar with an HZ value?
A Hertz frequency.
Q Hertz frequency?
A Sure, certainly.
0575
Q You do not have that type of device, do you?
A Yeah. Same -- same piece of equipment. It measures frequency, yes.
Q It measures frequency?
A Yes. That's how we determine whether it's a first tire or drive line, by the frequency.
Q And you're aware that the HZ is actually reflective of the RPM's in the vehicle.
A Yes, the RPM would be a frequency.
Q How many RPM's to reach HZ is that?
A It would be 60.

Q 60.
So, what are the specs for that vehicle, sir?
A There is no spec.
Q There's no specs?
A No.
Q There's no HZ frequency for that -- for that vehicle or any other vehicle?
A No, no.
Q You sure about that?
A Yeah.
Q So, if it didn't register, what was the RPM's on the vehicle when you inspected it?
0576
A I don't recall. It was idle, but I don't recall.
Q You then put down here -- I mean, this is obviously -- if it's relevant to the HZ, you wouldn't document it and say to the customer, wow, we did this test and it didn't register or this is the amount? Did you have anything here, sir?
A No, I didn't have anything.
Q Did you write these up, these invoices?
A No, service technicians.
Q Were you the actual mechanic on this truck?
A No. I worked with them though.
Q You work with them?
A I work with them as well --
Q In what way?
THE COURT: Wait a minute. Let him finish.
Go ahead.
THE WITNESS: I work with them as well as my foreman.
BY MR. KODSY:
Q As a foreman?
A With -- as well as my foreman. There was both of us involved, as well as the technician.
0577

Q But you did not actually put any type of measurements or reference to your alleged test, is that correct?
A No, myself and my foreman sat in it with EVA.
Q But there's nothing here?
A No, there was nothing to put in there.
Q You were aware that the initial complaint for all these repairs was a vibration, is that correct?
A We used the EVA at the same time we put the weights on because we wanted to see if there was a number that we could measure to see if we made an improvement. That was the whole reason of using the EVA. There was -- we wanted to get a number. So, if we saw .006 and put the weights on it and it went down to .003, we'd say, okay, we made an improvement, instead of just going by what we felt.
Again, like I said, when you tune into something, you may make an improvement, you may not. It's hard to really tell if you made an improvement. We're looking for a number. We couldn't get that number. That's the only reason I used the EVA.
Q .003 or .006 compared to what? What does that mean? What is it?

A That's -- that's the G force. That's what -- it's a measurement.
Q What's a G force, sir?
A That's what I said, one G force is --
Q What's a G?
THE COURT: Wait a minute. Just ask one question at a time, please.
BY MR. KODSY:
Q Go ahead.
THE COURT: What's your question?
MR. KODSY: What is a G force?
THE COURT: Okay.
THE WITNESS: A G force -- one G force would be the weight of your body against you.

Like if you're on a fighter jet or something,
you feel one G, that's your body weight one
time against you. Five G's is five times.
BY MR. KODSY:
Q I mean, the terminology G, what does that
stand for?
A I'm sorry, I don't know.
Q You're a master mechanic, sir, is that
correct?
A Yes, sir.
Q You don't know what you're telling me?
0579
A I don't know what G -- I know what G force
is. I don't know how to tell you what it is. I
don't know what it stands for.
Q Okay. Well, the next thing, sir, it would
be -- you did tell or rather stated that you had to
do some rust -- do some arusticator on the bottom of
that truck, is that right?
A We used 415 on it. That was strictly for
customer satisfaction.
Q So, it's not required, is that it?
A Yes.
MR. KODSY: Okay. Can I see some of the
exhibits?
MR. KLEIN: She's got the repair orders if
you're looking for those.
MR. KODSY: It's not repair orders.
BY MR. KODSY:
Q Does this look familiar to you?
A Yeah.
Q Okay. What is that?
A That's a window sticker.
Q That's a window sticker.
Can you tell me what it says here, sir?
Can you read chassis suspension on down
here just to the safety? And tell me, does it have
0580
a category in there for underbody protection?
A Yes, it does.

Q Okay. So, that truck is supposed to come from the factory with underbody protection. So it's not supposed to have any rust, is that correct?
A It does come with underbody protection. That does not mean that it will not rust. It's just surface rust.
Q Sir, when you did this repair you were talking about how many miles were on that vehicle?
A 5,000.
Q Okay. 5,000 approximately. 5,224, does that sound right?
A Right.
Q So, at 5,000 miles you have to do some major waterproofing, is that correct?
A No, it wasn't waterproofing.
Q Well, rust --
THE COURT: Sir, one question at a time, please.
THE WITNESS: It's a paint. It's a paint that they use in automotive restoration. It's a rust inhibiting paint.
BY MR. KODSY:
Q Yeah, I understand what you're saying,
0581
it's a rust inhibitive. But shouldn't that vehicle already come with it already there from the factory, because it says so on the sticker, is that correct?
A Yes, and it does.
Q But it wasn't -- it necessitated your additional work, is that correct?
A It was strictly aesthetic, strictly aesthetic.
Q What was that?
A Your complaint was strictly aesthetics.
Q Aesthetics?
A Yes. You didn't like the brown look on certain suspension parts.
Q It was rust, is that correct?
A Yes.
Q Okay. So, it's not really brown, it's

rust?
A But it was aesthetic. It's not functional. It didn't effect the functionality.
Q Isn't that truck an off road truck?
A Yes.
Q So it's made to get wet, is that correct?
A Yes.
Q So it's not supposed to have rust, is that correct?
0582
A No. You can't prevent rust.
Q Okay. You tried to, right?
A Uh-huh.
Q Okay. But that's --
A We tried to satisfy you.
Q Okay. But does this sticker says underbody protection?
A Yes, it does.
Q And what does that tell you?
What does that actually mean? Shouldn't that mean that it should have --
A Well, the metal has a coating on it.
Q Excuse me?
A The metal has a coating on it.
Q So, which part did you paint?
A Whatever was rusting. I don't recall. Whatever you were complaining --
Q Was it metal?
THE COURT: Sir, wait a minute. Let him finish talking before you ask another question. Go ahead.
THE WITNESS: I guess it was metal, yes.
BY MR. KODSY:
Q How many other vehicles did you have to disconnect and try to isolate the vibration on a
0583
vehicle? How many other times did you do that?
A I don't know. I don't know.
Q Was that the first time?
A No, no definitely not, no.

Q Okay. So you've done that before?
A Yes.
Q And what was the end result of that?
A Well, it's strictly done to isolate what -- where the vibration is coming from to see if it's in the engine or some other place.
Q And if it was in the engine, what would you do?
A In your case, it's normal characteristics.
Q I'm just asking you a general question. If it was in the engine, what would you do?
A It just gives us the direction to look. It's telling us it's in the engine.
Q And then as a remedy, what would you do?
A We'd proceed to diagnose it.
Q In what way?
Do you rebuild engines over there?
A Yes, sir.
Q And doesn't that void the warranty once you open up the engine?
A No.
0584
Q It doesn't?
A We would do it -- when you say rebuild, if we have an engine, a mechanical failure under warranty, we have the capability to completely rebuild that engine.
Q Do you do it there on the premises?
A Yes.
Q And isn't there a separate repair shop now that's handling all that?
A No, never have. I've had the same --
Q Was it --
A I've had the same engine technician since 1996.
Q So, what kind of specs did you have on the air and fuel ratio for that vehicle?
A I don't know. Remember, I wasn't involved in the repair when the mass air flow sensor failed.
Q I mean, don't you document stuff like that

for the customer to say, look, you know, here's G force or here's your air specs and -- don't you do anything like that?

A Well, they documented the DTC's on the ticket.

Q What was that?

A They documented the DTC's on the ticket.

0585

Q What is a DTC, sir?

A That's the trouble code, diagnostic trouble code.

Q Okay. And if you do not have a trouble code and you still have a problem, how do you proceed?

A As far as -- we would address the problem, what would the complaint be.

Q Okay. In this case you didn't have a trouble code for the vibration, is that correct?

A Never had a trouble code for the vibration.

Q Never had a trouble code?

A No. The vehicle was stalling when it came in with a trouble code.

Q But yet you did add weights, allegedly you added weights, you did dismantle the fly wheel from the engine, and you didn't have no trouble codes, is that correct?

A Correct.

Q Is it true that the oxygen sensors are the ones that usually send the trouble code?

A No, not at all.

Q How is the oxygen level usually measured?

A By the oxygen sensor.

0586

Q Okay. And that will tell you the fuel and air ratio, is that correct?

A Right. But that doesn't mean that the sensor is failing. The sensor is doing its job. If a sensor fails, it can't tell it's going to be fixed at a certain number. That's how an oxygen sensor fails.

Q So it won't really give you a trouble code?

A Yes, it will because it's seeing that it's not moving high and low assuming it's a fixed value.

Q Aren't those sensors have a wide range of detecting the measurement?

A Yes, yes. And they -- they very seldom fail anymore. It's not like years ago where they failed quite frequently.

Q Oh, okay.

Isn't it true that all these new vehicles, fuel injected, they have these new sensors with a wide range so they don't fail very often?

A The sensor is only -- the sensor's like a battery. It produces the voltage with the amount of oxygen that's in the exhaust system. So, how the oxygen sensors used to fail, is they would just get to a fixed value of half a volt, that's the applied

0587

voltage, and there would be no change. I'm not sure exactly what you're asking me.

Q Okay. I'm going to clarify it some more for you because I don't understand what you're telling me.

The oxygen sensor, it's a sensor, correct?

A Correct.

Q Okay. It detects what, a measurement, correct?

A Yes, oxygen, it creates a voltage.

Q Correct me if I'm wrong. It's an oxygen sensor, is that correct?

A Yes.

Q So that entails gas and air, is that correct?

A Yes.

Q Okay. So, now, what are the -- before we go further, let me ask you what's the standard for a fuel injected vehicle air and fuel ratio?

A 14:7:1.

Q Okay. Perfect.
Now, the sensor, what is its capacity from 14:7 to what or where?
A I think you don't --
Q Doesn't it have a reading for that?
0588
A No, I think you don't quite understand how it works. That -- the 14:7:1, that's what the combustion engine performs best at. It's the PCM, the power control module, that tries to keep the fueling at 14:7:1.
It looks at the information that the oxygen sensor's giving, as well as other information, and adds or detracts injector on time. And that's the fuel trim number that we get. It's gonna be a plus or a minus or a zero, zero being ideal, zero being 14:7:1.
If it's a minus number, that means the computer is taking away injector pulses to keep it at 14:7:1. So, you're still running at 14:7:1, but the computer's adjusting the fueling to keep it at 14:7:1.
When that number gets so far out of range, like about 10 percent, it's gonna turn the engine light on and say, hey, we got a problem, I can't keep this thing at 14:7:1.
Q Isn't it true that the new sensors provided on all these new vehicles are -- range from 9:1 to 18:1?
A That would be --
Q There is no zero because obviously the
0589
motor wouldn't run?
A That would be millivolts. Sensors are in millivolts. That's what you're looking at. Or a lambda number. You're probably looking at a lambda number.
Q Okay. So, what was the exact measurement when inspected? Because obviously you're saying you tested it, is that correct?

A We didn't check the oxygen sensors.
Q You did not?
A No.
Q You did replace the mass air flow sensor?
A Correct.
Q Okay. What -- isn't that for the air and the fuel mixture?
A Correct.
Q Okay. And you did not get a measurement on that?
A No. They didn't -- I don't know. I wasn't involved in the repair. They -- that's measured in grams. They didn't put it on the repair order, but it's not really necessary to put it on the repair order because it's going to be varying with the throttle, RPM and everything else.
Q Right. I believe that -- okay.
0590
So, this was not done?
A No. And there really would be no reason to.
Q And you never took it upon yourself to even check it?
A I was not even involved. But, yeah, I would have looked at it at idle to see what it was, but obviously it fixed the vehicle.
Q Okay. If the fuel and air sensor registered a 12.4, how would that vehicle run?
A At idle?
Q At idle or all times. Most likely at idle.
A If it's reading a 12.4 at idle, it would be running too rich.
Q Oh, rich.
So, would that also have a vibration?
A It's hard to say. It would probably be chugging and blowing black smoke, stalling, you know.
Q But it wouldn't give you a code either, would it?

A Yes, it would have, oh, yes.
Q Not if the sensor is gauged for more leaner and higher?
0591
A No, if you're reading 12.7 at idle you're gonna to turn a light on.
Q It depends on the sensor, is that right?
A No. On any vehicle if you're reading 12.7 at idle, you're gonna turn a light on.
Q But you're not sure about that because you haven't tested it?
A Haven't tested what?
Q You haven't done that test.
A I'm just --
Q That's not something you commonly do?
A When you have the mass air flow concern, I'm sure they looked to see what the number was.
Q Who?
A The technician that worked on the vehicle.
Q Which technician was that, sir? Do you have that in front of you?
A Yeah. Do you need his name or --
Q Yeah, yeah. Tell us his name and what you know about him.
A That was Brian Penny, who was my shop foreman.
Q He actually worked on the vehicle?
A Yes.
Q Okay. When you say he's a shop foreman,
0592
what kind of qualifications gives him to work on anybody's vehicle?
A Well, he has very similar qualifications to me. And actually I would say that he's more skilled than I am.
Q And you have not gotten any type of measurements from him either, is that correct?
A I'm sure he checked them. He didn't document them on the repair order, but it really wasn't necessary, as I said.

Q Okay. Now, to go back to your G force, sir, I do not understand what G stands for.

THE COURT: Well, this has been covered. Go on to something else. I -- you can't cover the same thing more than once.

MR. KODSY: Well, he never answered, your Honor. I was --

THE COURT: I'm telling you to go on. Don't talk back.

MR. KODSY: All right.

BY MR. KODSY:

Q Did you see the weights that were placed on the exhaust? Or where was that weight installed at?

A It was installed, I believe, in the vent.

0593

Q Excuse me?

A I believe in the vent towards the front of the catalytic converter, but I'm not 100 percent sure. And I was involved, I just don't remember exactly where they put it.

They put it in a place to be less -- as least conspicable (sic) as possible. It really doesn't matter where you put your finger on a guitar string, you're gonna stop the buzz, right?

Q And how does that prevent or insulate the surge from coming into the cab?

A The surge?

Q Yeah, the -- you said here on page 18 -- page six, do you have that?

See at the bottom, exhaust vibration engine firing pulses transferring into vehicle?

A Correct.

Q Do you see that?

A Correct.

Q Now, how did that prevent the pulses transferring into vehicle?

A Like I explained, it's like putting your finger on a guitar string. You're deadening the vibration.

Q The vibration. But how is that
0594
transferring into the vehicle?
A Through the exhaust system, the exhaust hangers, etcetera.
Q So, the insulation has nothing to do with it?
A Nothing to do with what?
Q Insulating the engine components from the cab has nothing to do with it?
A No, no, we didn't -- no, we did nothing to modify the installation of the engine. There's nothing you can do there.
Q Okay. So, did you attempt to open up the engine chain -- timing chain cover to see if it's set at the right setting?
A No.
Q Why?
A There would be no reason to. Like I explained, you would have a DTC associated with something there.
Q Now, as far as your brakes squeal, you replaced pads, is that correct?
A Right.
Q In other words, the dealership did?
A It was a new designed brake pad that came out, correct.
0595
Q And how did you come to that conclusion? Here's a customer comes to you, I got squealing brakes. How did you figure it out -- or was it you that figured it out that somebody -- that the pads need to be done?
A The technician would have done a service bulletin check and he saw the service bulletin. He basically would have --
Q What, replace pads?
A -- road tested your vehicle, heard the noise from the front, looked to see if there's any bulletins. He saw the bulletin, ordered the part.

Q Pads?
A Correct.
Q Is that normal at seven -- I mean on 5,000 miles?
A Brake squeal is across the board with every manufacturer out there. You could stand out by the side of the street, you're gonna hear it, you know what I mean. Once they took the asbestos out of brake pads, you know, it's been a fighting battle for 20 years. So ...
Q What if it was the sensor, sir, how would you determine that?
A What sensor?
0596
Q The brake sensor. Doesn't that squeal?
A The sensor on the pad?
Q It's called the electronic sensor. Let me see if I have it here. I think it's in the documents that were not allowed in.
A That would be done visually anyhow.
Q There's a brake sensor that is actually a recall. That wouldn't cause the squealing, sir, if the brake sensor was bad?
A I don't know what sensor you're talking about, but it would be done visually anyhow. But obviously --
Q Visually?
THE COURT: Let him finish, please.
THE WITNESS: Yes, there's a sensor wear. It wears the sensor. You can see it. But you would have also worn out the brake pads.
I mean, I don't even know why we're going here. I mean, it fixed -- the new pads are out there, there's a bulletin, we put them on your vehicle. I don't know.
BY MR. KODSY:
Q But you did not have those pads available in your shop at the time, is that correct?
A Correct.
0597

Q So, this is not something common that you have a shelf full of them ready for this?
A It's obviously common enough that they wrote a service bulletin for it. So, it obviously was out there.
Q But when a customer came back and says, my brakes still squeal, what -- what other measures did you take?
A I only saw the one repair order to put the brake pads on it.
Q I believe there's another order here that -- well, not order, but alleged service request which stated that there's still the squealing brakes and nothing was done about that. Let me see if I can find it.
Okay. Well, you didn't do any -- anything besides look for a recall. However, if the customer came back and said, I've still got squealing brakes how would you go about it?
A Well, you road test the vehicle and confirm that the squeal was from the brakes, front or rear.
Q Of course, yes. Okay.
A And then check to see if we properly lubricated all the caliper pins and that sort of
0598
thing.
Q So, when does it come to the point where you need to replace a sensor?
A I don't even understand what sensor you're talking about.
Q Did you resurface those rotors?
A I don't know. Let me check. No, sir, we did not.
Q Okay. Doesn't have -- doesn't that have a big effect on squealing as well?
A No, actually brake rotors do not cause a brake squeal. There is a -- typically H3 rear brake rotors do have something going on with them where they cause a brake squeal. But typically you get a

brake falsation from a rotor, not a squeal.
Technicians sometimes resurface them and sand the pads to try and repair a brake squeal concern, but it really -- resurfacing the rotor should never be done for a brake squeal. And there's actually service bulletins telling you that.
Q So if the pads are squealing -- the pads are squealing, is that what you're telling everybody?
A It's the composition of the pad. The brake pad -- the composition of the brake pad is
0599
what causes the squealing.
Q What does --
A The brake pad versus the rotor.
Q What does the pads rub on?
A The rotor.
Q The rotor?
A Right.
Q So, if the composition of the pad is being scraped on a rotor, don't you think that the rotor would need something too?
A No, not unless it has excessive lateral runout.
Q Can you go to page 11, please. Do you see in the middle of the page here it talks about the noise vibration at IPC?
A Correct.
Q Can you tell us what IPC stands for?
A Yeah, that's the instrument panel. That's the dash.
Q Okay. Tell us what this little paragraph is all about.
MR. KLEIN: Objection; asked and answered.
THE COURT: Sustained. We've covered this. If you've got a specific question --
MR. KODSY: Yes, I do.
0600
THE COURT: -- then go ahead and ask a specific question.

BY MR. KODSY:
Q It says relocate AC high pressure hose from wheel well area. That was not covered. So, tell us about that.
A They just moved the line. I do believe I covered that.
Q You moved the line?
A Pulled the line away from the wheel well.
Q And that was it?
A That's it.
Q And that was doing what?
A It's grounding out and that's what causes the noise to be transmitted into the vehicle.
Q Okay. So it wasn't for vibration, right?
A No. That was the buzz noise through the IPC.
Q Because it says here, after above repair still had some vibration in the steering wheel, which the above repair was the AC high pressure hose. But to your opinion, it's not related?
A Correct, it was not related.
Q Now, you're familiar with Schumacher Hummer?
0601
A Yes.
Q Okay. And do you know that after several repairs with your dealership and still having the same problem that this vehicle was at Schumacher Hummer?
A Yes, I do know that.
Q Okay. Do you know what Schumacher Hummer did to it?
A No.
Q If you go to page 15, can you tell us what they did?
MR. KLEIN: Objection, your Honor, beyond the scope of direct and relevance.
THE COURT: Overruled.
MR. KLEIN: The witness said he doesn't know what they did.

THE COURT: Overruled.
THE WITNESS: So you'd like me to read the repair order and try to explain to you what they did?
BY MR. KODSY:
Q Yes. Because allegedly after the Coral Cadillac repairs everything was fine and dandy --
THE COURT: Just -- just ask questions.
MR. KODSY: Yes.
0602
THE COURT: So, that's what you want him to do, right?
MR. KODSY: Yes, your Honor.
THE COURT: Go ahead.
THE WITNESS: They as well road tested your vehicle 45 miles an hour and up. They measured a 13 hertz frequency that you were speaking of earlier.
BY MR. KODSY:
Q Okay. So --
A That would be the first order. Tire vibration at .0 -- it wouldn't be .009 G's, but they have .09 G's. They checked rims of varying balance, road forced the tires. They had road force variation of 18, 31, 40 and 37 index three tires and --
BY MR. KODSY:
Q So, what was --
A It's hard to --
Q -- the outcome of the repair?
A It looks -- it looks like, but I can't really tell, that they maybe replaced three tires.
Q Okay.
A I'm not certain the way this is invoiced, but it looks like they possibly replaced three
0603
tires.
Q Okay. Do you know why they would replace three tires, sir, after leaving your shop?
A I know what their documentation says, but

obviously I don't know why other than the documentation.
Q Can you tell us --
A I just did.
Q -- what the document really tells because I didn't understand it.
A Well, the road force numbers were high, but that is a big wheel and tire assembly. And road force numbers don't always give you a vibration, but they were 18, 31, 40 and 37. They were indexed and down, but they felt that they needed to replace them. My guess is it was probably for customer satisfaction.
Q Can you read the top line there, what it says, A?
A At highway speeds there is a roaring and -- I guess they're trying to say hopping felt at nearly all speeds.
Q And keep going.
A Road tested tire vibration 45 miles and up.
0604
Q So, that's why they replaced the tires?
A That's why they put three tires on.
Q Okay. So it's not customer satisfaction.
And on page 17, can you tell me what their final outcome was after they replaced the tires? That was probably -- actually let me look at the dates. December 8th, that's the same day.
Okay. The same day, after they replaced the tires, what their comments were?
A Actually it looks like it's --
Q It's two pages.
A Right. You picked up the 3rd and then this repair order's the 5th. Your complaint was at idle there's a vibration felt through the truck. They found -- no problem found, no DTC's or bulletins.
Q Right. No codes.
A There's still a -- it says hope, but I

believe --

Q It's hop.

A But it says hope. There's still a hop at driving over 25 miles an hour, no problem found. Customer states still a hop after new tires. No current bulletin for this item.

Q Okay.

0605

A That was it.

MR. KODSY: Thank you, sir.

I have no more questions, your Honor.

THE COURT: Okay. Thanks. Anything further?

MR. KLEIN: Just briefly, your Honor.

THE COURT: Okay, sure.

REDIRECT EXAMINATION

BY MR. KLEIN:

Q Before we go into a little more detail, the two Schumacher repair visits you just talked about, those were before you saw it again December 22nd, right?

A Yes.

Q And when you saw it on December 22nd you confirmed everything was performing properly?

A Yes.

Q What's the normal idle RPM for a Hummer H2?

A Well, it's gonna vary.

MR. KODSY: Objection, your Honor, he couldn't answer that to me.

THE COURT: Overruled.

THE WITNESS: It's gonna vary with compressor cycle and that sort of thing.

0606

You're probably gonna be about 850 in park and probably somewhere in the 700, high 600's. But it's gonna vary.

BY MR. KLEIN:

Q At Coral Cadillac, do you have the ability to look at a vehicle by a VIN on a computer and determine whether any recalls are applicable?

A Yes.

Q Have you done that with Mr. Kodsy's vehicle?

A Yes.

Q Are there any recalls applicable in Mr. Kodsy's vehicle?

A No, he has no open recalls.

Q Mr. Kodsy asked you a little bit about the repeat repair process you discussed. What is the purpose of that process?

A The purpose of it is to prevent that from happening and gauge where we have a problem, where our problem lies, get me involved, management involved so that we can get the correct people involved, get technical assistance involved, if need be. Or also in our case we're one of 20 dealers that do a conference call with the engineers on Wednesdays and we'll reach out to those guys, the

0607

brand quality managers.

Q So, basically if a customer has a problem and they say it still exists, it goes further up, you look at it in more detail?

A Yes, yes.

Q Get more people involved?

A Yes. Even if it's -- even if it's deemed to be a normal concern and the customer's still upset, I'm gonna be involved.

Q And you're going to look at the vehicle?

A Yes.

Q And did you do that in Mr. Kodsy's case?

A Yes, I did.

Q Obviously Coral Cadillac is authorized to do warranty repairs for General Motors?

A Yeah.

Q If you do a repair, do you get reimbursed by GM?

A Yes.

Q If you find a problem with a vehicle, is

there ever a situation where GM would say, no, leave it alone, don't fix it?
A No, not at all.
Q So, if you were to find a problem with Mr. Kodsy's truck, would you have fixed it?
0608
A Yes, yes.
Q And if there had been something wrong with the engine, would you have repaired that under warranty?
A Yes, of course.
Q And did you find any problems with the engine?
A No.
Q How many different values and specifications would you get if you were to check every specification on a Hummer H2?
A As far as the sensor specs, you would need -- you would need a -- there's a list. You could look at the -- there's a list and it's got the sensor, the type of condition that it's operating under and what value is expected to see because it's so different, hot idle, cold idle, certain RPM. It's always gonna be different. But there is a list of service information that gives us that.
Q And how long --
A You'd have to refer to the list. Nobody knows that off the top of their head.
Q How long would it take you to write on a repair order every sensor value that was normal?
A First of all, who's gonna read it? It
0609
would take an extremely long time. And it's not gonna make sense to anybody anyway.
Q But from a diagnostic point of view, if you found an abnormal sensor reading, would you note that on a repair order?
A Myself, probably so, if I saw something. Like -- like if -- when Mr. Kodsy said 14, 14 grams on a mass air flow sensor, I would certainly put

that in the story because it's so out of whack. If it's just something you're seeing slightly out that you're thinking is probably the problem, but you're not sure until you put it on a vehicle, I probably wouldn't put that in the story.

Q But if there was something significantly out of whack, you would note it?

A Yes.

Q Now, you discussed road force variation when you talked about the Schumacher repair orders. Can you explain to the jury what road force variation is?

A Road force variation is a deflection of the side wall and it's just a number we use to measure on trucks. You want it less than 30 -- I believe the number's 33. I'm not a hundred percent sure. And if -- if you have a high number, what you

0610

do is you index the wheel to the tire to try and get that number down lower.

It's just to help us with diagnosing vibration instead of just balancing tires like we used to in the past. We still do the balance, but we check the road force to make sure that the vehicle -- the tire is able to be balanced.

The one drawback to road force variation is the tires -- really the wheel and tire assembly really needs to be hot. The vehicle really needs to be driven 10 miles before you take the wheel and tire assemblies off and road force them or you're gonna get a skewed number.

Whether that's what happened here or not, but I can tell that you it's very difficult to get the technician to drive the vehicle 10 miles, come back, check the road force and then drive it again when he's done 10 miles.

Q Based on the road force variations written down on the Schumacher repair order, would you consider the tire vibration to be substantial?

A Based on those numbers, if the customer had a vibration concern, I probably would have replaced the tires.

Q But would you consider those numbers to be

0611

substantial or you would do that more for goodwill?

A It would be goodwill, yes. It would have been customer satisfaction.

Q So, for instance, if you had a customer that brought the vehicle in -- and I understand you wouldn't normally road force them without a complaint.

A Right.

Q But if you did road force those tires and the customer was not complaining about any vibration and you got those figures, would you replace the tires?

A No, not at all, not at all. The road force is just a tool to help you diagnose a vibration concern.

Q Have you had customers at the dealership that, you know, you've done repeat repairs and confirmed there's nothing wrong with the vehicle and accepted that determination?

A Yes.

Q And have you had some that refused to accept that as well?

A Yes.

MR. KLEIN: I have no further questions, your Honor.

J

Name:Sherif Kodsy
Age:45 years
DOB:04/27/1964
Arr. Date:02/06/2010
Arr. Time:20:31
Account#:001862170
MRN:000438469
Sex:Male
Chief Complaint:Abdominal Pain
Bed:EX6
Private MD:None
Height:5ft. 8in.
Weight:270Lbs
Diagnosis:Umbilical Hernia - reduced; Hypertension
Delray Medical Center
Emergency Department
Nurses Notes

Presentation:
02/06 20:31 Patient arrived by : Walk-In am4
21:14 Presenting complaint: Patient states: umbilical area pain onset 530pm no home tx. No n/v. Reports "knot in umbilical area". Communication: Speaks Fluent English. Acuity: Less-Urgent. Method of Arrival: walk-in without assistance. Pt Arrived From: Home. Addt'l Private Dr(s): PCP none. Care PTA: None. jc
21:19 Acuity: 3-Urgent. jc

Historical:
- Allergies: No known drug Allergies;
- Home Meds: Percocet Oral as needed(02/06/2010, 08:00);
- PMHx: Degenerative disc disease;
- PSHx: left arm and left shoulder surgeries;
- The history from nurses notes was reviewed: and I generally agree with what's documented up to this point.
- Immunization history:: Pneumococcol Vaccine: None per patient choice. Influenza Vaccine: None per patient choice. Last tetanus immunization: none per patient choice.
- Social history: Lives alone. Tobacco info : 1 ppd.

Screening:
21:17 Abuse screen Denies threats or abuse. Becks Suicide Risk Assessment Infromation received from Patient Suicidal Thinking Present No (0 points). Nutritional screening: No deficits noted. Tuberculosis screening: No symptoms or risk factors identified. Pandemic Influenza Screening: Patient denies fever. Pneumonia Screening: Cough No Fever No O2 Sat < 92% No 99 %. On Room Air Total Score Total: 0. Diarrhea Screening Assessment: Patient denies diarrhea at time of Emergency Department visit. Fall Risk History of Fall within 12 months- No (0 pts) Secondary Diagnosis- No (0 pts) IV/IV Access- No (0 pts) Ambulatory Aid- None/Bed Rest/Nurse Assist (0 pts). Gait- Normal/Bed Rest/Wheelchair (0 pts) Mental Status- Oriented to own ability (0 pts). Total Morse Fall Scale indicates No Risk (0-24 pts). jc

Name:Sherif Kodsy
Age:45 years
DOB:04/27/1964
Arr. Date:02/06/2010
Arr. Time:20:31
Account#:001862170
MRN:000438469
Sex:Male
Chief Complaint:Abdominal Pain
Bed:EX6
Private MD:None
Height:5ft. 8in.
Weight:270Lbs
Diagnosis:Umbilical Hernia - reduced; Hypertension
Delray Medical Center
Emergency Department
Nurses Notes

22:00 Pandemic Influenza Screening: Positive Findings: No risk factor noted in this patient. ah2

Vital Signs:
21:17 BP 189 / 109; Pulse 74; Resp 18; Temp 98.6(O); Pulse Ox 99% on R/A; Weight 270Lbs / 122.45Kg; Height 5 ft. 8 in. (172.72 cm); Pain 10/10; jc
23:09 BP 148 / 79 RA Sitting (auto/reg); Pulse 74 MON; Resp 18; Temp 98.4; Pulse Ox 99% on R/A; Pain 0/10; ah2

Triage Assessment:
21:18 General: Appears in no apparent distress, Behavior is appropriate for age, cooperative. jc

Assessment:
21:30 General: Appears in no apparent distress, comfortable, Behavior is appropriate for age, cooperative. Pain assessment: Complains of pain in umbilical area Pain does not radiate. Pain Pain currently is 10 out of 10 on a pain scale. Quality of pain is described as sharp. Cardiovascular: Capillary refill < 2 seconds is brisk in bilateral Heart tones present Pulses are all present. Chest pain is denied. Respiratory: Airway is patent Respiratory effort is even, unlabored, Respiratory pattern is regular symmetrical, trachea is midline Breath sounds are clear bilaterally. Denies cough, shortness of breath air hunger. Derm: No deficits noted. EENT: No deficits noted. GI: Abdomen is Non- distended Bowel sounds present X 4 quads. Abd is soft X 4 quads Abd is tender to palpation in umbilical area Denies constipation, cramping, diarrhea, epigastric pain, nausea, pain, vomiting. GU: No deficits noted. Musculoskeletal: No deficits noted. Neuro: Level of Consciousness is awake, alert, Oriented to person, place, time, Gait is steady, Speech is normal, Denies weakness, blurred vision, dizziness, difficulty swallowing, paresthesias, numbness, headache. ah2
22:01 General: Appears in no apparent distress, comfortable, Behavior is appropriate for age, cooperative. Pain assessment: Denies pain. GI: Denies pain. ah2
23:10 General: Appears in no apparent distress, comfortable, Behavior is ah2

appropriate for age, cooperative. Pain assessment: Denies pain. GI: Denies diarrhea, nausea, pain, vomiting.

Pain:

21:18 Complains of pain in umbilical area. Pain does not radiate. Pain currently is 10 out of 10 on a pain scale. Quality of pain is described as sharp. Pain began suddenly. Is continuous. Current management - is no interventions. jc

Interventions:

21:18 Patient/family/visitor instructed to inform triage nurse or staff member for worsening symptoms or percived change in condition. I.D. band placed on Patient placed in exam room. on stretcher in view of nurse Patient notified of wait time. jc
22:00 Patient has correct arm band on for positive identification. Bed in low position. Call light in reach. Placed in gown. Side rails up X2. ah2
23:09 Critical Lab Value Not Applicable - No critical results reported on this pt. ah2

Observations:

20:31 Patient arrived in ED. am4
20:31 Patient moved to Waiting. am4
20:32 Patient name changed from sherif^^kodsky to Sherif^^Kodsy. am4
21:19 Patient moved to EX6. jc
21:19 Patient visited by Call, Jason, RN. jc
21:19 Hom, Andrew, RN is Primary Nurse. ah2
21:30 STURM, DAVID, MD is Attending Physician. ds2
21:30 ds2
21:30 Patient visited by STURM, DAVID, MD. ds2
22:01 Patient visited by Hom, Andrew, RN. ah2
22:46 Breslaw, Ralph, MD is Referral Physician. ds2
22:46 Gorokhovsky, Diana, DO is Referral Physician. ds2
23:10 Patient visited by Hom, Andrew, RN. ah2

Outcome:

22:46 Discharge ordered by MD. ds2

23:10 Discharged to home ambulatory. Home Med Reconciliation Not reviewed With Physician at this time. Instructed on benefits of quitting smoking and/or risks of second hand smoke for non smokers. diet: discharge instructions, follow up and referral plans. Pain control measures safety practices, Discharge instructions given to patient, Demonstrated understanding of instructions. IV Infusions No IV fluids given to patient. Pain assessment: Denies pain. ah2

23:11 Patient left the ED. ah2

Signatures:

Call, Jason, RN	RN	jc
Munoz, Adela		am4
Hom, Andrew, RN	RN	ah2
STURM, DAVID, MD	MD	ds2

Corrections: (The following items were deleted from the chart)

21:17 21:14 Allergies: No known drug Allergies; jc jc

21:17 21:14 PMHx: Degenerative disc disease; jc jc

21:17 21:14 PSHx: left arm and left shoulder surgeries; jc jc

Delray Diagnostics
101 N W 1st Ave
Delray Beach, FL 33444

Phone: 561-272-4770
Fax: 561-272-0811

To : CARL SALVATI, M.D.
13455 MILITARY TRAIL SUITE A
DELRAY BEACH, FL 33484
Fax: 561-495-5101

Name: SHERIF KODSY
MRN #: DD002378
Exam Start: 10/31/08 11:54 am

Phone: 561-737-8998
DOB: 04/27/1964
Gender: Male

Exam: MRI of the Brain With and Without Contrast
CPT Code(s): 70553 - MAGNETIC RESONANCE (EG, PROTON) IMAGING, BRAIN (INCLUDING BRAIN STEM); WITHOUT CONTRAST MATERIAL, FOLLOWED BY CONTRAST MATERIAL(S) AND FURTHER SEQUENC
Laterality:
Clinical: HEADACHES

PROCEDURE: This study consists of a variety of pulse sequences acquired in multiple imaging planes which include the entire brain and upper cervical spine. Axial and coronal images were obtained both before and after intravenous contrast administration.

FINDINGS: Exam of the brain demonstrates a normal size and configuration of the ventricular system with no evidence of intracranial mass effect or hydrocephalus. Subarachnoid cisterns and cortical sulci are normal in size as well.

The brain parenchyma is entirely normal in appearance with no evidence of mass effect or alteration of signal intensity. The brain stem and cerebellum appear normal as well. Following intravenous contrast infusion, there are no abnormal areas of contrast enhancement within the brain.

Normal flow voids are demonstrated within the intracranial, vertebrobasilar, and carotid circulations.

Exam of the mastoids is normal. There is evidence of mucosal thickening and fluid levels of the paranasal sinuses. The orbits and optic nerves are well visualized and are normal in appearance. The pituitary is also normal in size and configuration. Both internal auditory canals have a normal symmetric appearance.

CONCLUSION: Sinusitis.

Otherwise normal MR examination of the brain with and without contrast enhancement.

Interpreting Radiologist

Delray Diagnostics
101 N W 1st Ave
Delray Beach, Fl 33444

Phone: 561-272-4770
Fax: 561-272-0811

To : FARHAN SIDDIQUI, MD
16244 MILITARY TRAIL #650 DELRAY BEACH, FL
Fax: 561-638-8874

Name: SHERIF KODSY
MRN #: 00002376
Exam Start: 8/26/08 2:17 pm
Phone: 561-737-8998
DOB: 04/27/1964
Gender: Male

Exam: MRI of the Lumbar Spine
CPT Code(s): 72148 - MAGNETIC RESONANCE (EG, PROTON) IMAGING, SPINAL CANAL AND CONTENTS, LUMBAR, WITHOUT CONTRAST MATERIAL
Laterality:
Clinical: LUMBAR S/S, SP MVA

INDICATIONS: This patient has low back pain and lower extremity radiculopathy

PROCEDURE: Sagittal and axial images were produced following a coronal scout series. The pulse sequences were designed to emphasize T1, T2 and proton density characteristic of tissue. The analysis is spin-echo

FINDINGS:

Vertebral bodies T12 through S2 are studied. The vertebral bodies are well-maintained in vertical height and have normal signal characteristics on T1 and T2 imaging parameters. The study is negative for fracture. There is no evidence of paravertebral mass or paravertebral soft tissue swelling. The aorta, vena cava and adjacent tissues are normal

No evidence of soft tissue hematoma or soft tissue mass

Normal signal is demonstrated within the distal thoracic cord and the conus. The nerve roots of the cauda equina flow freely in the normal thecal sac. No abnormal T2 signal from the distal spinal canal

T12-L1 interspace is normal. The disc is well hydrated and confined to the intervertebral space. No elevation of the posterior longitudinal ligament and no foraminal compromise

At L1-L2, there is a normal disc with normal signal on T2 analysis. No identifiable disc herniation at this level. The facet joints, thecal sac and foramen are normal

At L2-L3, the vertebral body endplates are uniform and the disc is well-maintained in vertical heel-to-shin and in signal characteristics. No compression or displacement of the exiting nerve roots and no elevation of the posterior longitudinal ligament.

At L3-L4, the intervertebral disc is herniated. This herniation is broad-based and central. The posterior longitudinal ligament is elevated and there is impression on the dural sac. No foramen stenosis

At L4-L5, there are normal foramen, normal thecal sac and normal posterior longitudinal ligament. No herniation

At L5-S1, there is concentric disc bulging. No foramen compromise or thecal sac stenosis

The upper sacral segments are normal. No evidence of sacral cyst, Tarlov cyst or any other pathology

CONCLUSION:

1. Broad-based central disc herniation at L3-L4
2. Bulging disc at L5-S1

JVZ:bt mi

Interpreting Radiologist

James V. Zelch MD

Electronically Signed 9/10/08 9:09 am

Delray Diagnostics
101 N W 1st Ave
Delray Beach, FL 33444

Phone: 561-272-4770
Fax: 561-272-0811

To : CARL SALVATI, M.D.
13455 MILITARY TRAIL SUITE A
DELRAY BEACH, FL 33484
Fax: 561-495-5191

Name: SHERIF KODSY
MRN #: DD002378
Exam Start: 9/26/08 2:27 pm

Phone: 561-737-8998
DOB: 04/27/1964
Gender: Male

Exam: CT of the Pelvis
CPT Code(s): 72192 - COMPUTED TOMOGRAPHY, PELVIS; WITHOUT CONTRAST MATERIAL
Laterality:
Clinical: TRAUMA,MVA GROIN PAIN INTO LT LEG

INDICATIONS: Abdominal pain

PROCEDURE: Multi-slice thin axial images were obtained through the pelvis. No contrast was administered.

FINDINGS: The visualized bowel and associated bowel mesentery are normal. No free fluid is noted within the pelvis. No inguinal lymphadenopathy is identified. No masses are present. Prostatic calcifications are noted. The visualized osseous structures are intact without lytic or blastic lesions.

CONCLUSION: Bilateral inguinal lymphadenopathy. Otherwise normal CT of the abdomen and pelvis.

Interpreting Radiologist

James V. Zelch, MD
Electronically Signed: 9/26/08 11:02 pm

Thank you for referring SHERIF KODSY to Delray Diagnostics.

Delray Location: 6200 Linton Blvd. Delray Beach, FL 33484 • (P) 561.496.6035 (F) 561.496.6036
Boynton Location: 4800 Boynton Beach Blvd., Suite 140, Boynton Beach, FL 33437 • (P) 561.736.3227 (F) 561.424.0000
Medical Director: Daniel E. Rudansky, M.D.
Radiologist: [illegible] Radiology Group

Patient Name:	Sheriff Kedey	DOB	04/23/1964	Phone	(561) 737-8998
Referring Physician:	Jeffrey A. Zipper	Fax	(561) 495-8877		
Date of Exam:	04/16/09	Pt#	86218	BOYN	267499

MRI left knee.

HISTORY: Pain and swelling. Meniscal tear.

MR technique: T1 weighted and fat suppressed Turbo T2 weighted 4mm coronal sections, PD and fat suppressed Turbo T2 weighted sagittal and Turbo PD weighted axial sections were obtained.

FINDINGS:

There is small joint effusion. There is edema within the prepatellar and infrapatellar subcutaneous tissues extending about the medial and lateral margins of the knee. There is also edema and thickening along the MCL consistent with a strain or partial tear. No full thickness disruption. Interim posterior cruciate and lateral collateral ligaments intact.

Lateral meniscus demonstrates no morphology and signal characteristics.

There is a horizontal oblique tear within the posterior horn medial meniscus extending to the anterior articular surface . Preservation articular cartilage within all 3 compartments. No evidence for occult fracture or bone bruise. Small exostosis arises from the supracondylar region medial femoral condyle.

IMPRESSION:
I.
1. Strain/ partial tear MCL.
2. Torn posterior horn medial meniscus.
3. Small joint effusion with subcutaneous edema.

Electronically signed by: JOSEPH KLEINMAN, M.D. on 4/16/2009 4:23 PM

Delray Diagnostics
101 N W 1st Ave
...lray Beach, FL 33444

Phone: 561-272-4770
Fax: 561-272-0811

To : CARL SALVATI, M.D.
13455 MILITARY TRAIL SUITE A
DELRAY BEACH, FL 33484
Fax: 561-495-5191

Name: SHERIF KODSY	Phone: 561-737-8998
MRN #: DD002378	DOB: 04/27/1964
Exam Start: 11/12/08 8:38 pm	Gender: Male

Exam:	MRI of the Cervical Spine
CPT Code(s):	72141 - MAGNETIC RESONANCE (EG, PROTON) IMAGING, SPINAL CANAL AND CONTENTS, CERVICAL; WITHOUT CONTRAST MATERIAL
Laterality:	
Clinical:	**723.4** NECK PAIN, RADICULOPATHY S/P MVA

INDICATIONS: This patient has neck pain and upper extremity radiculopathy.

PROCEDURE: A coronal scout series was followed by T1, proton density and T2 weighted imaging sequences in sagittal and axial planes.

FINDINGS:
All vertebral bodies are well maintained in vertical height and have normal signal characteristics. No evidence of fracture or marrow replacement disease. The soft tissues adjacent to the cervical vertebral bodies are normal. No evidence of anterior/paraspinal mass and no paravertebral abnormal process. There are no hemorrhages and no fluid collections.

The spinal canal is normal in appearance with ample subarachnoid fluid surrounding the spinal cord.

Each foramen is widely patent with normal nerve roots traversing the foramen. The lateral recesses are clear at each cervical level.

At C2-C3, there is a normal disc and a normal vertebral segment. No evidence of cord compression or compression/displacement of the exiting nerve root.

At C3-C4, there is a right central disc herniation and right foramen stenosis.

At C4-C5, the thecal sac and nerve root are widely patent. No evidence of cord compression or compression/displacement of the exiting nerve root at this level.

At C5-C6, there is a focal midline disc herniation. There is impression on the dural sac but no cord compression or foramen stenosis.

At C6-C7, there is a left central disc herniation and left foramen stenosis.

At C7-T1, the thecal sac and foramen are widely patent and there is no evidence of cord compression or displacement of the exiting nerve root.

All other aspects of this study are normal.

CONCLUSION:

1. Right central disc herniation at C3-C4.
2. Midline disc herniation at C5-C6.
3. Left central disc herniation at C6-C7.

JVZ/bt:mj

Interpreting Radiologist

James V. Zelch, MD

Electronically Signed: 11/13/08 4:52 pm

- K -

- K -

OFFICE OF THE ATTORNEY GENERAL
LEMON LAW ARBITRATION PROGRAM

110 Southest 6th Street, 10th Floor
Fort Lauderdale, FL 33301

Case Number: 2009-0034/WPB

In Re: Board Meeting

SHERIF RAFIK KODSY,

Plaintiff.

vs

HUMMER,

Defendant.

_______________________________/.

Thursday, March 5th, 2009

Commencing at: 1:30 p.m.

Concluding at: 4:00 p.m.

BOARD MEETING

Taken at City of Delray Beach, 100 Northwest 1st Street, Delray Beach, FL. 33444.

ERRATA SHEET

PAGE	LINE	CHANGE FROM:	CHANGE TO:
92	23	11,138	11,128

Subscribed and sworn to before me
this 23RD day of June 2009

Notary Public

JACQUELINE DePAOLI
Notary Public, State of Florida
Commission# DD832214
My comm. expires Dec. 08, 2012

Witness

APPEARANCES

BOARD MEMBERS:

PAUL TUCK, Chairman

HAGERENESH SIMMONS, Board Attorney

LEONARD WOLFER

BERNARD FERNANDEZ

GENERAL MOTORS REPRESENTATIVES:

TOM THORNTON
5784 Northwest 127th Terrace
Coral Springs, FL. 33076

JOE BARDILL
470 Southeast 8th Avenue
Pompano Beach, FL. 33060

MARIO LOPEZ

Also Present:

SHERIF RAFIK KODSY, Plaintiff
15968 Laurel Oak Circle
Delray Beach, FL. 33484

HILLARY HOBBS, Progressive Insurance Agent
4063 Lake Tahoe Circle
West Palm Beach, FL. 33409

* * * * *

(Thereupon, the following proceedings were had.)

MR. TUCK: This is case number 2009-034/WPB. The matter of Kodsy against Hummer.

Is that the way you pronounce your name, Kodsy?

MR. KODSY: Kodsy.

MR. TUCK: It's being held on Thursday, March 5th, 2009 in Delray Beach. My name is Paul Tuck. I will be the chair. With me are Bernard Fernandez, Leonard Wolfer (phonetic) for the Board. Hager Simmons would be the Board attorney.

As you can see the hearing is being tape-recorded, actually it's digitally recorded now. We don't use tape recorders anymore. That recording will be the official transcript of the hearing if one is needed.

What we're going to start out doing is having everybody, starting with the people from the consumer side, introduce yourselves giving your name and your address. Each time you speak starting from here on out, we're going to ask you to identify yourself because whoever is transcribing the hearing can't tell all the time who is speaking.

So, would you give us your name and your address?

MS. HOBBS: Hillary Hobbs. My address is 4063 Lake Tahoe Circle, West Palm Beach. 33409.

MS. SIMMONS: Would you spell your last name?

MS. HOBBS: H-O-B-B-S.

MS. SIMMONS: And your first name is?

MS. HOBBS: Hillary with two L's. H-I-L-L-A-R-Y.

MR. TUCK: Next?

MR. KODSY: Sherif Kodsy. Do you want my address?

MR. TUCK: Yes, please.

MR. KODSY: 15968 Laurel Oak Circle, Delray Beach, Florida. 33484.

MR. TUCK: Next?

MR. THORNTON: Tom Thornton. T-H-O-R-N-T-O-N. Address 5784 Northwest

127th Terrace, Coral Springs, Florida. 33076.

MS. SIMMONS: Your title, Mr. Thornton?

MR. THORNTON: District Service Manager for General Motors.

MR. BARDILL: Joe Bardill. B-A-R-D-I-L-L. 470 Southeast 8th Avenue, Pompano Beach, Florida.

MS. SIMMONS: Your title, Mr. Bardill?

MR. BARDILL: Service manager.

MS. SIMMONS: At where?

MR. BARDILL: Coral Cadillac.

MR. TUCK: Okay.

MR. LOPEZ: Mario Lopez, parts manager for General Motors Corporation.

MR. TUCK: The way these hearings are conducted is informally. By that, I mean we still have standard rules of courtesy and not subject to the same rules of evidence like you see in a courtroom. What we're going to be doing is first I will be swearing in everybody who intends to testify, you will be testifying under oath. Then we're going to do what we call marked documents. It simply means that we're going to compare the documents that all the parties have to make sure everybody is working from the same set of documents.

After that, we're going to ask the manufacturer which of any of the allegations in the request for arbitration they can stipulate or agree to. What they will agree to or stipulate to doesn't have to be further proven by testimony or further documentary evidence. I'm going to have testimony from the consumer and the consumer's witnesses followed by questions from the manufacturer's side.

Then the manufacturer will present any witnesses it chooses to present followed by questions from the consumer. You can't interrupt each other. So if you need a pencil and paper feel free to take down any notes while the other party is testifying, so you can remind yourself what questions you may have wanted to ask.

After that, we will decide whether or not we need to test drive or inspect the vehicle. Is the vehicle here today?

MR. LOPEZ: Yes.

MR. TUCK: If we do test drive the vehicle, we'll have more instructions for you at that time.

Then we're going to have closing statements followed by our deliberations. You're free to stay in the room while we deliberate, but not to participate unless we have a particular question for somebody. Depending on the results of our deliberations, we either will or will not get into a remedy phase.

Any questions? All right. Would everybody who is going to testify, please raise their right hands?

(Thereupon, the witnesses were duly sworn to testify under oath.)

MR. TUCK: You can put your hands down. Thank you.

As a preliminary matter, would the consumer turn to the request for arbitration. That's the form that looks like this that you signed. If you go to the last page, page six, there should be a signature there.

Is that your signature?

MR. KODSY: Yes.

MR. TUCK: And you placed it there?

MR. KODSY: Yes.

MR. TUCK: Thank you. Turning now to the various documents that have been presented by the parties.

MS. SIMMONS: Mr. Tuck, before we go through the documents and enter them as an exhibit, I would let the Board know there were late submissions of documents from, what I see, mainly from the consumer side. From the manufacturer side, there is a late submission of prehearing information sheet and a BBB letter. These things the Board needs to decide of admitting before we start labeling as exhibits.

MR. TUCK: Okay.

MS. SIMMONS: I should let the Board know of the procedural history of getting up to that. The manufacturer's prehearing information sheet could not have been submitted any other time earlier than when it was done because an inspection did not occur until this week, the 2nd. That was the reason for the delay and there has been a motion that's been filed in here by the manufacturer asking the Board's assistance in scheduling this and part of the rationale in allowing this inspection to have was that even if it was untimely, that inspection report will be considered admitted to facilitate the hearing happened in the 40-day requirements.

MR. TUCK: I understand.

MS. SIMMONS: Just to let you know what's been submitted, a late submission from the consumer side is a consumer prehearing information sheet, amended prehearing information sheet. From the exhibit side of the consumer, there is a certificate of service, medical report, and GM checklist.

From the manufacturer's side, as far as pleadings, there is a late submission of manufacturer prehearing information sheet which I talked about. From the exhibit side, there is a BBB letter.

MR. TUCK: Let's briefly hear from the parties first. Both sides have submitted untimely documents. It doesn't mean they're wrong. It just means that the other side is supposed to have at least five or seven days beforehand to review these things. Since you both did it, would you both agree to allow the evidence to be considered by the Board?

MR. LOPEZ: I don't have a problem as long as the Board decides. I'm trying to be open as I have always been with the Boards. Whatever you decide will be okay, but as Ms. Simmons states we had some issues with the inspection. We couldn't agree on a date and then the consumer refused to go to their inspection. That's why we requested it.

MR. TUCK: Have you seen the documents that the consumer submitted?

MR. LOPEZ: I'm not sure because --

MR. TUCK: Can we show them to them and see if there is anything that might be unduly prejudicial.

MS. SIMMONS: Sure. Let me see, which is the consumer's amended prehearing information sheet.

Mr. Kodsy, I'm going to be showing to the manufacturer what you faxed over to us.

The consumer prehearing information sheet was faxed on the 2nd. That's one from the pleading side. Here, it has the witness list on the bottom.

MR. TUCK: Has the consumer been served with the documents that the manufacturer is looking to submit?

MS. SIMMONS: They were instructed to both fax to each other whenever they filed documents to the Board, so I'm assuming --

MR. TUCK: Did you receive those documents?

MR. KODSY: I'm not sure what documents we're talking about.

MS. SIMMONS: From the manufacturer's side, what they submitted was the prehearing inspection report. Did you get a copy of that?

MR. KODSY: From Schumacher? On a Schumacher, letterhead, yes.

MS. SIMMONS: I don't know if it's a letterhead. It's dated March 2nd. This document.

MR. TUCK: Have you seen that?

MR.. KODSY: Yes.

MS. SIMMONS: Then the BBB report was another document that was submitted by the manufacturer. I will show that to Mr. Kodsy to see if he has seen it, I assume it was faxed over. Actually, there is no BBB. I misspoke.

MR. LOPEZ: The only one that was late submission was the prehearing inspection --

MS.. SIMMONS: Prehearing inspection report.

MR. TUCK: Do you have any objection to us taking the documentation that he just submitted into consideration?

MR. KODSY: Not at all.

MR. TUCK: Do you have any objection to taking those documents into consideration?

MR. LOPEZ: Can I have a copy of that?

MS. SIMMONS: I thought you said it was already faxed to you, the March 2nd prehearing information sheet?

MR. LOPEZ: The last one? This is the last one that I got, so I'm not sure if that's the one that --

MS. SIMMONS: I will show it to you. This is one, the amended prehearing information sheet and then consumer's objection -- it's a written objection, it's a two-page document, and consumer's statement.

MR. LOPEZ: This one I got.

MS. SIMMONS: You've already gotten the amended prehearing report.

MR. KODSY: We faxed some more documents yesterday, consumer statement.

MS. SIMMONS: Yes, that's what I'm showing him, the consumer statement and the consumer written objection.

MR. TUCK: There is no objection?

MR. LOPEZ: I don't have any objection to that.

MR. TUCK: With the consent of both parties, does the Board have any objection to seeing the documents that have been submitted untimely?

Mr. Wolfer?

MR. WOLFER: No.

MR. TUCK: No objection, Mr. Fernandez?

MR. FERNANDEZ: No objection to both sides' documents.

MR. TUCK: Then we're unanimous, we

will accept them.

MS. SIMMONS: In that case, we have copies of those to the Board. Here's the final amended list of exhibits.

MR. TUCK: Okay. So now we're going to try to mark documents.

MS. SIMMONS: Yes.

MR. TUCK: The entry of further documents is officially closed.

From the consumer, we have his pleadings, the consumer's request for arbitration, consumer's prehearing information sheet, consumer's amended prehearing information sheet, consumer's objections, and the consumer's statement.

As exhibits from the consumer, we have repair orders which will be marked as C1; defect notification, C2; consumer's letter to dealership and return receipt, C3; Better Business Bureau letter, C4; retail installment contract, C5; motor vehicle title reassignment supplement registration, certificate of origin, C6; business card, C7; invoice, C8; insurance information, C9; online vehicle search information, C10; car rental receipts, 11; consumer's appeal to the response of intent to offer settlement, 12; e-mail correspondence, C13; consumer's appeal, C14; odometer disclosure statement, C15; used car buyer's order, C16; Better Business Bureau letter, C --

MS. SIMMONS: There's two different letters from the Better Business Bureau.

MR. TUCK: 17, this will be the second BBB letter. Repair invoice, 18; technical service bulletins listing, 19; insurance claim, 20; a second business card, 21; certificate of service, 22; a medical report, 23; GM checklist, 24; additional e-mail correspondence, 25; postage, 26; a third business card, 27; an e-mail, 28.

From the manufacturer, we have his pleadings and manufacturer's answer postmarked 2-4-09, manufacturer's prehearing information sheet, and manufacturer's amended prehearing information sheet.

As exhibits from the manufacturer, we have prehearing inspection letter which will be marked M1. General Motors' request for assistant from the Attorney General's

Office, M2; prehearing inspection confirmation e-mails; M2; Better Business Bureau letter, M4; prehearing inspection report, M5.

Now we're going to turn to the consumer's request for arbitration. We're going to ask the manufacturer's representative, can you agree to items one, two, and three?

MR. LOPEZ: Yes, sir.

MR. TUCK: Item four?

MR. LOPEZ: Yes, sir.

MR. TUCK: Number five, the consumer is looking for a replacement vehicle?

MR. KODSY: At this point --

MR. TUCK: Or a refund?

MR. KODSY: Whatever the Board decides is the best way to go, probably a refund.

MR. TUCK: That will be your choice, but we'll get to that when we get to the end of our deliberations and see what decision we render. For now, we'll just leave it open.

MS. SIMMONS: Okay.

MR. TUCK: Can the manufacturer agree

to number six?

MR. LOPEZ: Yes, sir.

MR. TUCK: Seven, is it less than 10,000 pounds?

MR. LOPEZ: 8600 pounds.

MR. TUCK: Eight?

MR. LOPEZ: It's GM manufactured.

MR. TUCK: Nine?

MR. LOPEZ: It's a Hummer H2 2008.

MR. TUCK: Number ten, if that's the correct vehicle identification number, would you please read it into the record?

MR. LOPEZ: Yes, sir. 5GRGN23878H107653.

MR. TUCK: Thank you. 12, two parts.

MR. LOPEZ: Number 12, the mileage is correct. It's 238 miles. The delivery date when it was sold to him was 8-19, that's correct, but the warranty started on June 11th, 2008 because this was a special event vehicle when it was sold to him.

MR. TUCK: It was a what?

MR. LOPEZ: Special event, a vehicle that is used for a show and then the dealer buys. It's a new vehicle. It's not a used vehicle.

MR. TUCK: It's a new vehicle?

MR. LOPEZ: It's a new vehicle, yes, it's a new vehicle.

MS. SIMMONS: Is it a demo?

MR. LOPEZ: Similar to a demo. It's in the same category, it's just that they call it a special event. It's been in a show or whatever. It hasn't been titled in any state.

MR. TUCK: Okay. Thank you.

MR. LOPEZ: You're welcome, sir.

MR. TUCK: Are we going to call it new or a demonstrator?

MS. SIMMONS: I'm not sure.

MR. TUCK: I thought the testimony said that it was sold as a new vehicle. It was not used to show to other potential buyers.

MR. LOPEZ: Right.

MR. TUCK: It was used in a single event.

MR. LOPEZ: It was in a single event, exactly.

MS. SIMMONS: So it's not like a demo --

MR. LOPEZ: GM, like they get a new car and they put it in a show for a single event and then the dealer says I want that car so they buy it from you and they sell it.

MS. SIMMONS: So it would be a new vehicle?

MR. LOPEZ: It's a new vehicle.

MR. FERNANDEZ: This is Bernard Fernandez.

Good afternoon, Mr. Lopez. You are here and unequivocally you're saying that the vehicle is new?

MR. LOPEZ: Exactly.

MR. FERNANDEZ: Okay. Fine with me.

MR. TUCK: 15, consumer still possesses the vehicle that's here today?

MR. KODSY: Yes.

MR. TUCK: 16 becomes irrelevant.

MS. SIMMONS: What is 16?

MR. TUCK: 16, if purchased used.

MS. SIMMONS: Okay.

MR. TUCK: Under 17, can the manufacturer stipulate or agree that on the dates listed there the vehicle was brought to the dealership for the problems listed in lines one through six?

MR. LOPEZ: We can stipulate to some -- most of the dates there --

MR. TUCK: Then you take exceptions.

MR. LOPEZ: We'll have to take an exception to a few of them.

MR. TUCK: Why don't you tell us which ones you take exceptions?

MR. LOPEZ: Okay. We'll start with number one?

MR. TUCK: Yes.

MR. LOPEZ: That one, the first one, 10-20-08.

MR. TUCK: Yes?

MR. LOPEZ: That didn't go in for that.

MR. TUCK: It was not in for that?

MR. LOPEZ: It was not in for that.

MR. TUCK: So we'll have to take testimony.

MR. LOPEZ: Yes. The other one, the next day, I think it is 11-5, it's not 11-12.

MR. WOLFER: I'm sorry, it was on 11-5?

MR. LOPEZ: I think it's 11-5.

MR. TUCK: Yes. We'll look at the

repair order.

MR.. LOPEZ: I'm trying to sort the complaints by the repair orders.

MR. TUCK: What he is referring to is on the repair orders is an open date and a ready date. The dates that we referred to -- there is no reason why you should know this if you haven't done it before. We always refer to the repair order opening date, so I presume you have no objection to --

MR. KODSY: Correct.

MR. LOPEZ: The other one is --

MS. SIMMONS: When you say other one, is it number three?

MR. LOPEZ: Number three, 12-1-08 is correct.

MS. SIMMONS: You don't stipulate to 10-20 and 11-5?

MR. LOPEZ: We would have to take a look at the repair orders to see.

MS. SIMMONS: Number three?

MR. TUCK: Line three. Wait a second.

What line are you on now? As far as I understand starting with line one, you had a question about the first date under date one.

MR. LOPEZ: Under date two. That same line, item number one, that's where I am. I'm looking at date one, date two, and date three.

MR. TUCK: All right. So you're taking exception to all three dates?

MR. LOPEZ: Not the last one, we agree that's --

MR. TUCK: So you're taking exception to 10-20-08 and 11-12-08?

MR. LOPEZ: Yes.

MR. TUCK: Okay.

MR. WOLFER: Are you taking exception to 11-12 because it should be 11-5?

MR. LOPEZ: I think it is, yes.

MR. WOLFER: Okay.

MR. FERNANDEZ: Bernard Fernandez. I believe the manufacturer had no objection to changing the November 12th date to November 5th?

MR. TUCK: That's correct.

MR. FERNANDEZ: Is that correct?

MR. TUCK: Yes.

MR. FERNANDEZ: Okay.

MR. TUCK: So now let's go down to line three. Is that the same situation with 11-12.

MS. SIMMONS: Line two.

MR. TUCK: I thought we just did line two.

MR. LOPEZ: It was line one.

MS. SIMMONS: Complaints, the rough vibration during driving, what dates do you --

MR. LOPEZ: That's number two.

MS. SIMMONS: Yes. What dates do you stipulate to?

MR. LOPEZ: I couldn't find any rough vibration claim --

MS. SIMMONS: So you don't stipulate to any one of those dates?

MR. LOPEZ: No.

MS. SIMMONS: The third one which states the hopping of vehicle at low speeds. Is there any date that you stipulate to?

MR. LOPEZ: 12-1-08, date number three.

MR. TUCK: Line four?

MR. LOPEZ: Vehicle bounces. I cannot

stipulate to the first two. The third one, we would have to look at it because I'm not sure because he complains about hopping.

MR. TUCK: So you're not going to stipulate to any of these, we'll take testimony.

MR. LOPEZ: Yes, we would have to look at them.

MR. TUCK: Line five?

MR. LOPEZ: Line five would be the 12-22. That one we can stipulate to.

MR. TUCK: That's the only one?

MR. LOPEZ: Yes.

MR. TUCK: Finally, line six?

MR. LOPEZ: Brakes squealing, I can stipulate to 12-22, and I believe the consumer agrees on 11-5 instead of 11-12.

MR. TUCK: Okay.

MR. LOPEZ: We can stipulate to that.

MR. WOLFER: But not the 10-20?

MR. LOPEZ: Not the 10-20, no.

MR. TUCK: Moving to line 18.

MR. LOPEZ: Yes, sir.

MR. TUCK: On that date, 12-18?

MR. LOPEZ: Yes.

MR. TUCK: Line 19?

MR. LOPEZ: Final repair of 12-22, yes.

MR. TUCK: Under line 20, the days out, 27 days?

MR. LOPEZ: I think I just have one day difference, I think I count 26.

MR. TUCK: 26. We'll have to check that later.

MR. LOPEZ: He marked yes on 21, but this is not a conversion.

MR. TUCK: This is not asking that. What it appears to be saying is did the manufacturer or the conversion company or authorized service agent had the opportunity to inspect or repair the vehicle. So it's the same yes as before.

MS. SIMMONS: Do you stipulate that you had an opportunity to inspect it?

MR. LOPEZ: Yes.

MR. TUCK: Under 22, is there any allegation that the conditions complained about are the result of accident, use, neglect or modification or alteration?

MR. LOPEZ: Not that I know.

MR. TUCK: Under 23, there is a Better

Business certified program connected with this vehicle?

MR. LOPEZ: Yes, there was.

MR. TUCK: It's my understanding from the file that the Better Business Bureau declined it because they said there was some report of accident or fire from the consumer?

MS. SIMMONS: There's a second BBB letter, I know you didn't have an opportunity to see it in the file because this is late submission. Page 80 and 81. On the consumer side, page 80.

MR. FERNANDEZ: Madam Counsel, we just wanted to address your attention to our page 22 on the supplemental reports that were received timely.

MS. SIMMONS: Yes.

MR. FERNANDEZ: The very last page that I seem to be reading here is a letter from the BBB received February 27th.

MS. SIMMONS: Page 22?

MR. FERNANDEZ: On our amended -- the final packet that we first received on the very last page.

MR. TUCK: This letter is dated January 9th, 2009.

MS. SIMMONS: Yes.

MR. TUCK: It's from the Better Business Bureau?

MS. SIMMONS: Yes.

MR. TUCK: At the end of the first paragraph, it says, "We have determined that your claim is ineligible for arbitration because you have alleged that the defect was caused by an accident --

MR. FERNANDEZ: Has caused an accident.

MR. TUCK: -- has caused an accident or fire that resulted in property damage or bodily injury."

MS. SIMMONS: Yes. It's also on page 36.

MR. TUCK: We already had that.

MS. SIMMONS: We have that. Thank you. I think that needs to be clarified through testimony what happened as to the BBB.

MR. FERNANDEZ: I agree.

MR. TUCK: Yes.

MS. SIMMONS: On the consumer side, I just want to make sure you have it. On the packet that we gave you, page 36 has the letter that Mr. Fernandez just pointed out from the BBB. Page 80, you should have a second letter from the BBB.

MR. TUCK: This is the same letter that we just read from, you have two copies of it?

MS. SIMMONS: No, it should be a different one.

MR. TUCK: In my file it says January 9th.

MR. WOLFER: That's 36. We've got to go to 80.

MR. TUCK: This is the same letter that we just received another copy of. I just want to clarify that we were just given something as an addition which appears to be the same letter.

MS. SIMMONS: Yes.

MR. TUCK: In place it's circle number 22 and another page it's circle number 36.

MS. SIMMONS: They both filed it, both parties. I just want to make sure, Mr. Tuck, you do have this letter. Do you have that?

MR. TUCK: Now we're going to circle number eight. Yes, I have it..

MS. SIMMONS: I just want to make sure you have that.

MR. TUCK: Now we're going to start the consumer's testimony. Who's going to speak for the consumer?

MR. KODSY: I will.

MR. TUCK: What we're going to ask you to do is starting from when complaints first arose. I know we have a lot of different issues here.

MS. SIMMONS: I should let the Board know that the witness who is sitting here, Ms. Hobbs, she is here under subpoena. I don't know if you want to take her out of order or just go ahead.

MR. TUCK: Are you under a time constraint?

MS. HOBBS: Well, I left work to come here so.

MR. TUCK: Do you need to get back?

MS. HOBBS: As soon as I can, yes.

MR. TUCK: All right.

With everybody's consent then, why

don't we have this witness testify first so she is not held outside of work? Does the Board have any objection?

MR. FERNANDEZ: I have no objection.

MR. WOLFER: No.

MR. TUCK: All right. What we're going to ask you to do -- do you know why you're here to testify? You're not sure?

MS. HOBBS: I think it has something to do with the claim that was filed with Progressive.

MR. TUCK: What kind of claim, an insurance claim?

MS. SIMMONS: The consumer listed her as a witness.

MR. TUCK: Right.

MR. KODSY: If I may? She test drove the vehicle, so she is aware of the condition of the vehicle. She is aware of my complaint to the Board today of how the vehicle was performing.

MR. TUCK: Was there any written report made of her test --

MR. KODSY: There was --

MR. TUCK: Is it part of our

documentation?

MR. KODSY: There is a part of it, yes, from the insurance company stating that this problem was due to a Progressive defect, not an accidental one.

MR. TUCK: All right. What I would like to ask you to do is frame questions to the witness that will elicit the kind of information that you want us to hear.

MR. KODSY: Do you want me to go ahead?

MR. TUCK: Yes.

MR. KODSY: When you test drove the vehicle, did it feel normal to you from your prior experience of driving a Hummer H2 that that was normal for the way the vehicle performed?

MS. HOBBS: When you brought the car in to our service center for the claim -- I've driven Hummers a couple of times, I'm by no means an expert on them. I did feel some type of vibration when we were driving the vehicle; however, I couldn't tell you what it is.

MR. WOLFER: Excuse me. Can you just give us a little bit of background about yourself?

MS. HOBBS: Sure. I am a claims manager for Progressive Insurance. That's the company that Mr. Kodsy has his Hummer insured with. He filed a claim with us and I manage the service center where customers bring their vehicles for repairs or estimates.

MR. TUCK: What was the nature of the claim?

MS. HOBBS: The nature of the claim was unknown. He filed the claim and said that he had an issue with the vehicle. It came into my service center. I actually took him in. When he came in, I was working up front that day. I asked him what's going on with the vehicle, what is your claim for? He said he has a vibration and he just wanted us to have documentation that he had an issue with it. After discussing it with him, he said he hadn't had an accident or anything like that. So it wasn't any kind of issue that would be something covered under our policy.

MR. TUCK: No personal injury claims?

MS. HOBBS: No personal injury claim or anything like that, no. So I test drove the vehicle with him because he brought it in. I drove with him down the road and there was vibration. I don't know what it is or isn't, but there was a vibration with the vehicle.

MR. TUCK: Okay. Do you have any other questions?

MR. KODSY: Sure. You heard the vehicle idling kind of loud from the outside as well when we stood on the outside with the vehicle running. I know that we noticed that the vehicle was idling high and was making a noise.

MS. HOBBS: Again, the first time I had seen the vehicle is when he brought it in. So as far as what RPM's or whatever the car is supposed to idle at, I don't know. You could hear it kind of idling and then coming back down more frequent than what I have ever experienced with those vehicles previously.

MR. TUCK: How long did you drive it for and under what conditions?

MS. HOBBS: I probably drove it for three to five minutes at best from what I recall. I don't remember what the weather conditions were. I drove it up the road where my office is located onto Haverhill Road up maybe like a mile and then back down and back into my parking lot.

MR. TUCK: At what speeds?

MS. HOBBS: The posted speed limit on my road is 25, on Haverhill it's 45.

MR. TUCK: You drove it the posted speeds, of course?

MS. HOBBS: I don't recall. I could not tell you that.

MR. KODSY: She did.

MR. FERNANDEZ: Bernard Fernandez.

Ms. Hobbs, did you have any difficulty maintaining control of the vehicle?

MS. HOBBS: As in driving it straight down the road?

MR. FERNANDEZ: Yes. Did you have any difficulty keeping it in a straight course or when you had to turn, did the vehicle turn correctly?

MS. HOBBS: I didn't have any

difficulty maintaining it straight or turning it, no, not that I recall.

MR. FERNANDEZ: You have driven Hummers before and there was no such vibration?

MS. HOBBS: I have driven other Hummers before in the past. I can't say necessarily that none of them had a vibration similar to that. When we were driving the vehicle, I felt like there was a vibration more severe than anything I had experienced before. Like I said, I drive all kinds of different cars everyday so.

MR. TUCK: Anything else?

MR. KODSY: Yes. The mass air flow sensor on that vehicle, is that normal for it to go out at 5,000 miles and have to be replaced? Do you have any idea?

MR. LOPEZ: I think I have an objection to that. She has no way --

MR. TUCK: Are you motor vehicle repair person?

MS. SIMMONS: Is that a no? She is shaking her head no.

MS. HOBBS: No, I am not.

MR. KODSY: From experience?

MS. SIMMONS: What's the ruling on the objection?

MR. TUCK: I'm going to give her a chance to say if she knows about these things and if she doesn't, then she is not qualified to answer it.

MS. HOBBS: I wouldn't say that I know about it where I'm an expert on it to say that I know one way or another how long on that particular vehicle that they're supposed to last for.

MR. TUCK: Okay. But we do have some technical experts here that you will get an opportunity to question later and clarify that.

Any other questions for the witness?

MR. KODSY: No.

MR. TUCK: Any questions?

MR. LOPEZ: Mr. Lopez to Ms. Hobbs, did I say it right?

MS. HOBBS: Yes, you did.

MR. LOPEZ: H-O-B-E-S?

MS. HOBBS: H-O-B-B-S.

MR. LOPEZ: Thank you.

Ms. Hobbs, so you work for Progressive,

that's an insurance company, correct?

MS. HOBBS: Yes, that's correct.

MR. LOPEZ: You stated to the Board that you didn't have any difficulty in driving the vehicle, correct?

MS. HOBBS: In driving it straight down the road or turning it, no, I did not.

MR. LOPEZ: Turning it, did you have any problem with it?

MS. HOBBS: No, I did not.

MR. LOPEZ: Okay. Did you feel any hopping of the vehicle or any like, it would bounce like that or make noises or --

MS. HOBBS: As far as hopping of the vehicle, I wouldn't be able to say yes or no on that. There was a vibration going down the road where you could visually see the steering wheel doing this.

MR. LOPEZ: Do you see Hummers often at your insurance company?

MS. HOBBS: I couldn't tell you how often I see them. Have I seen them over the course of five years? Yes. How many? I couldn't tell you that.

MR. LOPEZ: Did you see more or less

two, three, ten, in five years?

MS. HOBBS: I probably would say more, 20 to 30.

MR. LOPEZ: With accidents?

MS. HOBBS: With accidents, correct.

MR. LOPEZ: And you drive each one of them every time they come in?

MS. HOBBS: Not every car every time they come in, no.

MR. LOPEZ: So this was kind of a special request by Mr. Kodsy requested from you, correct?

MS. HOBBS: I don't know if special request would be the right to say it. He came in and presented the claim to the insurance company that I work for. So it is our duty to see if there is any kind of damage that currently exists on the vehicle that we need to inspect if there is any kind of damage to the vehicle that would be a covered loss. So that's what I was doing was ruling that out.

MR. LOPEZ: So basically there was no damage to the vehicle?

MS. HOBBS: There was no damage that

would be covered under our policy, no.

MR. TUCK: Was there damage that was excluded under your policy?

MS. HOBBS: Well, we don't cover any kind of wear and tear under the policy. Whatever the vibration, I couldn't say what it is or isn't. We don't cover that under our policy. We just cover comprehensive or collision losses.

MR. TUCK: Did you notice any cosmetic defects or damage?

MS. HOBBS: No, I did not see any.

MR. LOPEZ: Are you aware that the Hummer, the H2, looks similar on the outside but has different powertrains? Are you aware of that?

MS. HOBBS: Of the different powertrains on the vehicles?

MR. LOPEZ: Yes.

MS. HOBBS: I'm aware that there are different ones, yes.

MR. LOPEZ: Okay. Thank you.

MR. TUCK: Do you have any questions regarding the answers that she just gave to these questions?

MR. KODSY: No.

MR. TUCK: Okay. Does anybody object to this witness being excused with our thanks?

MR. LOPEZ: She may be excused. I know she has to work.

MR. TUCK: Are you ready to release the witness?

MR. KODSY: Sure.

MR. TUCK: Thank you for your cooperation and participation..

MS. HOBBS: Not a problem, thank you.

(Thereupon, Hillary Hobbs was excused from the hearing.)

MR. TUCK: The record will reflect that this witness is leaving the hearing.

Now we're going to ask you starting at the beginning to explain your concerns as they arose. We're going to start with the rough vibration and idle.

MR. KODSY: Okay.

MS. SIMMONS: Excuse me, Mr. Tuck. If we could do similar to what we just did earlier, address by issues?

MR. TUCK: That's what I said.

Starting with the rough idle, when did you first observe it, describe the condition to us and then refer us -- hopefully you've got your repair orders in order.

MR. KODSY: Can I speak?

MR. TUCK: Yes.

MR. KODSY: Basically what happened is the vehicle -- it was giving me a difficulty of steady ride. So I took it in for service. That was the first time I took it in for service.

MR. TUCK: When was that?

MR. KODSY: The first date of service here was 10-20, it looks the earliest time this vehicle was serviced.

MR. TUCK: Of 2008?

MR. KODSY: Of 2008.

MR. TUCK: All right. That would be our number eight.

MR. KODSY: The service department confirmed or rather discovered that the mass air flow sensor was the problem and went ahead to replace it. Ever since that air mass flow sensor was replaced, this vehicle never ran like it did originally. I've had constant problems with the vibration and the irregular idle on that vehicle.

MR. TUCK: So how long had you had it, it looks like you had put about 5200 miles on it?

MR. KODSY: Exactly, which was about in one month's time.

MR. TUCK: In the first month it was running fine until --

MR. KODSY: It was running I would say, if I had to put it in a scale from one to 100, it was running roughly about 85 percent with no problem. The other 15 percent was undetermined.. I had no idea what it is until it got worse and I had to take it in for service.

MR. TUCK: Had the engine stalled before you brought it in on October 20th?

MR. KODSY: Yes.

MR. TUCK: It had actually stalled?

MR. KODSY: It had actually stalled.

MR. TUCK: Did it stall after they changed the --

MR. KODSY: It didn't stall afterwards.

MR.. TUCK: Okay.

MR. KODSY: But it did have an irregular heartbeat or idle.

MR. TUCK: That was not there prior?

MR. KODSY: It was not there prior, plus the vibration.

MR. TUCK: We'll get to the vibration. So when is the next time that you brought it in for this complaint?

MR. KODSY: I believe that the first time I took it out of there and I brought it back the next day, which was --

MR. TUCK: The next one we have here is November 5th.

MR. KODSY: November 5th, yes, but the first one extended and I guess they put it on the same, but my rental receipts will show that there was two in one work order.

MR. TUCK: From October 20th to October 23rd?

MR. KODSY: Yes. There were two rentals involved because the vehicle was returned and then -- it was returned after the repair as non-satisfactory because still the vibration was existing.

MR. TUCK: You had two different kinds

of vibration. Is there a difference? It says, "Rough vibration at idle, rough vibration during driving."

MR. KODSY: Yes.

MR. TUCK: Is that the same condition?

MR. KODSY: It's the same, but it gets worse. When you drive it on high RPM's, you're obviously feeling the vehicle put out while it's being choked causing the vibration.

MR. TUCK: Is that related to items three and four, "Hopping of vehicle at all speeds and vehicle bounces at road conditions"?

MR. KODSY: No, that was later observed and submitted for remedy to the dealership.

MR. TUCK: All right. So let's just stay with one and two which is the engine vibrations.

MR. KODSY: Okay.

MR. TUCK: On the 23rd you brought it back out again?

MR. KODSY: I brought it back on the 23rd.

MR. TUCK: You picked it up on the 23rd

according to these. You brought it in on the 20th and you picked it up ready on the 23rd.

MR. KODSY: Okay.

MR. TUCK: The next time after that was November 5th that you brought it back in.

MR. KODSY: November 5th, I believe, is when I took it to Schumacher's, right? Is this --

MR. TUCK: Coral Cadillac.

MR. KODSY: Coral Cadillac did a lot of work to it. They replaced the brakes.

MR. TUCK: We're still staying with the rough engine.

MR. KODSY: Okay.

MR. TUCK: They attributed it to an exhaust vibration.

MR. KODSY: Right.

MR. TUCK: And they realigned the exhaust system.

MS. SIMMONS: Was it taken in for the number one and two complaint, for the rough idle at driving?

MR. TUCK: That's what it looks like. Customer states, "Engine runs rough."

What kind of tires do you have on the vehicle?

MR. KODSY: I have BF Goodrich tires which are supposed to be the best tires out there. $400 a piece.

MR. TUCK: Are they off-road?

MR. KODSY: No, they're not off-road.

MR. TUCK: Are they knobby?

MR. KODSY: I wouldn't say knobby, they've got some meat to them.

MR. TUCK: Rough tread?

MR. KODSY: It's not rough tread. This is my second Hummer. My first Hummer had the same wheels and tires and it didn't have this problem.

MR. TUCK: So after the 12th, was the problem resolved?

MR. KODSY: No.

MR. TUCK: When was the next time that you brought it back for the rough engine?

MR. KODSY: I believe I took it over to Schumacher at that point because I wasn't able to get Coral Cadillac to properly address my concerns with the vibration.

MR. TUCK: Well, I see Coral Cadillac

again here on November 12th. Customer states, "Engine has constant vibration."

MR. KODSY: Okay. There were several attempts to get this resolved.

MR. TUCK: It says down below after above repair, "Still had some vibrations, steering wheel and seat compared with light vehicle, had same vibration."

MR. KODSY: Right. That was not -- there was no other vehicle produced to me to show me that this is actually the way it is. I know better. I had another vehicle prior to that that was exactly the same, that's not normal for that vehicle to do that.

MR. TUCK: Same engine and transmission?

MR. KODSY: Same engine and transmission. It was six months earlier, same year that I had the other one.

MR. TUCK: The way we look at these things is at your particular vehicle that's the subject of the hearing. We can't consider what other similar cars do.

MR. KODSY: Right, exactly. It was a 6.2 engine, Hummer H2.

MR. TUCK: So this indicates that there is still some vibration?

MR. KODSY: Right.

MS. SIMMONS: This meaning the November 12th repair order?

MR. TUCK: Yes.

MR.. KODSY: So then I took it to Schumacher. Do you see that?

MR. TUCK: Let's see. Here it is. This is December 1st through December 3rd. It's our number 23. This only refers to the road, not the engine vibration.

MR. KODSY: I have one here, it's dated December 5th, invoice date.

MR. TUCK: There is another one at circle 25..

MS. SIMMONS: So we're not considering 12-1?

MR. TUCK: That one is not for this complaint.

MR. KODSY: There's one of 12-5 and one of 12-8.

MR. TUCK: So we're at the one of 12-5.

MR. KODSY: It says --

MR. TUCK: It says, "There is an engine

vibration felt through the truck -- at idle there is a vibration." Is this the one that you're attributing to the engine or the one you're attributing to driving conditions on the road?

MR. KODSY: That's the engine.

MR. TUCK: This is the engine here?

MR. KODSY: At idle.

MR. TUCK: Okay. What was done there?

MR. KODSY: It goes down at the bottom -- well, what he did was he replaced three new tires on that truck.

MR. TUCK: Not on this occasion.

MR. KODSY: Not this one, the next one?

MR. TUCK: Yes.

MR. KODSY: It doesn't look like he did anything. He said there is still a hop as driving --

MR. TUCK: We're not talking about the hop, we're still on the engine vibration, the idle vibration.

MR. KODSY: I don't think he did anything about that. I have to go back to that.

MS. SIMMONS: You can testify later on.

MR. KODSY: That was an inspection, bulleted. I don't think he repaired anything for that instance.

MR. TUCK: So did you take it in again?

MR. KODSY: I took it back on the 8th.

MS. SIMMONS: December?

MR. KODSY: That's when I believe he did the tires.

MR. WOLFER: Of what month?

MR. KODSY: December.

MR. TUCK: We don't have a repair order for that. We have one for December 5th.

MR. KODSY: Let me make sure.

MR. WOLFER: December 1st is the tire -- we're trying to handle the vibration from the engine.

MR. KODSY: December 1st, yes, that's the one he replaced the tires on.

MR. TUCK: So that doesn't have anything to do with the rough engine idle?

MR. KODSY: This one is for the hopping.

MR. TUCK: We didn't get there yet. We'll come back to that.

MR. KODSY: It says road-tested tire

vibration.

MR. TUCK: No, we're looking for engine vibration.

MR. WOLFER: Go to December 22nd, Complaint's C. Customer states, "Engine idle rough."

MR. KODSY: And he did something else for it. He inspected and regapped the spark plugs on that vehicle to make sure that that's not the problem. He found no problem there.

MR. WOLFER: It doesn't state that.

MR. TUCK: It just says, "Engine exhibits normal idle quality for 6.2 liter." Not on this repair, at least it's not listed.

MR. KODSY: Well, he did check the gap on that. He did regap the spark plugs.

MR. TUCK: That was the last time that you brought it to anybody?

MR. KODSY: To Schumacher, yes.

MR. TUCK: For that complaint, okay. Let's go back and go over the next one. "Rough vibration during driving." Is that related to the hopping?

MR. KODSY: Yes, that would cause the hopping.

MR. TUCK: And the bouncing?

MR. KODSY: And the bouncing.

MR. TUCK: When did you first notice that?

MR. KODSY: I noticed that prior, sooner to the mass air flow sensor going out, but I didn't think nothing of it. I figured well, the truck is new, it's stiff, it's going to loosen up as I drive it. I did drive it and there was no change.

MR. TUCK: Did it get any worse?

MR. KODSY: It's a little worse because you have a higher RPM in the vehicle. After the air flow sensor was replaced, it wasn't completely tuned to where it's supposed to be, so I was getting more activity out of the truck that wasn't present before.

MR. TUCK: So the next time you brought in for the driving complaints or concerns was --

MS. SIMMONS: Did this hopping issue get addressed?

MR. TUCK: I'm looking for the next

repair order, hoping the consumer can point it out to me.

MR. KODSY: For which --

MR. TUCK: For the complaint, the noise vibrations while driving.

MR. KODSY: There's a couple of these work orders that actually address two or three items.

MR. TUCK: Right, I want to go back and find those starting from the beginning.

MR. KODSY: The beginning would be -- well, the mass air flow sensor was one.

MR. TUCK: Right. When did you first bring it in after that?

MR. KODSY: Once I --

MR. TUCK: The driving concerns, the hopping or the road vibration.

MR. KODSY: Right. That was within -- actually that was within a week because I was without my truck for so long I just had to do what I had to do. I believe it's this one here. Is it November 12th?

MR. TUCK: We have one that begins November 5th and ends November 12th.

MR. KODSY: Okay, that might be one.

MR. TUCK: Where on there does it complain about -- here it is. Customer states, "Transmission won't shift." That's not it. We'll get to that one. "Engine runs rough", we did that before where they installed the new exhaust. So I don't see anything here about driving concerns.

MR. KODSY: The driving concerns were pretty much being addressed with the actual vibrations and the high idle because that was as a result of the high idle and vibration of the vehicle. The vehicle is more tentative to any road conditions.

MR. TUCK: Here is the next one that I see, that would be December 1st of 2008. "Tire vibration, 45 miles per hour and up." That's where they replace the tires. That's our number 23.

When they replaced the tires, did they put the same type of tires on or a different type?

MR. KODSY: Same exact tires.

MR. TUCK: Did it make any difference?

MR. KODSY: It did not. They actually left me with one semi-used tire and three brand new tires on the vehicle, which was not acceptable, but I had nothing to say about that at the time. That's the way they let me go.

MR. TUCK: Then it says they did a force test on the tires. You said that when you drove it out there was no difference?

MR. KODSY: No difference. The service rep indicated that there was no improvement as well to that after he replaced the tires.

MR. TUCK: Then we have December 5th, which is 25. It's still a hop driving over 25. They say they put on new tires, there's no current for this item. It sounds like they're pretty saying --

MR. KODSY: This is all you get.

MR. TUCK: Operating to specifications at this time. That's on December 22nd.

MR. KODSY: But it was severe enough to replace tires.

MR. TUCK: Where it says customer states, "Engine runs rough, road-tested for six miles, exhibits normal idle quality for a 6.2 liter engine." I guess at that point you threw up your hands and said you're coming here.

MR. KODSY: Yeah, there was one more -- I don't think I have it in this file. There was the one with the spark plugs. It looks like it's not in here. Just for the record, I will state that they did, in fact, check my spark plugs physically.

MR. TUCK: Did they find anything wrong with them?

MR. KODSY: They didn't find anything wrong with them.

MR. TUCK: Let's go now to the transmission. It says, "Transmission kicks when shifting." When did you first feel that?

MR. KODSY: When I bought it that, believe it or not, is somewhat of a characteristic of that vehicle which was not perfected by the manufacturer. I wasn't making that my major complaint here. However, that tranny does slip at various speeds. The service maintenance manager indicated that there is an update for the transmission and they should help. It did help, but it was still present.

MR. TUCK: Is it a warming shift or it's just that you're aware of it -- how would you characterize it?

MR. KODSY: It's very weird because there is no other vehicle like it. You're driving down the road, you take your foot off the gas, and you go to accelerate again and the vehicle doesn't know which gear you're in until it actually slams into gear.

MR. TUCK: It has to rev up a little bit?

MR. KODSY: Yes.

MR. TUCK: I don't want to put words in your mouth.

MR. KODSY: Well, it spins before it connects to the gear. That's why you get a little kick.

MR. TUCK: How many times did you bring it in for that concern?

MR. KODSY: I was more concerned about the vibrations.

MR. TUCK: Here it is, we have November 5th. That's our number 14. Transmission control module.

MR. KODSY: That's abnormal for a

control module to be needed on a new vehicle with 5,000 miles.

MR. TUCK: At this point you had 6500.

MR. KODSY: 6500 miles.

MR. TUCK: Did this make any difference that you noticed?

MR. KODSY: It depends on how -- I got used to driving a vehicle like that, but it did make a little bit of a difference, but it was still slipping.

MR. TUCK: Did you bring it in again for that?

MR. KODSY: No, because we talked about it and I can of agreed with them that my other Hummer did the same thing so.

MR. TUCK: Then the last is squealing brakes. How many times did you get it for squealing brakes?

MR. KODSY: A couple of times, two times. He actually replaced the brakes.

MR. TUCK: Did that solve the squealing?

MR. KODSY: No.

MR. TUCK: It still squeals?

MR. KODSY: It still squeals.

MR. TUCK: All the time?

MR. KODSY: Well, when it gets hot -- I drive the vehicle 100 miles plus a day and sometimes 200 or 300 miles a day. When that vehicle gets hot, it squeals. It's very embarrassing, driving down the road and just stopping at the light, you know.

MR. TUCK: Does it affect your stopping or anything, the steering?

MR. KODSY: No, but it's just very uncomfortable.

MR. TUCK: Can you hear it with your windows rolled up?

MR. KODSY: Yes.

MR. TUCK: You can?

MR. KODSY: Yes.

MR. TUCK: With the radio on?

MR. KODSY: That's the thing I did, I kept the radio up.

MR. TUCK: And that worked?

MR. KODSY: Not so much. It covered the noise, but the vibration was present, so you still get that tired feeling coming out of that truck.

MS. SIMMONS: I need dates, Mr. Tuck,

for these brakes and things. The consumer put down that he brought it in for the brakes issue on October 20th, 2008.

MR.. WOLFER: No, 11-5 is there.

MR. TUCK: 11-5, that's our number 13.

MR. KODSY: They did two things for the brakes. They cut the rotors first.

MR. TUCK: When was that?

MR. KODSY: That was on the first visit.

MS. SIMMONS: What date are you considering the first visit?

MR. TUCK: The first visit would be November 5th?

MR. KODSY: Or 10-20, wasn't it?

MS. SIMMONS: That's what I'm trying to figure out. Why did you put down 10-20 when I don't see it that day?

MR. KODSY: I don't think he wrote it down on this, but he did cut the brakes. Maybe we can ask him on cross-examination as well as to what he did that day for the brakes.

MR. WOLFER: There is nothing on 10-20 to indicate anything about the brakes.

MR. TUCK: Anything else you want to add?

MR. KODSY: I did have some independent repair shops look at my truck as well. After all these repairs were done and the manufacturer or rather the dealer service techs over there letting me know that this is normal, there's nothing wrong with the vehicle. I have to take it somewhere else because obviously it's my credibility here that's the issue. I took it to Progressive where she was able to document the vibration and I took it to a couple other service shops. One was the Texaco service shop and --

MS. SIMMONS: Page 44 on the consumer side, there is an invoice is what I see from Texaco?

MR. KODSY: Yes. Basically he didn't want to get involved, but he did state it's a new vehicle, it's still under warranty, take it back to the dealer. That's basically all he documented, take it back to the dealer for more warranty work.

MR. TUCK: Has the car been in an

accident?

MR. KODSY: No, not by me, but it may have been prior to purchasing it. I suspect a couple of problems with that vehicle, major undercarriage rust. The vehicle just feels like it was in an accident.

MR. TUCK: Was there a reference in the documents here somewhere?

MS. SIMMONS: There's a medical report of --

MR. TUCK: That indicates a side impact.

MR. KODSY: That was prior to this purchase. That was one of my other issues is I was during recovery when I bought this truck from a prior accident.

MS. SIMMONS: So it was a different 2008 Hummer?

MR. KODSY: Yes, it was a different 2008 Hummer.

MR. TUCK: This vehicle, to your knowledge, has never been in an accident?

MR. KODSY: No.

MR. TUCK: Mr. Fernandez?

MR. FERNANDEZ: Yes. Good afternoon,

Mr. Kodsy. I'm a little unclear now because now the Better Business Bureau letter says that because an accident was alleged, that's why they couldn't hear the case.

Are you saying that you were never in an accident in this vehicle?

MR. KODSY: Correct. The Better Business Bureau misunderstood what I said; however, they went ahead and further documented the fact that just because you're complaining of any discomforts, physical discomforts, that they cannot arbitrate.

MR. FERNANDEZ: Thank you. So you just clarified that point here. There was never an accident in your vehicle?

MR. KODSY: There was never an accident in my vehicle. I was recovering from another --

MR. FERNANDEZ: Unrelated.

MR. KODSY: -- unrelated to this one and going through all of these back and forth repairs on the new truck.

MR. TUCK: If we were to test drive that vehicle today, of all of these complaints, what might we find?

MR. KODSY: You're going to find, obviously if you drive it long enough, you're going to find the squealing brakes. You're going to find the missing tranny shifting. You're going to find the miss that there is on idle. You're going to find this vehicle to be not a smooth vehicle on the road.

MR. TUCK: At what speeds do we have to drive at to see these things?

MR. KODSY: 45 miles.

MR. TUCK: That should be sufficient?

MR. KODSY: Yes.

MR. TUCK: We don't have to get it up over 70 or anything like that?

MR. KODSY: The thing is long driving of this vehicle, let's say for a half hour or hour of driving this vehicle on the highway with high RPM's and you've got this vibration, you will feel very tired.

MR. WOLFER: If we took the car out, we would have to drive it for half an hour to an hour to feel this problem?

MR. KODSY: No, you will feel it right away. It gets worse as you drive for a longer period of time because once that engine starts getting hot -- it was referenced from some other people that I spoke to that it may be carbon deposits in the engine to where it's running like that.

You will notice the miss and the vibration right where it sits.

MS. SIMMONS: When you say miss, is that the transmission?

MR. TUCK: No, that's the engine. When the engine misses, it would be --

MR. KODSY: Right.

MS. SIMMONS: That's characterized here as what?

MR. KODSY: Rough engine idle.

MR. TUCK: Anything you want to add?

MR. KODSY: No.

MR. TUCK: Okay. Questions. I will note, without rushing anybody, that it's ten minutes to three. To the extent that we can move things along without putting anybody at risk of not making their case, I would like to try to move along as best as we can.

MR. LOPEZ: Good afternoon, Mr. Kodsy.

MR. KODSY: Good afternoon.

MR. LOPEZ: Let's go to the first item, the rough idle. You state that, as of today, the Board will find a rough idle in the vehicle that is not acceptable to you?

MR. KODSY: Correct.

MR. LOPEZ: You were present at the inspection we performed at Schumacher with the persons present here, Mr. Thornton and Mr. --

MR. KODSY: I believe that was your request, yes.

MR. LOPEZ: You advised us at that time that the vehicle is not being driven, it's being stored in a rental place, correct?

MR. KODSY: Two vehicles not being driven for the last 5,000 miles that I put on the rental.

MR. TUCK: Why is that?

MR. KODSY: I'm tired of driving that truck. It's just giving me migraines. I have many medical issues, I don't need to be driving a truck that's just (makes noise) down the road, making me ill. We went through several steps with the repairs and nothing solved it. I started this process and I parked the truck.

MR. TUCK: What did you observe at the prehearing inspection? What did you see happen when these gentlemen went over and looked at the truck?

MR. KODSY: Exactly what I'm complaining about. They didn't want to comment on it at the time.

MR. TUCK: So nothing was said about it to you?

MR. KODSY: No, no. They don't want to admit to the problem.

MR. LOPEZ: You refused to do the inspection the first time we asked. Was there any particular reason?

MR. KODSY: Sure.

MR. LOPEZ: Can you explain more?

MR. KODSY: I will explain, yes. There was already a request to produce my vehicle prior to Mr. Gonzalez's involvement with this case. I was in the position to deliver the vehicle to Schumacher where they had a representative from there who claimed to be an engineer.

MR. TUCK: Is that what's characterized

as the final repair attempt?

MR. KODSY: Right, that's what I thought it was.

MR. TUCK: All right.

MR. KODSY: No, no. It was after that. It was the final repair attempt but after that.

MR. TUCK: What was the date of the final repair attempt?

MR. KODSY: The 22nd, I think.

MR. TUCK: That was the final repair attempt, the 22nd?

MR. KODSY: Right. So two weeks later -- I will tell you exactly when it was. It was before I filed this motion.

MR. TUCK: I don't know that we need to get too far into that subject to the Board's approval. You ultimately consented to that inspection?

MR. KODSY: Another inspection after the final inspection.

MR. TUCK: Okay.

MR. KODSY: So when Mr. Gonzalez says one, we need to do a prehearing inspection, so you already got your's.

MR. TUCK: Okay. We can move on.
MR. LOPEZ: You state that the Board asked you if your vehicle has off-road tires. Does your vehicle have off-road tires?
MR. KODSY: Excuse me?
MR. LOPEZ: Does your vehicle have off-road tires?
MR. KODSY: They don't look like off-road tires to me. They look like regular Hummer tires.
MR. LOPEZ: Hummer tires. Is this the adventure-type vehicle?
MR. KODSY: Is the adventure-type vehicle?
MR. LOPEZ: What type of engine does this vehicle have?
MR. KODSY: Engine?
MR. LOPEZ: Yes, engine.
MR. KODSY: 6.2 liter.
MR. LOPEZ: Do you know how much horsepower that vehicle has?
MR. KODSY: 393 horsepower or something like that.
MR. LOPEZ: Regarding the transmission,

how many shifting speeds does the transmission have, one, two, three, four, one, two, three, four, and five?

MR. KODSY: It's a six-speed.

MR. LOPEZ: Okay.

MR. TUCK: How many cylinders is it?

MR. KODSY: Eight.

MR. LOPEZ: This vehicle has the special equipment to climb, correct?

MR. KODSY: All Hummers do.

MR. LOPEZ: This particular one with the adventure package?

MR. KODSY: They all have the same --

MR. TUCK: Should we take that as a yes?

MR. KODSY: Yes.

MR. LOPEZ: You had advised that you drive the vehicle, but also it was being stored. Are you aware that rust can get into the rotors?

MR. KODSY: From what, from parking it for a month?

MR. LOPEZ: Yes. Are you aware of that?

MR. KODSY: Not really.

MR. LOPEZ: Okay. You said that the BBB misunderstood what you said on your complaint. But we got two letters, one, the letter of December 15th of 2008 states that you have agreed to have the vehicle be checked by the dealer under the terms of the warranty and that they ask you to file the motor vehicle defect notice at that time; is that correct?

MR. KODSY: I believe I've been following the steps as I was advised.

MR. LOPEZ: So the motor vehicle defect notice was filed just after the BBB told you about that, correct?

MR. KODSY: Yes.

MR. LOPEZ: Then there is a letter from the BBB advising that you have some issues because you had a previous accident that advised us on another 2008 Hummer that was turned to its side by another vehicle, correct?

MR. KODSY: Incorrect. I never gave them details. I told them that I'm recovering from a car accident, I don't need to be driving this truck like that, it's very uncomfortable. They said --

MR. FERNANDEZ: Excuse me. Mr. Lopez, what is the relevance of -- the witness has already stated that --

MR. LOPEZ: I was just trying to clarify.

MR. FERNANDEZ: He said that it has absolutely nothing to do with this vehicle, he was never involved in an accident with this vehicle.

MR. LOPEZ: Okay. You stated to the Board now that in order to feel the rough idle or the condition that you mentioned, that we have to drive the vehicle above 45. However, at the inspection we had, you advised that we didn't have to drive the vehicle. Could you explain more on that?

MR. TUCK: If I understood his testimony that he stated earlier, the shaking of the engine and the miss in the engine we could see at rest in the parking lot.

MR. LOPEZ: Thank you very much. That's it.

MR. TUCK: Do you want to call a

witness?

MR. LOPEZ: Yes, I would like to have Mr. Thomas Thornton.

MR. THORNTON: Yes.

MR. LOPEZ: Mr. Thornton, who do you work for?

MR. THORNTON: I work for General Motors. I'm the district service manager for geography, we cover Broward County and Delray Beach.

MR. LOPEZ: Briefly could you tell me more information of this case, your personal knowledge of this case?

MR. THORNTON: My personal knowledge of this case has mostly been through working with the dealership, Joe Bardill at Coral Cadillac. Relative to the case, my first meeting with Mr. Kodsy was the other day at Schumacher.

MR. LOPEZ: It was at the prehearing inspection?

MR. THORNTON: Yes.

MR. LOPEZ: Did you drive the vehicle?

MR. THORNTON: I was a passenger in the vehicle.

MR. LOPEZ: Did you feel anything abnormal, any rough idle that Mr. Kodsy considers abnormal?

MR. THORNTON: No, everything felt completely normal to me.

MR. LOPEZ: Did he state something to the effect that it doesn't drive like a luxury vehicle or something like that?

MR. THORNTON: He did make statements to that effect. Words to the effect of his expectations that it was a luxury vehicle and should drive differently.

MR. LOPEZ: Okay. How do you consider, based on your experience of working with GM vehicles as a district service manager, do you consider this vehicle acceptable or not?

MR. THORNTON: Yes, and just a quick note on my experience working specifically with Hummers, I have been involved with the Hummer brand since 2005. I have driven several Hummers of virtually every configuration.. This vehicle drove absolutely normal and was acceptable to me. I thought the vehicle was in great condition and the number of miles on the odometer seemed to me as an as new vehicle.

MR. TUCK: At anytime during your examination of the vehicle, did the consumer point out to you his concerns like there it is or do you feel that or do you hear that or see that?

MR. THORNTON: Yes, sir, he did.

MR. TUCK: Did you see what he was talking about?

MR. THORNTON: When he pointed out what he was observing, I understood what he was observing, but it is my opinion that those things he was observing are normal characteristics of this type of vehicle.

MR. TUCK: Was there anything radical or extreme or noticeable about the things that he was pointing at?

MR. THORNTON: No, sir.

MR. TUCK: Anything that would be inconsistent with the car as the miles were out on? In other words, does it deteriorate under 30,000 miles?

MR. THORNTON: I think I understand what you're asking. If I may clarify, you're asking did the things that we observed on the vehicle, were they abnormal for the number of miles on the car?

MR. TUCK: Right.

MR. THORNTON: No, it seemed absolutely normal to me. In fact, as I kind of eluded to earlier, you could have told me that it was a brand new truck on the lot and other than the number of miles on the odometer indicating otherwise, the truck acted as new.

MR. TUCK: Did you have any questions?

MR. FERNANDEZ: Just very briefly. Good afternoon, Mr. Thornton. Bernard Fernandez. Those points that Mr. Kodsy brought your attention, he's experienced in driving a Hummer, he's had one before. I've never been in a Hummer in my life. For example, we may have the opportunity later to inspect the vehicle, but would I as someone who has never been in a Hummer, notice what the consumer was pointing out saying hey, what's going on here, this thing is coming apart?

MR. THORNTON: You would probably notice a different ride quality than what you're accustomed to if you've never driven a heavy-duty off-road vehicle. The Hummer brand is targeted towards the outdoor enthusiasts, it's an off-road vehicle. It's obviously a street legal vehicle. It's a very heavy, very large, very powerful, very capable truck. The tires on the vehicle are BF Goodrich All Terrain T/A's. They are very heavy, large, aggressive tread pattern tires intended as the name suggests for all terrain. BF Goodrich also makes specific off-road tires for off-road use only.

They have several other names of tires that are offered for the light duty truck market. The BF Goodrich all terrain tires that are on this truck are designed for aggressive off-road use. Again, they are street legal. That specific to the tires and for the ride quality, the tires in it of themselves being heavy tires, are going to give a stiffer ride. They are going to be louder. You will probably feel them as you drive.

As far as the suspension is concerned as well, bear in mind that the adventure package on this truck is intended to appeal to outdoor enthusiasts, people who are off-road enthusiasts, and the truck is designed to handle hard off-road driving. It is designed for that.

If your driving experience has been limited to sedans, for example, this thing is going to drive like a beast. It is a beast. It is a heavy duty vehicle.

MR. TUCK: Would that mean that it would have a much stiffer suspension and ride?

MR. THORNTON: Yes, sir.

MR. WOLFER: The consumer made mention, as far as the engine goes, it seems to rev higher. Is this characteristic of -- normally the RPM's of a vehicle are 700, 750. Is the V8 going to be higher revving because it's more compression and you need to keep it from stalling?

MR. THORNTON: In my observation of the vehicle, this particular vehicle, it was consistent with other vehicles of its kind. I did not look at the tachometer to see what the idle speed was. However, I would say that it seemed to me to be in a normal range in just listening to it. It's typically 600 to 850 RPM's at idle.

Now, it's also a normal thing for many engines to rev higher during, for example, the air-conditioner compressor cycling is one example of a vehicle that might cause the engine RPM to change at idle. I do not recall if his air-conditioner was turned on at the time that we observed his truck.

There's also other things that can occur at idle with the engine that can give the perception of an RPM change. For example, an electric cooling fan may come on or it may turn off to keep the engine temperature regulated. Those things can be perceived by an external listener as a change in engine RPM. I do want to clarify that what I observed was absolutely normal.

MR. WOLFER: Is the compressor a cycling compressor, when the evaporated temperature gets low and it cycles?

MR. THORNTON: Yes.

MR. WOLFER: So it has a fixed expansion to it?

MR. THORNTON: I'm not certain about that.

MR. TUCK: Any further questions?

MR. LOPEZ: Not by me.

MR. TUCK: Do you have any questions of this witness?

MR. KODSY: I have one question.

The 2009 H2 now by the manufacturer does not have the BF Goodrich tires; is that correct?

MR. TUCK: I will remind you that we can only consider this tire so what they do with other models, if it's not this one --

MR. KODSY: My point was is that they discontinued those tires on that truck for having many complaints.

MR. TUCK: Do you want to call any other witnesses?

MR. LOPEZ: Yes, I'm going to call Mr. Joe Bardill.

MR. TUCK: Sure.

MR. LOPEZ: Mr. Bardill, based on the time frame and I'm going to make it quick. I know we have gone through all the repair orders. Could you give us a synopsis of what you have experienced in the case of Mr. Kodsy?

MR. BARDILL: I basically -- Sherif protested with Mike Stammet (phonetic), the service advisor, on the second repair order and the second trip in on the -- that would be on the November 5th repair order. He was complaining about roughness in the idle, vibration at all speeds, 45 and also highway speed, and the brakes squeal. I did duplicate with him the brakes squeal. I felt -- Sherif kept referring to it as an engine missing. I kept telling him it's not an engine miss. It's just like possibly the engine is not isolated enough from the vehicle or a firing frequency exciting the steering wheel a little bit, a little tingle on the steering wheel. But keep in mind, this was the first '08 Hummer that I had driven and I wasn't thinking about the fact that it has a 6.2 liter in it. The 6.0 liter had a much better idle quality than the 6.2. It also had 20 percent less horsepower. So there was a trade off to get the horsepower, you had a little bit of a rougher idle. Once realizing that we had the same idle quality in the 6.2 liter in the Escalade, the Escalade idles exactly the same way. Feeling that, going up on the highway, I said that I didn't feel any kind of abnormal vibration at all. I did feel the transmission. It had an extreme flare on a down shift and I believe we put a valve body in at that time.

MR. TUCK: Did that solve the problem?

MR. BARDILL: That solved the problem, but we did have to come back and do the reprogram because when they did the valve body, they didn't put the updated program in.

MR. TUCK: Did that resolve the problem?

MR. BARDILL: Yes.

MR. WOLFER: I'm sorry. What is a flare?

MR. BARDILL: Basically the engine flared up, the transmission didn't down shift. It was in a down shift type of --

MR. WOLFER: So the RPM's went up?

MR. BARDILL: The RPM's went up, yes.

So we addressed the idle quality at that time, basically trying to isolate the firing frequency from getting in the vehicle, we put a weight on a weight on the exhaust system. It's basically like putting your finger on a guitar string to deaden the sound from a guitar string. It made some improvement.. We had some buzzing coming through the IPC. We relocated the line, but it still had that little vibration in the steering wheel.

There was another '08. I went to my shop foreman and I said, "I still feel something here, Brian, feel it." He says, "There is an '08 right next to it." So we sat in that '08 and it had exactly the same vibration.

MS. SIMMONS: This was on the 11-5 repair date?

MR. BARDILL: This is on 11-5. You have 11-5 to 11-12. He left and came back the same day. So it's actually on the 11-12 repair order. I'm sorry, the weight was done on 11-5. Then on 11-12 is where we compared it to another vehicle. So we have two things going on at the same time, but two different repair orders.

At that time, I contacted Bob Martin, the quality manager for H2, and I spoke to him about it because I still wasn't -- it still hadn't hit me about the 6.2 versus the 6.0 liter. He has isolate the engine, disconnect the transmission from the engine and see if we still had the vibration which we did. That was pretty much it. We did that and still had the vibration. Then we compared it with another car and the other car had the same vibration. I called Bob back and that's when he said, "Joe, we've got a 6.2 liter in here and there is a trade off." As soon as he said that, I felt stupid, I felt like I wasted a lot of time. It's the exact same idle quality as in the Escalade, it's the same engine that's in the Escalade and I just never thought about it because it was the first '08 that I was involved with.

MR. LOPEZ: How much is the horsepower?

MR. BARDILL: 393 horsepower, which is 20 percent more than what we had in the six liter.

MR. TUCK: Any other questions?

MR. LOPEZ: No more questions.

MR. TUCK: Do you have any questions of this witness?

MR. KODSY: Just one to confirm what Joe what has said. You did isolate the starter as per Bob Martin and the fly wheel bolts and restart the engine to isolate vibration, still has vibration with fly wheel disconnected?

MR. BARDILL: Correct.

MR. KODSY: Okay. I just wanted to confirm that.

MR. WOLFER: Can I just ask one question? The repair order dated December 23rd, it says, "Vehicle exhibits some rail snake characteristics." What is that?

MR. BARDILL: Rail shake.

MR. WOLFER: I'm sorry, rail shake.

MR. BARDILL: Rail shake is terminology that we use for the pick-up trucks and just about any of the SUV's, about 45 miles an hour down typical roads like Federal Highway, you get a little bit of vibration in the seat from the chassis. It's pretty much in every truck. There's nothing that can be done for that.

MR. WOLFER: Okay.

MR. TUCK: Any further witnesses?

MR. FERNANDEZ: I just have one quick follow up question also. On your December 5th invoice, where at idle there is still vibration felt throughout the truck.

MR. BARDILL: Which one was that?

MR. TUCK: Schumacher.

MR. FERNANDEZ: Okay. Did you know about that?

MR. BARDILL: No. What does it say?

MR. FERNANDEZ: Schumacher. I'm reading here, "There is still a hope at driving over 25 miles."

MR. BARDILL: That's the customer's complaint.

MR. FERNANDEZ: Still a hope?

MS. SIMMONS: Hop.

MR. TUCK: Hop.

MR. FERNANDEZ: Oh, okay. I got hope. Okay. Thank you.

MR. TUCK: Are you going to testify to

anything?

MR. LOPEZ: Basically it would be what I have said so I am not --

MR. TUCK: If we've heard it, then we've heard it. Do you have anything further before we close out the evidence?

MR. KODSY: I may have one more question.

MR. TUCK: Okay.

MR. KODSY: On the last documentation that we received today in regards to this witness list, we have one rep which is Robert from Schumacher was listed as a witness. He is not present today while we do have invoices here reflecting work that was done by that dealership. Is there any reason for that?

MR. LOPEZ: He told me he couldn't be here today. I cannot --

MR. KODSY: Because he could have clarified a couple of things.

MR. TUCK: Do you have any further documentary evidence or testimony?

MR. KODSY: I have one more recent inspection done by Palm Beach Garage, which is right here.

MR. TUCK: Is that already in your documentation that we have received?

MR. KODSY: It should be. It basically states, I told him --

MS. SIMMONS: Mr. Kodsy, can you hold on a second while we find that invoice?

MR. KODSY: Sure.

MS. SIMMONS: I believe I did see it in the file.

MR. LOPEZ: Give me date.

MS. SIMMONS: 2-10-09, Palm Beach Garage.

MR. LOPEZ: I've got it, yes.

MR. KODSY: Basically I requested from Mr. Proper (phonetic), which is the owner of the garage, check the vehicle, I have a vibration, and the engine idle is rough. His conclusion was, after test driving the vehicle, which is short and not trying to be involved in this matter at all, he stated, "Exhaust vibration felt throughout the car."

MR. TUCK: Was that before or after?

MR. KODSY: No, this is on 2-20-09. So this was two weeks ago.

MR. TUCK: After all the treatments were done, okay.

MR. KODSY: Exactly.

MR. TUCK: Any questions regarding that?

MR. LOPEZ: No. Unfortunately, we don't have the person here to cross-examine him.

MS. SIMMONS: Was that 2-20?

MR. KODSY: Yes.

MR. TUCK: All right. We have to decide whether to inspect or test drive the vehicle. If I understood the testimony correctly, we don't need to drive it to see that it's shaking. So I think at the very least we should go out and see if and how much it shakes.

Does anybody think we need to drive it?

MR. KODSY: I would recommend driving it, get the feel of it.

MR. TUCK: We've also talked about the tires. So I think at the very least drive it around the road, he says at 20 or 25 miles we'll hear it.

MR. KODSY: You have to understand this

truck has been sitting --

MS. SIMMONS: Mr. Kodsy, one moment. This is an opportunity for the Board to take a vote on that issue.

MR. KODSY: Sorry.

MS. SIMMONS: So the vote is to test drive?

MR. TUCK: I think we need to test drive it briefly. If you agree that that would be sufficient?

MR. LOPEZ: I do.

MR. TUCK: Do you have proof of insurance here with you?

MR. KODSY: Of course..

MR. TUCK: May we see it?

MR. KODSY: Yes.

MR. TUCK: This is Progressive. I'm looking for a VIN number here. It looks like 5GRGN2 something 87811107653.

MS. SIMMONS: That's a different number than what's listed on the request for arbitration.

MR. KODSY: What's the date on that?

MR. WOLFER: This December of '08 through June '09.

MR. KODSY: That's the one.
MS. SIMMONS: The VIN number that I have is 5GRGN23878H107653.
MR. WOLFER: That's correct.
MS. SIMMONS: It's from Progressive?
MR. WOLFER: Yes, from December 27th, '08 through June 27th, '09.
MS. SIMMONS: Mr. Wolfer, could you read out the policy number please?
MR. WOLFER: 76759112-2.
MS. SIMMONS: Thank you.
MR. TUCK: All right. The way this works is the vehicle will hold five people?
MR. KODSY: Yes.
MR. TUCK: Who do you want to go from the manufacturer?
MR. THORNTON: I can go.
MR. TUCK: We're going to be off-the-record when we go out.
MR. KODSY: I just want to mention something if we're still on the record.
MR. TUCK: We are.
MR. KODSY: The longer you drive this vehicle -- obviously it's been sitting, it has not been driven for about a month.

We're going to drive it for half an hour, that's not going to do much.

MR. TUCK: We're only driving it for a few minutes.

MR. WOLFER: We're not driving it half an hour.

MR. KODSY: That's even less. But when you drive it for an hour or so, the mechanisms get hot and it gets rougher.

MS. SIMMONS: Mr. Tuck, do you want me to stop the record?

MR. TUCK: Yes. When we get back, we will discuss what we all saw. You can point out to us, did you see that, did you hear it, but we can't answer you. We'll talk about it when we get back.

(Thereupon, a brief recess was had to test drive the vehicle.)

MR. TUCK: It's 3:32. We're back from the test drive. The mileage in and out was --

MR. LOPEZ: 11,127, that was the mileage in and the mileage out was 11,138.

MR. TUCK: Do you want to start, Mr. Fernandez?

MR. FERNANDEZ: Sure. I participated in the drive. I heard the sound of the engine quite louder.. I heard the squeaking brakes intermittent, but more often than not. I don't know if my fellow Board members heard this, but at the end of the drive I was with Mr. Kodsy and we heard momentarily exactly from the rear end, knock, knock, knock, and then it stopped.

I believe, like Mr. Thornton said, it is a beast, a beautiful beast, but it is a beast nevertheless.

MS. SIMMONS: Mr. Fernandez, where were you seated?

MR. FERNANDEZ: I was seated in the right rear passenger.

MS. SIMMONS: Okay.

MR. WOLFER: I drove the vehicle. Before driving the vehicle, I walked around and I inspected all the tires. I really expected to see hot marks or bounce marks or flat spots on the tires because the consumer really complained that the vehicle hopped all along. I observed all four tires and the one tire that was not replaced looked almost similar to the other three tires. I didn't see any malformation of the tires in any way to indicate any kind of bouncing effect that would then make the tires look flat or anything like that. The tires are off-road type tires and are not smooth type of tires that would give you a nice, comfortable ride.

I got in and I started it up. It's a truck, so I don't expect to drive in that vehicle and feel comfortable. Vibration from the steering wheel, I didn't feel any or at most very, very slightly. Again, like I said, the vehicle looks pretty inside and all, but this is a massive type of a truck vehicle. Did I hear engine noise in the vehicle when I hard accelerated? Yes. But the way the vehicle is constructed, there is not super insulation and such to keep the noise from entering the cabin. I really watched the tachometer which at idle never got above 750. It was maybe, very slightly it might fluctuate a little bit, but I couldn't discern any kind of a miss like there was a hesitation where I would see the needle really drop off. Those were my observances of the vehicle.

MR. TUCK: I sat in the front passenger seat. We drove on local roads for the miles that we did go at speeds of up to 30, 35 miles an hour, mostly around 25 to 30, with frequent stops. The consumer asked us to within gear stop a few times and see if we felt anything different. I did notice that when you're stopped in gear, you feel a -- I would guess it is a surge in the motor, but light enough that would be like a mild vibration. I don't want to incorrectly state it. I think mild vibration when you stop with your foot on the brake. It is a big engine and you can hear it, but not to a point where I felt it was evasive. We didn't have the radio on. We did have the windows closed and the air-conditioner on.

MS. SIMMONS: The windows were up?

MR. TUCK: Closed, yes.

MS. SIMMONS: And the AC was on?

MR. TUCK: Yes.

MS. SIMMONS: How about the brakes that Mr. Fernandez talked about, did you hear any squeaking?

MR. TUCK: I heard a light squeak but it's nothing I haven't heard many times. We had testimony that the brake pads had been redone. So the only time I would be concerned about a squeak like the one I heard would be if it was constant and the brakes had been checked and the brakes might be worn, but these brakes were recently serviced.

MS. SIMMONS: The squeak that you heard, was it constant or just once in a while?

MR. TUCK: No, just very occasionally when putting your foot on the brake at slow speeds. On rapid deceleration I didn't hear it all. I had my hand on the steering wheel at times, on the dashboard, on the shifter level, and you could feel that the engine was running, but I felt nothing that would make me say oh, there is something wrong here.. As far as the miss, I didn't see it. I missed that if it happened.

MS. SIMMONS: Mr. Tuck, I just wanted to clarify. Did you experience the squeak that Mr. Fernandez was talking about during braking?

MR. TUCK: No.

MS. SIMMONS: I'm sorry, Mr. Wolfer?

MR. WOLFER: No, I didn't hear any noise --

MS. SIMMONS: Did you hear the brakes squeak?

MR. WOLFER: Not from the brakes squeak, I just didn't hear it at all.

MR. TUCK: The acceleration was definitely smooth and more than adequately powered. I didn't see any break up upon acceleration or any hesitation.

MS. SIMMONS: Thank you.

MR. TUCK: I'm going to ask the consumer what were your observations?

MR. KODSY: My observation is it's not as bad as it can be because the vehicle has been sitting. However, that particular vehicle as much as it looks like a beast, it is not supposed to drive like a beast. If you drive that truck the way it runs like now claiming it's a beast, then you can only drive it for a limited distance. If you go here to the store and back --

MR. TUCK: You'll have a chance to make a closing statement. What we're asking you now is what did you see and hear?

MR. KODSY: I felt the vibration.

MS. SIMMONS: Where were seated, Mr. Kodsy?

MR. KODSY: I was sitting behind the driver's side. I felt the hopping because every bump on the road, whether it was there or not, was being felt inside the truck as it bounced. That type of truck is not supposed to do that. I also felt the vibration in the idle where the truck is idling like a beast and it is not supposed to do that, not for $60,000.

The other thing was the gentleman over here stated that there was no tire wear. I just want to bring it up to your attention that those tires only have 3,000 miles on them. Basically they were replaced, because they had some unevenness to them, by Schumacher. The one low skip at idle when you're -- I felt it, too, it was light. It is light, but it is very annoying when you drive that truck all day and you stop and this and that. That's not normal for any vehicle to do that. That's basically it.

MR. TUCK: Manufacturer's observations?

MR. THORNTON: This is Tom Thornton with General Motors. I was seated in the second row middle. During the drive, I felt the vehicle drove exactly as it drove earlier in the week when we had the prehearing inspection. All characteristics of the vehicle worked as they were designed.

MR. TUCK: Thank you.

We come now to closing statements. Now is the time for you to put together what you want us to hear in five minutes or less.

MR. KODSY: Yes, of course. Thank you for your time for being here today.

Basically what I want to say is there were many, many repairs done to this truck. Whether it's better now or it isn't, this truck is no longer new to me. It's been abused by repairs. It's not acceptable.

MR. TUCK: Anything else?

MR. KODSY: That's it.

MR. TUCK: Thank you.

MR. LOPEZ: Mr. Lopez of General Motors. Very briefly. We believe that this truck is operating normally as designed. We have been able to corroborate the hearing inspection and tested by Mr. Joe Bardill, sorry. I'm bad with names, I'm sorry. We believe that this vehicle is working as designed and it should not be considered a lemon. The value, use, and safety is not compromised on this vehicle at all.

Again, we feel that he's in a situation -- we understand the situation that Mr. Kodsy is in, that he had an accident and he has damage to his cervical spine and it feels so bad, but this is a truck and this is how it rides. You cannot correct anything when there is no problem. Again, I would say it is the nature of the beast. Thank you very much.

MR. TUCK: Thank you.

We come now to the deliberation phase. As I said earlier, you're free to remain here while we speak, but you're not free to participate unless we have a particular questions for somebody. In keeping with Ms.

Simmons' preference for analytical thinking, we're going to go through the complaints in the order that they are here.

Rough idle, rough vibration at idle, and rough vibration during driving, hopping of vehicle and bouncing of vehicle. I think we can categorize those as one operational issue.

MS. SIMMONS: One through four?

MR. TUCK: Yes. What does the Board think, unless you want to split them up between engine idle and operation and driving? We can do that.

MR. WOLFER: Yes.

MR. TUCK: So we're going to start out with just the vibration in the engine.

MS. SIMMONS: That would be what, one and two?

MR. TUCK: That's number one. Two is vibration during driving.

MS. SIMMONS: So we're just dealing now with vibration?

MR. TUCK: Right. I know we talked earlier about consolidating the different ones, but as the testimony evolved, it became clear that there was one problem with the engine at idle and engine vibration and the other problem with vibration of the vehicle.

MS. SIMMONS: Which is two, three, and four?

MR. TUCK: Yes.

MS. SIMMONS: Thank you for clarifying that.

MR. TUCK: Vibration at idle. Why don't we start with our technician.

MR. WOLFER: Okay. Originally, there must have been some kind of problem because the mass air flow sensor failed and, of course, that would cause the engine to vibrate. I just find that -- I don't want to say this vehicle is a beast. The vehicle is a truck. In getting into this vehicle, I really felt that I was going to really feel a vibration, something really is going to knock my socks off. I found that this vehicle idles beautifully. If there was a problem with the idle, I feel that it's been repaired and there is absolutely no problem with the idle.

MS. SIMMONS: Before we move on from Mr. Wolfer, did you believe at the time originally when it existed, do you believe that was substantial to use, safety, or value?

MR. WOLFER: It would have to be for use because the vehicle wouldn't stay running, but it was corrected.

MS. SIMMONS: So you believe it was substantial but it was corrected?

MR. WOLFER: Correct.

MR. TUCK: At the time of the air mass --

MR. WOLFER: At the time that they changed the mass air flow sensor.

MS. SIMMONS: Thank you.

MR. TUCK: Mr. Fernandez?

MR. FERNANDEZ: I agree with my co-member. The rough idle, the rough vibration at idle, I did not feel it was substantial. I did not feel that it impacted the use, value, or safety.

MS. SIMMONS: You don't feel that it impacts it now or did you believe, like Mr. Wolfer, it was a substantial --

MR. FERNANDEZ: It was a substantial impairment of --

MR. TUCK: Of use?

MR. FERNANDEZ: Of use and value of the vehicle that no longer exists.

MS. SIMMONS: Do you also believe that it was repaired at the time that the mass air flow was replaced?

MR. FERNANDEZ: Yes.

MS. SIMMONS: Thank you. Mr. Tuck?

MR. TUCK: I concur also on all three issues.

MS. SIMMONS: Thank you.

MR. TUCK: Moving now to the vibration.

Two, three, and four. Mr. Wolfer?

MR. WOLFER: Yes. I think we can link all of these together on two, three, and four.

MS. SIMMONS: What would you call them as a tech because I need to name them something?

MR. WOLFER: I think driving vibration.

MS. SIMMONS: Okay.

MR. TUCK: Now it's difficult to sort out --

MR. WOLFER: Right. I inspected all four tires. In fact, the consumer even pointed out that the right rear tire was the one that was not replaced. So I paid particular attention to that making the assumption that there should be some kind of distortion of the tire, which I didn't find.

I drove the vehicle and I know that this is just part of the conditions. Evidently, there were some minor adjustments made, that being relocating a hose, which seemed to transmit some kind of vibration. Also, doing something to the exhaust system in order to stop some kind of a vibration that's coming through when the vehicle was being driven. I don't get the feeling that there is something there. I don't know if there was anything there. I don't know if the tires were replaced to placate the customer. I just don't know, but I get into this vehicle and I drive this vehicle. In my opinion, the vehicle drives nicely.

MR. TUCK: But would you say operating as designed?

MR. WOLFER: I would think it's

operating as designed because I would not get into a big vehicle like this and expect to have a cushioney drive as if I got into a Cadillac and drove that down the road. I mean, they're two entirely different vehicles. This vehicle is not made so that you don't feel a bump in the road, that it's supposed to be nice and smooth. It's just not.

MS. SIMMONS: But you realize not operating as designed doesn't necessarily mean it's not a lemon if that, in fact, it is a substantial non-conforming --

MR. WOLFER: Correct.

MR. TUCK: It could have a bad design.

MS. SIMMONS: Yes.

MR. WOLFER: No, no.

MS. SIMMONS: Do you feel that, not only based on your test drive, but based on your documents and testimony, do you feel as to this driving vibration that there is a non-conformity?

MR. WOLFER: No, I don't feel that there is any non-conformity for that.

MR. FERNANDEZ: As to points one, two,

three, and four, I also agree, I do not feel that they are not non-conformities. They're conformities. That's how the vehicle, in my opinion, is designed to operate.

MS. SIMMONS: Do you believe that the way that's designed, does it substantially affect its use, value, or safety?

MR. FERNANDEZ: No.

MS. SIMMONS: Mr. Tuck?

MR. TUCK: When we were driving down the street there, the consumer pointed out that you could feel the bumps on the road. He is absolutely right. When you over a bump you feel it, even the smaller bumps.

In looking at the aggressive tread of the tires and how large and hard they are and hearing the testimony earlier from the technicians that the truck was designed for both on and off-road use, it was designed to maintain contact with the road or the ground. So it wouldn't have this soft feel that you would expect in a car. I know the consumer felt that for that kind of money, you should have a softer drive. I would respectfully suggest for that kind of money it should have been test-driven before spending that kind of money. This is all you can expect in it. It's been that way since the very beginning and that's the way it was designed. From what I saw -- and I fully respect the consumer's opinion and his frankness in his testimony.

MR. KODSY: It's not an opinion, sir.

MR. TUCK: Well, his statement in his testimony.

MR. KODSY: I --

MR. TUCK: You're not permitted to interrupt, I'm sorry.

MR. KODSY: Yes.

MR. TUCK: What I saw here is the way the truck was supposed to be and it seems like it was doing just what it was supposed to be and it's not a non-conformity on those issues.

MS. SIMMONS: Do you believe that when it was doing what it was supposed to be doing that you don't -- do you believe that that was a substantial impairment in the safety, use, or value?

MR. TUCK: No.

MS. SIMMONS: So you don't find a non-conformity?

MR. TUCK: No, I don't.

The transmissions kicks.

MR. WOLFER: Yes. I find that at the time that would be a non-conformity. The dealer had opportunity to repair it. It took them two repair attempts. Evidently, the first time they changed the solenoid, but either they didn't have the software or they had it and they didn't put it in. The vehicle was subsequently brought back and the software was installed, which corrected the transmission shifting. In fact, when I went down the road I really accelerated hard on that and that transmission just kept right on going. I didn't feel any knock into another gear or anything like that, it just went. So I would say there was a non-conformity in the transmission.

MS. SIMMONS: For what, use, safety, or value?

MR. WOLFER: Use. I'll stick with use, but that the transmission has been repaired and there is no non-conformity at this time.

MS. SIMMONS: Was repaired when, Mr. Wolfer?

MR. WOLFER: The second repair -- I think the second repair was the 22nd. Is that when they put the software in?

MS. SIMMONS: The final repair?

MR. TUCK: No..

MS. SIMMONS: November 12th, page 18?

MR. WOLFER: No, that's when they tried to isolate the vibration and they took things apart. I know I saw a solenoid replaced. Anyone can jump in.

MR. BARDILL: November 5th is when they did a reprogramming.

MR. TUCK: On November 12th --

MR. WOLFER: The 5th through the 12th?

MR. TUCK: It's number 20.

MR. WOLFER: Right.

MS. SIMMONS: So you believe it was repaired on November 12th through November 21st repair?

MR. WOLFER: Yes.

MS. SIMMONS: Thank you, Mr. Wolfer.

Mr. Fernandez?

MR. FERNANDEZ: As to the transmission,

I do find that it's substantial as to both the use and value of the vehicle. I'm glad Mr. Wolfer was the driver and he gave that good summarization. I concur with his impressions that there was nothing there, just very smooth acceleration. I believe that the non-conformity was repaired on the November 12th.

MS. SIMMONS: Thank you. Mr. Tuck?

MR. TUCK: I certainly believe a transmission that's not functioning properly is a substantial non-conformity as to use, value, and safety, and that it was repaired by the November 12th through 21 repair invoice.

Which brings us to --

MS. SIMMONS: The squealing brakes.

MR. TUCK: Squealing brakes.

MR. WOLFER: Okay. I did not hear any noise from the brakes, but the manufacturer stated that and the consumer also told us that this car has been in storage for a while. The rotors can pick up a little bit of rust if the car has been in storage and it's damp down here. Possibly on our road test, my two colleagues did hear a slight squeak, but no squeal. I didn't hear any noise at all. At the time, if there is a brake noise I would say that that would arise to not only value but safety and use. If I heard the noises, I would be afraid, but the dealer addressed it and replaced the pads on 12-23. I believe that cured the squealing noise.

MS. SIMMONS: Just to clarify here. Do you believe prior to 12-23, was there a brake issue that was a substantial non-conformity to safety, use, or value?

MR. WOLFER: Yes, because previous they addressed the brake issue I think on October 10th through 20th. They also did some work on the brake pads at that time.

MS. SIMMONS: Okay.

MR. WOLFER: But yes --

MS. SIMMONS: All three, use, safety, and value?

MR. WOLFER: Right.

MS. SIMMONS: But you believe it was repaired on the final repair attempt, 12-22?

MR. WOLFER: No. 12-22, we're

considering that the final?

MS. SIMMONS: Well, that's what we stipulated to as the final repair.

MR. WOLFER: Then yes, that's it.

MR. TUCK: Mr. Fernandez?

MR. FERNANDEZ: As to the squealing brakes, I heard them today, so I can't say that they were repaired. It may be as Mr. Wolfer says that there might be some moisture, maybe not. It doesn't rise to -- and that's also evidenced by the fact that not everyone heard them. I wouldn't say that the noise is to a point of distraction or to a point where I couldn't drive the vehicle because of the noise. I would find that the problem is still there. I do not believe it is substantial and I do not believe it impacts the use, value, or safety of the car.

MS. SIMMONS: How about from a safety point of view, do you believe there was a brake condition that contributed to this squeak noise?

MR. FERNANDEZ: There is a brake condition that is contributed to the brake noise that I believe I heard this afternoon.

MS. SIMMONS: Do you believe then, if you say there is a brake condition, do you think that perhaps would substantially affect its safety, use, or value?

MR. FERNANDEZ: Noise?

MS. SIMMONS: A brake condition -- you're saying that you felt there was a brake condition that contributed to this noise.

MR. FERNANDEZ: If there were a brake condition, it would certainly apply to all three, the safety, use, and value of the vehicle.

MS. SIMMONS: Are you saying that there is a brake condition that is a non-conformity to the substantial impairment to use, safety, or value?

MR. FERNANDEZ: I do not believe it's a substantial impairment.

MS. SIMMONS: Mr. Tuck?

MR. TUCK: As evidenced by the repairs that were done to the brake system, to me that makes it evident that there was a substantial non-conformity as to use, value, and safety. Brakes that don't work can variably affect all those issues. It was fixed when they did that last repair on 12-22.

MS. SIMMONS: Before doing your vote, would the Board count the days and make sure for the ones that you found were non-conformities. In this case, you found to be non-conformities that the vibration at the time it existed was a non-conformity, right, but it was repaired?

MR. TUCK: Yes.

MS. SIMMONS: Do you believe there were 30 days out for that condition?

MR. WOLFER: No.

MS. SIMMONS: Or any of the conditions that were found today as a non-conformity?

MR. TUCK: We agreed earlier I thought, as a stipulation of the parties, that the vehicle was out for 26 days for everything. So I don't know how breaking it up would bring us out of the 30-day limit.

MS. SIMMONS: That brings me to my next point then. Is the Board speaking to the 30-day presumption or is the Board going to consider 26 is close enough, let's now break it down to the dates? It's the Board's decision.

MR. TUCK: I think with the nature of our findings as to the seriousness of the complaints that that shouldn't bring us to where we set aside the 30-day presumption.

MS. SIMMONS: Okay. Do the other board members agree?

MR. TUCK: I'm going to ask them now.

MR. FERNANDEZ: I agree that we should follow the legislative --

MR. WOLFER: I agree that it would need to be the 30 days.

MS. SIMMONS: I guess a vote is left for you.

MR. TUCK: Mr.. Wolfer started all the time, so we will let Mr. Fernandez start.

MR. FERNANDEZ: As to?

MR. TUCK: Final vote as to the consumer or manufacturer?

MR. FERNANDEZ: The manufacturer.

MR. WOLFER: I find for the manufacturer.

MR. TUCK: I concur.

That's going to conclude the hearing. I want to thank you all for your presentations and your patience. Any questions can be addressed to the attorney's office tomorrow. A decision should be rendered within a few days and sent out by mail to everybody.

Again, that concludes the hearing. The recorder will continue to run until everybody has left the hearing room, which I'm going to ask you all to do now. Thank you.

(Thereupon, the above proceedings were concluded.)

CERTIFICATE

I, MICHELLE RUSSELL, do hereby certify that I was authorized to and did transcribe the foregoing proceedings and that the transcript is a true and correct transcription of the above-styled proceedings.

Dated the 2nd day of April, 2009

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MICHELLE RUSSELL
Stenograph Reporter
March 15, 2013

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WHOLE-BODY-VIBRATION EXPOSURE EXPERIENCED DURING THE OPERATION OF SMALL AND LARGE LOAD-HAUL-DUMP VEHICLES

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Abstract
The body harmlessly attenuates most vibration, however frequencies between 1 and 20 Hz cause the body (pelvis and spine) to resonate (Kitazaki & Griffin, 1998; Thalheimer, 1996) leading eventually to structural damage and health problems including lower-back pain, spinal degeneration, gastro-intestinal track problems, sleep problems, headaches, neck problems, autonomic nervous system dysfunction, hearing loss, and nausea (Scutter et al., 1997; Seidel, 1993; Thalheimer, 1996). Despite the health concerns related to WBV exposure, little attention has been given to understanding the levels of WBV experienced by mining equipment operators. The primary purpose of the present study was to measure WBV exposure levels at the vehicle seat interface and the operator seat interface, during the operation of both small and larger LHD vehicles. Results were compared to the ISO 2631-1 health guidance caution zones to determine safe exposure durations. Preliminary test results indicated that LHD operators were exposed to whole-body vibration levels putting them at risk for injury. ISO 2631-1 exposure guidelines for the health caution zone were exceeded during the operation of several different vehicles. Some seats were also found to amplify the vibration signal resulting in a reduction in the recommended exposure duration.

Key words: Whole-body vibration, ISO 2631-1, LHD vehicle

EXPOSITION AUX VIBRATIONS GLOBALES DU CORPS ÉPROUVÉES PAR LES CONDUCTEURS DE PETITE OU GROSSE CHARGEUSE-DÉCHARGEUSE

Résumé
Même si le corps atténue sans danger la plus grande partie des vibrations, les fréquences qui se situent entre 1 et 20 Hz occasionnent une résonance au corps (bassin et colonne vertébrale) (Kitazaki & Griffin, 1998; Thalheimer, 1996), ce qui peut entraîner des troubles structurels et des problèmes de santé comme : douleur lombaire, dégénérescence rachidienne, troubles gastro-intestinaux, troubles de sommeil, maux de tête, cervicalgie, trouble neurologique, perte de l'ouie et nausées (Scutter et autres, 1997; Seidel, 1993; Thalheimer, 1996). Malgré les préoccupations pour la santé liées à l'exposition des vibrations globales du corps, très peu d'attention a été portée à la compréhension des vibrations globales du corps éprouvées par les conducteurs de matériel d'exploitation des mines. L'objectif premier de la présente étude visait à mesurer les taux d'exposition aux vibrations globales du corps à l'interface du siège du véhicule et l'interface du siège du conducteur lors de l'opération d'une petite ou grosse chargeuse-déchargeuse. Les résultats ont été comparés aux zones de risques pour la santé afin de déterminer les durées d'exposition sécuritaire. Les résultats de tests préliminaires ont indiqué que les conducteurs de

chargeuse-déchargeuse sont exposés à des taux de vibrations globales du corps risquant d'entraîner des blessures. Les directives de risques pour la santé de l'ISO 2631-1 ont été dépassées lors de l'opération de plusieurs véhicules différents. On a également remarqué que certains sièges amplifiaient le signal de vibrations donnant lieu à une diminution de la durée d'exposition recommandée.

Mots clés : vibrations globales du corps, ISO 2631–1, chargeuse-déchargeuse

INTRODUCTION

Increased mechanization in mining has resulted in a larger number of workers exposed to longer durations of whole-body vibration, WBV, and the trend towards extended shift lengths (10+ hrs) has resulted in longer durations of exposure. Adverse health outcomes associated with WBV exposure have been well documented and include damage to the nervous, circulatory, and digestive systems. Degenerative changes to the spine are also a concern as they are linked with increased rates of low-back pain and injury (Scutter et al., 1997; Seidel, 1993; Thalheimer, 1996). Research has also shown that health concerns are more likely if the vibration experienced is in the resonance zone which is 4-8 hz for the z-axis and 1-2 hz for the x, y axes (ISO 2631-1). The amount of vibration experienced by an operator of mobile equipment is also determined by driving speed, road condition, vehicle maintenance, vehicle load, vehicle suspension, vehicle size and seat type (Ozkaya et al., 1994; Village et al., 1989; Bush and Hubbard, 2000; Eger et al., 2004).

In a 1989 study by Village, Morrison, and Leong WBV experienced by LHD vehicle operators was measured (11 vehicles, 8 operators, and 4 work locations). The variables of interest were LHD size (3.5 to 8 yard capacities), task (mucking, dumping, driving full, driving empty), and driving speed. Attempts were made to control for operator experience (all experienced), tire pressure, seat suspension (all seats the same), and road conditions (all vehicles driven over the same terrain). The study found that WBV exposure was higher when driving (empty or full) than under all other conditions. The authors also reported higher values of exposure when driving at higher speeds and for smaller capacity LHD vehicles. The present study builds on these results. WBV was measured during the operation of small and large haulage capacity LHDs, while performing three tasks (tramming full, tramming empty and mucking) under similar underground mining terrain. However, WBV exposure levels were measured at the vehicle floor/seatbase interface and the seatpad/operator interface in order to determine the effectiveness of the seat.

METHODOLOGY

WBV Measurement

Whole-body vibration was measured in accordance with the guidelines set out in the 1997 ISO 2631-1 standard. A tri-axial seat-pad accelerometer was used to measure vibration exposure at the seatpad/operator interface and a tri-axial accelerometer mounted with a large magnet was placed on the floor at the base of the seat in order to measure WBV at the vehicle floor/seatbase interface. Measured vibration values were compared to the 1997 ISO 2631-1 Health Guidance Caution Zones (HGCZ) in

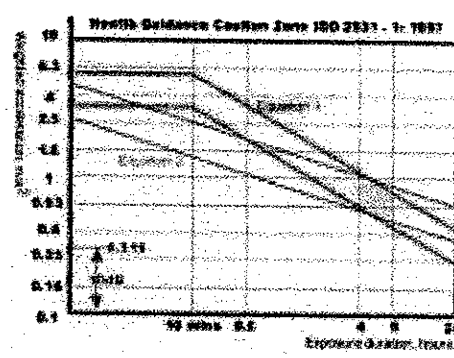

Fig. 1 Health guidance caution zone (ISO 2631-1)

order to determine recommended exposure durations (Fig. 1). No crest factors were measured above 9 therefore frequency weighted RMS acceleration values were used when making comparisons to the HGCZ.

Test Sites and LHD Vehicles

WBV measurements were conducted at 8 underground mine sites in Ontario on 16 different LHD vehicle models. WBV levels were recorded during tramming (loaded and unloaded) and mucking tasks.

RESULTS AND DISCUSSION

Preliminary Results

Preliminary results are shown for two LHD vehicles tested in Table 1. For Model A (10 yard haulage capacity), the highest vibration magnitudes were observed in the z-axis, the seat acted to increase the magnitude of the vibration signal in all axes and the maximum vibration magnitudes fell between 0.89-1.18 m/s/s. The vibration levels experienced fell in the HGCZ indicating harmful health effects are likely. Moreover the seat installed in the vehicle was not appropriate for the vibration experienced in the underground mining environment. For Model B (6 yard haulage capacity), the highest vibration magnitudes were observed in the x-axis, the seat acted to increase the magnitude of the vibration signal, and the maximum vibration magnitudes fell between 0.55-0.64 m/s/s. The vibration levels experienced fell within the zone of caution with respect to health effects and the seat was not appropriate for the vibration experienced in the underground environment.

Control Strategies

Preliminary results from this study support the findings of Village et al., (1989) and Eger et al., (2004). Vibration levels were found to be higher when the vehicles were operated with the buckets empty and WBV exposure measured at the seatpad/operator interface indicated increased health risks for the LHD operators. In order to reduce harmful levels of WBV exposure mining companies were encouraged to maintain equipment (will result in less mechanical vibration), maintain roadways (regular care will act to reduce the peak values in the vibration signal) and operators were encouraged to reduce driving speeds (decreased rate of travel will decrease the magnitude of vibration).

Future Research Directions

Further research is required to evaluate the effectiveness of seating used in underground mining vehicles (for maximum damping, the seat's resonant frequency needs to be smaller than the frequencies produced by the vehicle or amplification of the vibration can occur). In order to tackle this issue the authors of this paper will conduct controlled experiments (reproducing WBV measured in the field) in a laboratory environment in order to evaluate current seat design in an effort to identify seat characteristics required for mining applications.

ACKNOWLEDGEMENTS

Support for this research project has been provided by the Workplace Safety and Insurance Board of Ontario. The research team would also like to thank the Mines and Aggregates Safety and Health Association, the Ontario mining industry and the mining equipment manufacturers for their continued support.

Table1. Frequency weighted RMS acceleration for the X, Y, and Z axis for two LHD models. Measured crest factors were less than 9 for all measured reported. Recommendations based on the ISO 2631-1 health guidance caution zone are reported.

Machine Model	Haulage Capacity and Activity	Frequency Weighted RMS Acceleration Values (m/s/s)						Recommendation based on ISO-2631-1 HGCZ
		LHD Floor/Seatbase Interface			LHD Seatpad/Operator Interface			
		X-axis	Y-axis	Z-axis	X-axis	Y-axis	Z-axis	
Model A	• 10 yard haulage capacity • Tramming with a fully loaded bucket	0.54	0.43	0.86	0.51	0.61	0.89	Caution with respect to health risks is necessary. Interventions should be put in place.
Model A	• 10 yard haulage capacity • Tramming with an EMPTY bucket	0.51	0.46	0.78	0.57	0.58	1.00	Health effects are likely. Operator should not be exposed to vibration of this magnitude for 8 hour periods. Therefore the duration of exposure should be reduced or vibration magnitude attenuated.
Model A	• 10 yard haulage capacity • Mucking (process to load the bucket)	0.65	0.61	1.47	0.64	0.78	1.18	Health effects are likely. Operators should not be exposed to vibration of this magnitude for 8 hour periods. Therefore the duration of exposure should be reduced or vibration magnitude attenuated
Model B	• 6 yard haulage capacity • Tramming with a fully loaded bucket	0.39	0.24	0.44	0.51	0.30	0.55	Caution with respect to health risks is necessary. Interventions should be put in place.
Model B	• 6 yard haulage capacity • Tramming with an EMPTY bucket	0.81	0.56	1.07	0.59	0.46	0.46	Caution with respect to health risks is necessary. Interventions should be put in place.
Model B	• 6 yard haulage capacity • Mucking (process to load the bucket)	0.41	0.34	0.73	0.64	0.55	0.54	Caution with respect to health risks is necessary. Interventions should be put in place.

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> Vibration - Measurement, Control and Standards

How can you measure vibration?

A complete assessment of exposure to vibration requires the measurement of vibration acceleration in meters per second squared (m/s^2). Vibration exposure direction is also important and is measured in a well-defined directions. Vibration frequencies and duration of exposure are also determined. How hard a person grips a tool affects the amount of vibrational energy entering the hands; therefore, hand-grip force is another important factor in the exposure assessment.

The amount of exposure is determined by measuring acceleration in the units of m/s^2. Most regulating jurisdictions and standard agencies use acceleration as a measure of vibration exposure for the following reasons:

- Several types of instruments are available for measuring acceleration, the rate of change of velocity in speed or direction per unit time (e.g., per second).
- Measuring acceleration can also give information about velocity and amplitude of vibration.
- The degree of harm is related to the magnitude of acceleration.

Health research data tells us that the degree of harm is related to the magnitude of acceleration.

Instrumentation

A typical vibration measurement system includes a device to sense the vibration (accelerometer), and an instrument to measure the level of vibration. Today a number of industries are making vibration measuring instruments that look like sound level meters. This equipment also has settings for measuring frequency, a frequency-weighting network, and a display such as a meter, printer or recorder.

The accelerometer produces an electrical signal. The size of this signal is proportional to the acceleration applied to it. The frequency-weighting network mimics the human sensitivity to vibration of different frequencies. The use of weighting networks gives a single number as a measure of vibration exposure and is expressed as the frequency-weighted vibration exposure in metres per second squared (m/s^2), units of acceleration.

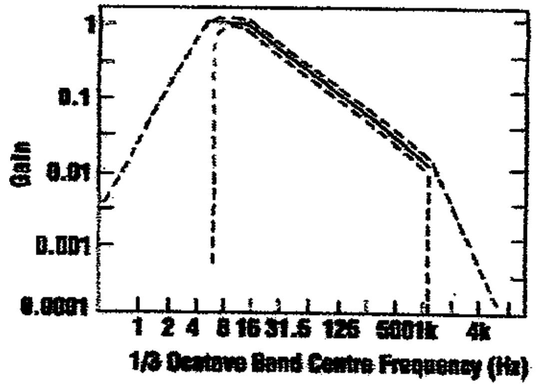

Figure 1

The frequency-weighting network for hand-arm vibration is given in the International Organization for Standardization (ISO) standard ISO 5349. Human hand is not equally sensitive to vibration energy at all frequencies. The sensitivity is the highest around 8-16 Hz (Hertz or cycles per second). Measuring equipment takes this fact into account by using a weighting network. The gain is assigned a value of 1 for vibration frequencies to which the hand-arm system has the highest sensitivity. The dashed lines in Figure 1 represent the filter tolerances in the weighting network.

Are there methods for controlling exposure to vibration?

Protecting workers from the effects of vibration usually requires a combination of appropriate tool selection, the use of appropriate vibration-absorbing materials (in gloves, for example), good work practices, and education programs.

What are some examples of controlling exposure to vibration?

Anti-Vibration Tools

Tools can be designed or mounted in ways that help reduce the vibration level. For example, using anti-vibration chain saws reduces acceleration levels by a factor of about 10. These types of chain saws must be well maintained. Maintenance must include periodic replacement of shock absorbers. Some pneumatic tool companies manufacture anti-vibration tools such as anti-vibration pneumatic chipping hammers, pavement breakers and vibration-damped pneumatic riveting guns.

Anti-Vibration Gloves

Conventional protective gloves (e.g., cotton, leather), commonly used by workers, do not reduce the vibration that is transferred to workers' hands when they are using vibrating tools or equipment. Anti-vibration gloves are made using a layer of viscoelastic material. Actual measurements have shown that such gloves have limited effectiveness in absorbing low-frequency vibration, the major contributor to vibration-related disorders. Therefore, they offer little protection against developing vibration-induced white finger syndrome. However, gloves do provide protection from typical industrial hazards (e.g., cuts, abrasions) and from cold temperatures that, in turn, may reduce the initial sensation of white finger attacks.

Safe Work Practices

Along with using anti-vibration tools and gloves, workers can reduce the risk of hand-arm vibration syndrome (HAVS) by following work practices:

- Employ a minimum hand grip consistent with safe operation of the tool or process.
- Wear sufficient clothing, including gloves, to keep warm.
- Avoid continuous exposure by taking rest periods.
- Rest the tool on the work piece whenever practical.
- Refrain from using faulty tools.
- Maintain properly sharpened cutting tools.
- Consult a doctor at the first sign of vibration disease and ask about the possibility of changing to a job with less exposure.

Employee Education

Training programs are an effective means of heightening the awareness of HAVS in the workplace. Training should include proper use and maintain vibrating tools to avoid unnecessary exposure to vibration. Vibrating machines and equipment often produce loud noise as well. Therefore, training and education in controlling vibration should also address concerns about noise control.

Whole-Body Vibration

The following precautions help to reduce whole-body vibration exposure:

- Limit the time spent by workers on a vibrating surface.
- Mechanically isolate the vibrating source or surface to reduce exposure.
- Ensure that equipment is well maintained to avoid excessive vibration.
- Install vibration damping seats.

The vibration control design is an intricate engineering problem and must be set up by qualified professionals. Many factors specific to the individual work station govern the choice of the vibration isolation material and the machine mounting methods.

Are there any Canadian regulations or guidelines for vibration exposure?

Many Canadian jurisdictions do not have regulations concerning vibration exposure. However, it is prudent to reduce the level of exposure as much as practical since vibration causes ill health effects. It is possible to do this by engineering controls, the use of protective equipment and safe work practices. The design of vibration-damped equipment and engine mountings are the most effective engineering methods of controlling vibration exposure.

In the absence of formal regulations, Canadian agencies often use the Threshold Limit Values (TLVs) and guidelines recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). These TLVs are based on the recommendations of the International Organization for Standardization (ISO).

What are the standards or guidelines for exposure to hand-arm vibration?

The American Conference of Governmental Industrial Hygienists (ACGIH) has developed Threshold Limit Values (TLVs) for vibration exposure from hand-held tools. The exposure limits are given as frequency-weighted acceleration that represents a single number measure of the vibration exposure level. The frequency-weighting is based on a scheme recommended in the international standard ISO 5349. Vibration-measuring instruments have a frequency-weighting network as an option for vibration measurement. Table 1 lists acceleration levels and exposure durations to which, ACGIH has determined, most workers may be exposed repeatedly without severe damage to fingers. ACGIH advises that these guidelines be applied in conjunction with other protective measures including vibration control.

Table 1
The ACGIH Threshold Limit Values (TLVs) for exposure of the hand to vibration in X, Y, or Z direction*

Total Daily Exposure Duration (hours)	Maximum value of frequency weighted acceleration (m/s^2) in any direction*
4 to less than 8 hours	4
2 to less than 4 hours	6
1 to less than 2 hours	8
less than 1hour	12

* Directions of axes in the three-dimensional system

The International Organization for Standardization (ISO) has published a method for measuring vibration and interpreting the resulting data. This 2001 standard (ISO 5349-1) also gives the set of curves shown in Figure 2 that can determine exposure levels likely to cause the first signs of white finger in workers.

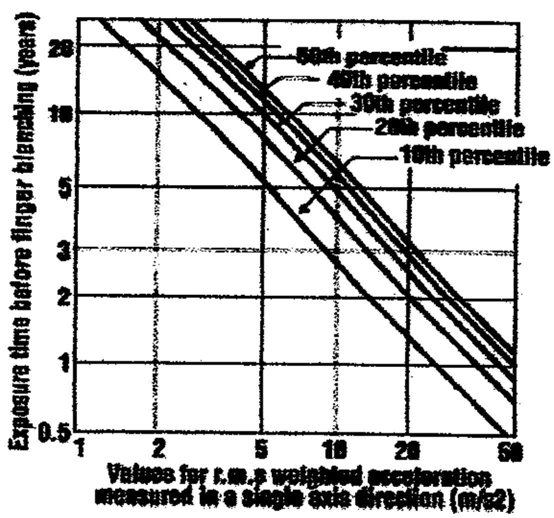

Figure 2 - Curves for exposure times of percentiles of population groups (ISO 5349) to suffer mild effects on tip of finger (see Stage 1, Table 2)

The horizontal axis in Figure 2 represents vibration acceleration. This is measured as RMS (Root Mean Square) weighted acceleration in m/s^2. RMS is a method of

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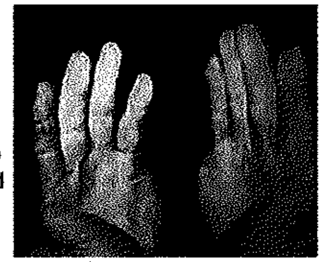
Acquisition Safety - Vibration

Introduction



Hands of vibrating pneumatic hand-tool operator in later stages of irreversible Hand Arm Vibration Syndrome1

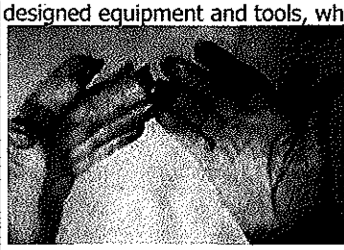
* Copyright 1990, D.E. Wasserman, Inc.; Image of hands (not U.S. Navy worker) used with permission.

The Navy cares deeply about protecting the safety and health of its greatest resource - its people. In today's workplaces, there exist many potentially serious occupational hazards. Some hazards, like noise-induced hearing loss and heat stress, are well known, heavily reported, and well documented. Much less is known about other workplace perils, which can produce serious, irreversible, and unsuspected diseases. *Occupational Vibration*, affecting eight to ten million people in the U.S. alone, is one of these lessobvious workplace hazards. Because Navy Leadership is concerned about the safety and health of its military and civilian workers, they are working hard to address this under-recognized occupational health problem through acquisition of safe, cost-effective, and performance-improving designs and equipment. This section of the Acquisition Safety website addresses the vibration issue uniquely and in depth. Included are the potential health effects of uncontrolled vibration and ongoing efforts to control this risk to Navy personnel. Also provided are best business practices and technical assistance for acquisition (research, development, design and procurement) of designs and equipment that will maximize productivity and operational effectiveness while protecting operators and maintainers of this equipment.

Top

Background

Continuous exposure to excessive levels of vibration can cause irreversible damage to the human body. Workers who continually interact with machinery are affected to some degree by occupational vibration. Vibration exposure can be caused by use of poorly designed equipment and tools, which do nothing to attenuate vibration exposures. Two different types of vibration exposures - segmental (hand/arm) and whole body - affect the health and safety of some eight million U.S. workers. What Is Vibration?



Rare case of gangrene in hands of vibrating pneumatic hand-tool operator at terminal stage of irreversible Hand Arm Vibration Syndrome2

* Copyright 1990, D.E. Wasserman, Inc.; Image of hands (not U.S. Navy worker) used with permission

A common category of segmental vibration exposure, affecting two million workers, is called Hand-Arm Vibration (HAV). This type of vibration exposure is caused by the regular use of vibrating pneumatic, electric, hydraulic, or gasoline-powered hand tools. Excessive HAV exposure can produce an irreversible condition of the hands called Hand-Arm Vibration Syndrome, or HAVS. (Click here to learn more about HAVS.)

Workers using manual grinders, swing grinders, cutting tools and similar equipment may be susceptible to HAVS. Table1 shows HAV exposures of U.S. Navy personnel.

Regular exposure to WBV from heavy equipment can lead to lower back pain in equipment operators

A second type of vibration exposure, affecting six million workers from "head-to-toe," is called Whole-Body Vibration, or WBV. Whole-Body Vibration may occur in workers who regularly operate trucks, buses, heavy equipment, forklift trucks, trains, helicopters, rotary and fixed wing aircraft, ships, etc. Both health and safety problems may arise from WBV. The body becomes tuned to and amplifies some WBV frequencies. The safety concern is that under these circumstances operators can experience a loss of vehicle control due to vibrations forcing their hands away from the steering wheel and other controls. Table 2 shows potential WBV exposures of U.S. Navy personnel. (Click here to learn more about WBV.)

Disabled workers suffering from HAVS and/or WBV-related degenerative disc disease are not as productive as employees who are not so affected. Uncomfortable workers may subvert built-in safety mechanisms that they feel hinder them from performing their jobs quickly and easily, for example by using ill-fitting anti-vibration gloves, hearing protection,etc. Additionally, pain may cause fatigue and loss of concentration. These factors can contribute to workplace accidents, which can mean personnel injuries, even deaths. Aside from costs for treatment and rehabilitation, injuries mean lost time and productivity on the job. Accidents also result in time and material costs when equipment has to be repaired or replaced and operations are delayed or cancelled.

Top

Relevance of Vibration Control to Acquisition

Acquisition managers and design engineers should continue to consider the potential negative impact of excessive vibration on mission performance, direct acquisition expenditure (acquisition life cycle cost), delivery schedule, and total ownership costs (TOC = lifecycle cost plus infrastructure support costs). Optimal use of existing technology can reduce risk factors and produce a superior product while protecting the safety and health of system operators/maintenance personnel. Prevention of vibration hazards has high return on investment in avoided workers' compensation for all areas of acquisition - during construction, maintenance, and disposal.

Full-finger protected AntiVibration Gloves, which meet: ANSI/ISO standards

Acquisition managers and design engineers are strongly encouraged to use and purchase, as applicable, "air ride" seats for Whole-Body Vibration situations requiring effective attenuation in the vertical (up-down) direction, fore-aft (front to back) direction, and sway (side to side) direction.

This technology has been highly developed and used in the transportation industry. Similarly, for Hand-Arm Vibration maximum safety, health, and performance requirements, acquisition managers are strongly encouraged to purchase AntiVibration, ergonomically designed power tools. These tools have numerous applications commonly found in both ship and base installations. Equally encouraged is the purchase of full-finger protected AntiVibration Gloves, which meet or exceed domestic/international standard: ANSI S3.40-2002 - ISO 10819.

Potential Effects of Excessive Equipment Vibration on Acquisition Projects

Whole Body Vibration (WBV) - Equipment that creates excessive vibration can adversely affect the programs for building and buying equipment and vehicles and the life cycle costs for their operation. Vibration transmitted to operators and other occupants can impair their comfort, performance, and visual acuity and in extreme cases, even the ability to control a vehicle or aircraft. Whole body vibration in the range of 4 Hz vertical and 1-2 Hz side to side will create loss of control for vehicle operators. This is a resonant frequency (the range of motion is increased rhythmically with this frequency) and operators will be literally unable to control the vehicle.

Whole Body Vibration can cause operator to lose control of a vehicle

Designs that avoid this pitfall will be more effective and operate at reduced cost and risk. Excessive vibration is also likely to degrade equipment and can be an indicator of wear or impaired equipment condition. Fortunately, the control measures often have relatively low costs. For example, vibration control seats for vehicles are available for $400 to $500 each. Good vibration control is a hallmark of well-designed equipment in applications ranging from ventilation systems to engine mounting.

Control of vibration and noise is considered mission essential for many ships and certain land-based equipment because it reduces the vulnerability of their detection by the enemy. Lack of attention to vibration and noise control in the design phase can result in products that do not meet performance requirements and require costly re-design and schedule delays. This was the case for a minesweeper (ship designed to detect mines) that required improved mounting (isolation) of its engines, acoustical insulation, and other controls to reduce transmitted vibration to an acceptable level. The immediate impact on the first ship of this class was increased cost and delay required for re-engineering. But, the end result was a much quieter vessel that was healthier and safer to operate.

Hand Arm (Segmental) Vibration (HAV) - Tools and processes that create excessive hand-arm vibration to users (workers) may have an impact on production and maintenance, which may impact schedule or cost. Products may be more costly to produce and maintain due to effects of HAV on skilled production and repair workers. Aircraft (especially airframes) and ship production include many processes that may create risks for hand-arm vibration in manufacturing workers. This is also a design and production issue related to quality control. For example, better castings will reduce the need for rework in the cleaning/finishing department where excess material is ground off.

Better tools and work process layout almost always yield results in productivity. This is particularly true in applications such as the aircraft production industry where assembly layout and tool selection can reduce worker exposure to awkward postures and hand-arm vibration while improving efficiency. Maintenance and repair costs can be influenced by measures such as selection of low-vibration tools and ongoing tool and equipment upkeep.

Table3 summarizes the potential effects of vibration on acquisition projects.

Noise and Vibration Control in Design

- DoD Instruction 5000.2 and SECNAVINST 5000.2D require evaluation of health and safety hazards for all acquisition programs. Relevant sections include: DoD 5000.2 section; 4.3.7.3/SECNAVINST 5000.2D Part 7 section 7.2.1 ("PMs and sponsors shall address HSI throughout all phases of the acquisition process").
- Ergonomic and vibration related sections of OPNAVINST 9640,
- OPNAVINST 5100.23 (Series) and DoD Instruction 6055.12 (Series)


The Navy faces the challenge of finding improved vibration-reducing materials and technologies

A discussion of control of hand arm vibration in Navy workplaces is provided in *Protecting Our People from Bad Vibrations* (Success Stories section of this website).

The Programmatic Environmental Safety and Health Evaluation (PESHE) is an ongoing process that requires:

- Assessing environmental and safety regulations that will impact the weapon system throughout its lifetime.
- Identifying safety and health risk factors identified by review of legacy systems and proposed designs along with formal documentation of any decisions to accept those risks.
- Taking action to reduce safety and/or health risk factors. Note: Protective equipment and warning signal/notices are considered the least effective measures and are not considered design controls.

Role of Personal Protective Equipment in Vibration Control

Personal protective equipment alone is ***not*** hazard abatement relative to the acquisition process. OSHA and supporting Navy Instruction OPNAVINST 5100.23 Chapter 5 require that designs abate hazards and allow interim use of protective equipment only where design feasibility and cost considerations preclude exclusive use of engineering controls. System safety and associated hazard abatement tracking (Mil Std 882) also do not consider personal protective equipment as abating a hazard, and require a hierarchy of controls beginning with engineering controls.

Use of gloves meeting ISO 10819 certification criteria for reduction of transmitted vibration is an important mitigating measure in control of vibration transmitted to the hands/arm. Certified anti-vibration gloves must be used in combination with selection of tools and processes designed to minimize or avoid vibration, worker education, medical evaluation and overall process management in order to reduce the risk of hand-arm vibration syndrome.

Use of anti-vibration gloves certified by a third party is essential to be assured of suitable protection. Information on HAV standards is provided in the Vibration Resources section, "Further Reading on Vibration and Vibration Control." Because the Hand Arm Vibration disease begins in the fingers, and because maintaining warm, dry hands to protect against vasoconstriction is essential; products described as "half finger" gloves do not meet ISO/ANSI standard for anti-vibration products and should not be used as "anti-vibration" gloves.

Two certified, US manufactured products have been given global (national stock numbers) and should be available within the Federal supply system. Click here to see a brochure describing these products.

Additionally, one category of certified anti-vibration glove has been made available through GSA Advantage (see the Vibration Resources section) for product information. The GSA advantage process allows vendors to provide products which do not have national stock number (NSNs) to be marketed with the support of the Federal system. It is a more rapid process.

Defense Safety Oversight Council-Sponsored Projects
A project to provide improved power hand tools and certified anti-vibration gloves was sponsored by the Defense Safety Oversight Council's Acquisition and Technology Task Force with the support of the Government Services Administration and National Institute for Occupational Safety and Health. A report was presented to the 3rd American Conference on Human Vibration in June 2010. A focused one-year project extension has been funded and initiated in November 2010.

Note: Distribution of this information does not constitute product endorsement for a particular vendor or manufacture. However, the product certification has been independently verified.

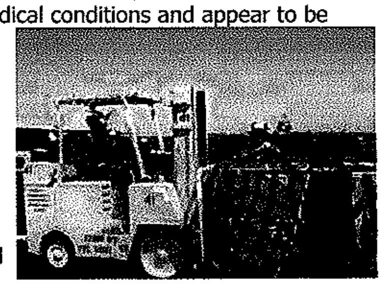
Other certified anti-vibration gloves are available through a limited number of vendors. Anyone ordering such products should ask the vendor to confirm ISO 10819 certification, as well as considering other performance and comfort factors.

Individual fit and worker preferences as well as adaptation to particular work tasks are key factors to consider in use of any protective equipment. However, if the products described in this material are suitable for your application, their use should be strongly considered for processes which expose workers to high levels of hand-arm vibration.

Top

Discussion

Vibration-related diseases are not new. HAVS was described in U.S. literature as early as 1918, and WBV problems became apparent around 1945. However, vibration-related diseases are often mistaken for other medical conditions and appear to be under reported in the medical literature. In addition, vibration measurements are difficult to perform at times because of the variability of the exposure, complexity of the measuring equipment, and techniques and skill required by the evaluator. The Navy recognizes these problem areas and has sponsored courses that include training on vibration for industrial hygiene and medical personnel. The greatest challenges are vibration recognition, disease prevention, and minimizing vibration exposures. Vibration induced disorders can be minimized by early intervention. The American National Standards Institute (ANSI) and American Conference of Governmental Industrial Hygienists (ACGIH) have developed recommended standards and guidelines, respectively, for exposures to both whole body and segmental vibration. These criteria identify recommended maximum exposures to vibration. The Navy faces the continual challenge of finding better and improved vibration-reducing materials and technologies that meet these guidelines and standards and can be incorporated into ships and shore facility designs during the acquisition process.


Aviation Ordnancemen use a forklift to move weapons and cargo

Top

Recommendations

Protecting Navy workers from hazardous *Whole-Body Vibration* means minimizing vibration source generation together with providing a protective whole-body cocoon for exposed workers with follow-up by regularly monitoring the vibration environment while employing sensible work practices. These include:

- Purchasing vehicles with suspension systems that minimize vibration and, where possible, mechanical isolated/floating cabs;
- Purchasing "air-ride seats," (seats provide a protective cushion of air) for both drivers and passengers, as applicable, either as part of an original equipment manufacturer purchase of vehicles and/or;
- Removing non-protective driver's seats from existing vehicles and replacing them with air-ride seats;
- Using air-ride seats for some non-vehicle WBV applications such as hovercraft at sea and in fixed work station situations where the floor vibrates due to functioning equipment processes;
- Adding or designing 'isolators' under machinery to reduce source vibration in some fixed facility situations. This would include foundation mounts that prevent vibration transmission to other structures;
- Incorporating shock mount stand plates, chairs, and vibration dampened controls in acquisition design stages;
- Using good work practices, which include workers taking periodic rest breaks for every one to two hours of continuous WBV exposure and not lifting objects immediately after prolonged WBV exposure, leaving the vehicle using simple egress motions, walking around for a few minutes, and performing other non lifting tasks before attempting any lifting tasks;
- Making workers aware of signs and symptoms of WBV-induced back problems and the need to see their safety managers and health care providers if signs and symptoms occur.

Protecting Navy workers from hazardous Hand-Arm Vibration is multifaceted and begins with minimizing vibration source generation together with providing effective personal protection for exposed workers, regularly monitoring the vibration environment, and employing sensible work practices. These include:

- Purchasing and using only power tools, which are designed to reduce vibration (called AntiVibration, or A/V) and reduce musculoskeletal injuries.
Important Note: An ergonomically designed power tool, does not mean the tool has reduced vibration attributes and vice versa; thus power tools which are either A/V designated alone or ergonomically designated alone are not the best choice. The former solution alone, while reducing HAV, can leave tool workers at possible risk for Carpal Tunnel Syndrome, CTS (syndrome of the median nerve and flexor tendons of the hand and wrist). The latter solution alone, while reducing CTS, can leave tool workers at risk for irreversible HAVS.
- Not purchasing or using so-called "vibration reducing tool wraps" which are merely tool handle sleeves that attempt to reduce vibration of conventional power tools. These wraps are generally ineffective and do little to reduce vibration. They also pose an added problem by increasing tool handle diameter, which can possibly lead to cumulative trauma disorders (CTDs) of the forearm, elbow, and shoulder.

- Using only full-finger protected AntiVibration gloves, which meet or exceed the following A/V Glove standard: ANSI S3.40-2002 - ISO 10819. AntiVibration gloves:
  - Must be full-finger protected (no exposed fingers);
  - Must fit well (allowing maximum finger tactility and proper grip);
  - Must keep the fingers and hands warm and dry (to avoid cold-triggered HAVS attacks).
- Using good work practices, including:
  - Letting the power tool do the work;
  - Holding the power tool with the lightest grip possible consistent with safe work practices;
  - Keeping hands and body warm and dry;
  - Not smoking (nicotine, cold, and vibration all constrict blood vessels impeding circulation).
- Maintaining power tools & associated implements in good condition. Otherwise, vibration levels will eventually increase. Thus, regularly scheduled HAV tool monitoring is necessary.
- Making workers aware of HAVS signs and symptoms and the need to see their safety managers and health care providers if signs and symptoms occur.

Further guidance for users of anti-vibration gloves is provided in DoD Ergonomics Working Group News - *Guidance for Users of Anti-Vibration Gloves* and in the Resources section below.

Top

References & Best Practices

Further Reading On Vibration and Vibration Control

Health and Safety Executive (HSE)
The European Union has developed regulations for evaluation and management of whole body and hand arm vibration. The United Kingdom's Health and Safety Executive (HSE) (English counterpart of OSHA and NIOSH) provides information on the standard and cost-effective recommendations for control of occupational exposures in varied industries and operations.

Hand Arm Vibration — Just Facts, July 2008
In the U.S. alone about 2.5 million workers are exposed daily to Hand-Arm Vibration [HAV] from the power tools they use on their jobs.

Hand-Arm Vibration Standards: The New ANSI S2.70 Standard
Article by Donald Wasserman, MSEE, MBA describing HAVS, the history of hand arm vibration safety standards, and the background, terminology, and provisions of ANSI Standard S2.70.

Certified Anti-Vibration Gloves
Photos and sources of certified anti-vibration gloves.

GSA Advantage Certified Glove
One category of certified anti-vibration glove has been made available through GSA Advantage (see www.gsaadvantage.gov). The GSA advantage process allows vendors to provide products which do not have national stock numbers (NSNs) to be marketed with the support of the Federal system. **Note**: Distribution of this information does not constitute product endorsement for a particular vendor or manufacture. However, the product certification has been independently verified.

Procurement Criteria to Minimize Hand-Arm Vibration Risk
Description of project to identify criteria and procurement guidelines for anti-vibration gloves and power hand tools which will eliminate or at least reduce workplace hand-arm vibration injuries.

A Guide to Users of Anti-Vibration Gloves
From the DoD Ergonomics Working Group Newsletter of October 2009

High Speed Craft Human Factors Engineering Design Guide
Designed for Naval Architects, Academia, Procurement Agencies, Regulatory Bodies, and Human Factors Subject Matter Experts (see page 3).
Source: High Speed Craft Human Factors & Craft Design web forum

Hand Arm Vibration Threshold Limits," DoD Ergonomics Working Group News, Issue 55, August 2006
Measuring exposure levels of hand-arm vibration is a complicated process. An instrument called an accelerometer is used to measure the vibration present from a power tool and then converts it to a proportional electrical output. This output signal is modified to account for the range of frequencies that are particularly harmful to the hand and arm.

NIOSH Power Tools Database
NIOSH recently released a Power Tool Database that can be used to find such information as sound power levels, sound pressure levels, and downloadable exposure and wave files related to commonly used power tools.

"Occupational Vibration Exposure-Ch. 4" in Physical & Biological Hazards of the Workplace, 2nd.Ed. [P.Wald & G. Stave, Eds.], Wiley Pub., New York, 2002.

"Occupational Vibration-Ch. 105 in Patty's Toxicology, 5th.Ed [E.Bingham, B. Cohrssen, & C. Powell, Eds.], Wiley Pub., New York, 2001.

"Hand-Arm Vibration: A Comprehensive Guide for Occupational Health Professionals-2nd.Ed., P. Pelmear & D. Wasserman, OEM, Medical Press, Beverly Farms, MA, 1998. [ISB 1-88-3595-22-3]

"Musculoskeletal Disorders & Workplace Factors", NIOSH, Pub. #97-141, Cinti., 1997.

"Human Aspects of Occupational Vibration", D. Wasserman, Elsevier Pub., New York, 1987.

Vibration Syndrome
NIOSH Current Intelligence Bulletin #38, Pub. #83-110, Cinti., 1983.

U.S. Army Combat Systems Test Activity (Aberdeen Test Center) - Aberdeen, MD: Data Analysis
To accommodate the large volume of data collected during vehicle testing, CSTA has developed software for anomaly analysis in near real time. The Vibration Expert System Analyzer (VESA) is a series of C programs that performs the quick look function and recommends continuing or halting the test to correct a problem with the data acquisition system.

Best Manufacturing Practices: Guideline Documents: NAVMAT P-9492:
Random Vibration

Third American Conference on Human Vibration Abstracts

Protecting Our People from Bad Vibrations
Success story and discussion of control of hand arm vibration in Navy workplaces

Top

Occupational Vibration Videotapes

"WHOLE-BODY VIBRATION & THE SPINE", 12 minutes, from: Univ. of Iowa, [attn. D. Wilder], Dept. Biomedical Engr., 1408 SC, Iowa City, IA 52242-1088 [email: wilder@engineering.uiowa.edu]

Top

Occupational Vibration Guidelines and Standards

American Conference of Government Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240-1634, ph. 513-742-2020, FAX 513-742-3355.
Threshold Limit Values for Chemical & Physical Agents: Whole-Body Vibration -TLV; Hand-Arm Vibration-TLV

American National Standards Institute [ANSI]

- Antivibration Glove Standard: ANSI S3.40-2002 - ISO 10819
- Hand-Arm Vibration Standard: ANSI S3.34-1986
- Whole-Body Vibration Standard: ANSI S3.18-1979

National Institute for Occupational Safety & Health [NIOSH]
Publications Dept., DSDTT, 4676 Columbia Parkway, Cincinnati, Ohio 45226-1998, ph. 1-800-35-NIOSH, 513-533-8287

- Criteria for a Recommended Standard: Occupational Exposure to Hand-Arm Vibration, NIOSH Publication #89-106

Top

Occupational Vibration Training & Education

Through its 16 university-based Education and Research Centers (ERCs), NIOSH supports academic degree programs and research training opportunities in the core areas of industrial hygiene, occupational health nursing, occupational medicine, and occupational safety, plus specialized areas relevant to the occupational safety and health field. In addition to the academic training programs, NIOSH supports ERC short-term continuing education (CE) programs for occupational safety and health professionals, and others with worker safety and health responsibilities. A current CE course schedule for all NIOSH Education and Research Centers can be accessed at the NIOSH ERC Web site http://www.niosh-erc.org/, or by contacting the NIOSH/CDC 800-number 1-800-232-4636 or the NIOSH Publications Office. **Note**: Vibration is NIOSH Course 596.

Top

DoD and Other Safety Websites Dealing with Vibration

Defense Safety Oversight Council HAVS Project Forum

{**Note**: This is a password protected website. To gain access, please send an email request to bustles@ctc.com].

A forum where users can consolidate and collaborate on various documents related to Hand-Arm Vibration Syndrome (HAVS) as it relates to the DoD Defense Safety Oversight Council (DSOC) Project. This site is meant to provide a central repository of resources (briefings, meeting minutes, correspondence, educational materials, etc.) in a collaborative environment where ideas and knowledge can be shared in efforts to enhance the DSOC goals to provide industrial protection for the Federal workforce. This site is geared to encompass commercial vendors as well as responsible Government agencies regarding their respective roles in protecting against HAVS.

Naval Undersea Warfare Center Division - Keyport, WA : Environmental Testing
Naval Undersea Warfare Center (NUWC) Division Keyport has improved its environmental test area capabilities and procedures. These improvements include an upgrade of the vibration systems, development of new dynamic test fixture designs, and use of a computer-aided status system.

Naval Undersea Warfare Center Division - Keyport, WA : Failure Analysis, Non-destructive Testing, & Chemistry Lab
The failure analysis and testing facility at Naval Undersea Warfare Center (NUWC) Division Keyport was established over 25 years ago and maintains numerous analytical and chemical analysis capabilities run by failure analysis experts. These capabilities include non-destructive testing, gas chromatography, use of a scanning electron microscope, elemental analysis, spectrometry, ion chromatography, chemistry laboratory, microscopy laboratory, microsectioning, hardness and tensile testing, and

thermocycling and vibration testing.

Top

How to Contribute

We need input from the Defense Acquisition community to address each of the ten Acquisition Safety challenges that are the subject of this website. Grow with us as we share information on how to meet the above challenges through the Defense Acquisition Process. Through the exchange of ideas, information resources, and improvements in methodology and design, these challenges can and will be met.

To submit general information or information on Best Practices, or to submit a success story, please send an email to safe-webmaster@navy.mil with the subject line "Acquisition Safety."

Return to Acquisition

Study about the human body response under the vertical vibrations action into a vehicle

by Simona Rodean, Mariana Arghir

Abstract: This paper investigates the biodynamic response of human body subjected to vertical vibrations into an auto vehicle, in two different situations: the driver sitting on a rigid seat and respectively the driver sitting on a vehicle seat with seat cushion and additional seat suspension. In doing so, a seat suspension model with a detailed lumped parameter model of the human body, was developed. The human body can be considered as a mechanical system and it may be roughly approximated by a linear lumped parameter at low frequencies and low vibration levels. The lumped parameter model of the human body consists of four parts: pelvis, upper torso, viscera and head. The seat suspension is formed by spring and dashpot. Key words: mechanical model, biodynamic response, vertical vibrations, seats suspension.

1. INTRODUCTION

In vehicle systems occupational drivers might expose themselves to vibration for a long time. Whole-body vibration (WBV) occurs when the mechanical vibration from the vehicle is transmitted to the vehicle occupants. The amount of vibration exposure depends on a number of factors, including the type and design of the vehicle, the speed at which the vehicle is traveling, the environmental conditions, and the body posture. Repeated and prolonged exposure to vibration has been linked to fatigue, pain and even injury over time

Recently, the ride comfort and safety for both vehicle drivers and passengers has become a critical issue in vehicle design. It is desirable to isolate the driver and passengers from road induced shock and vibration during transport in order to increase the ride comfort. Therefore, seat suspensions for vehicles are inevitably needed to attenuate and mitigate the whole-body vibration and shock, which is transmitted from the floor of the vehicles to the operator and passengers.

Vibration may be sinusoidal (containing only a single frequency) or complex (containing multiple frequencies). In practice, vibration exposure is always complex, although there may be certain frequencies that are dominant. The vibration frequency range that is considered important for health, comfort and perception is between 0.5 and 80 Hz (ISO 2631-1: 1997); the discussion will be limited to this frequency range, in this paper. Vibration has been shown to have a negative effect on complex cognitive tasks; however, vibration frequency or magnitude dependencies have not been proved.

The majority of the studies use vertical (z-axis) vibration rather than horizontal (x--and y-axes) vibrations.

However, the relationships between vibration frequency and magnitude vs. performance are unclear.

Using the mechanical model of the human body in a sitting position, we want to show the importance of cushion properties and seat suspension for a comfortable seat vehicle.

In this study, there are a comparison between the eigenvalues of the system made by the human sitting upright on the rigid seat and the eigenvalues from the same mechanical model of the human body sitting upright on the seat cushion, represented by mass [M.sub.1], spring [K.sub.2c] and damping [C.sub.2c]

2. MECHANICAL MODEL OF THE HUMAN BODY / SEAT ASSEMBLY

Automotive driver/passenger comfort is strongly influenced by the perception of whole-body vehicular vibration, which is further related to the body posture, static and dynamic properties of the seat, and characteristics of vibration at the body-seat interface.

The mechanical response of the human body can be predicted using a biomechanical model in a vibrating environment such as the driving vehicle.

This study developed a linear biomechanical model of the human body for evaluating the vibration transmissibility and dynamic response to vertical vibrations in sitting posture. For the human body/seat system model, the 4-DOFs model of the human body, proposed by Payne and Band (1971) (Figure 1) is used. This model will help in simulating ride quality and designing the vibration isolator, i.e. seat.

The biomechanical model consists of several lumped masses connected by linear springs and dampers. Considering the human body as a mechanical system it may, at low frequencies (less than 100 Hz) and low vibration levels, it may be roughly approximated by linear lumped parameter systems. The lumped parameter systems comprising masses [M.sub.i], springs [K.sub.i] and dampers [C.sub.i] for i = 2, 3, 4 and 5, [y.sub.i] (i = 2, 3, 4, 5) coordinates are the displacement of the human body for pelvis, upper torso, viscera and head, respectively. The soft seat cushion was implemented as a linear spring [K.sub.2c] and damper [C.sub.2c] system. The mass of the moving part of the seat, [M.sub.1], was estimated at about 13,5 kg. The seat is fixed to the floor through the seat suspension which is formed by the spring and dashpot and is represented by the spring [K.sub.1] = 2.26 x [10.sup.4] N/m and damping [C.sub.1] = 750 Ns/m (Figure 2). The human linear parameters given in the literature are presented in Table 1.

3. THE MOTION DIFFERENTIAL EQUATIONS

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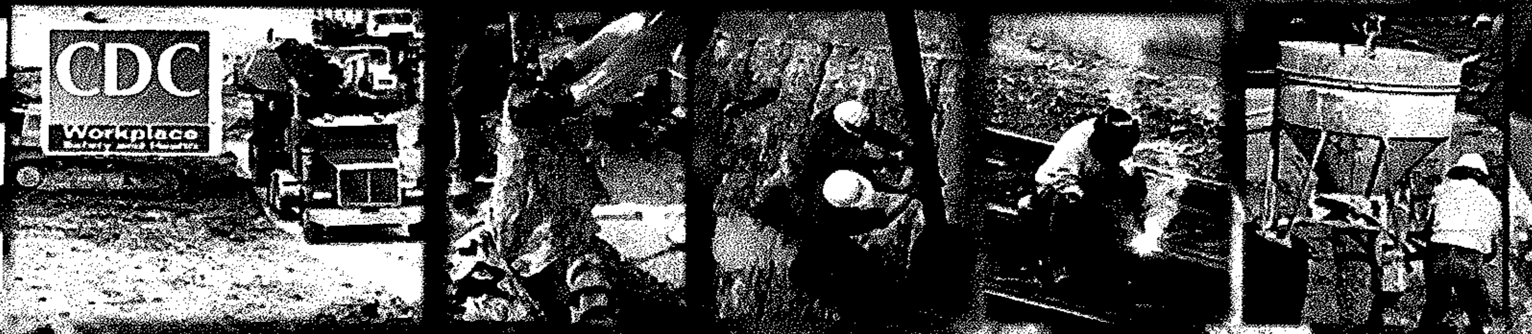
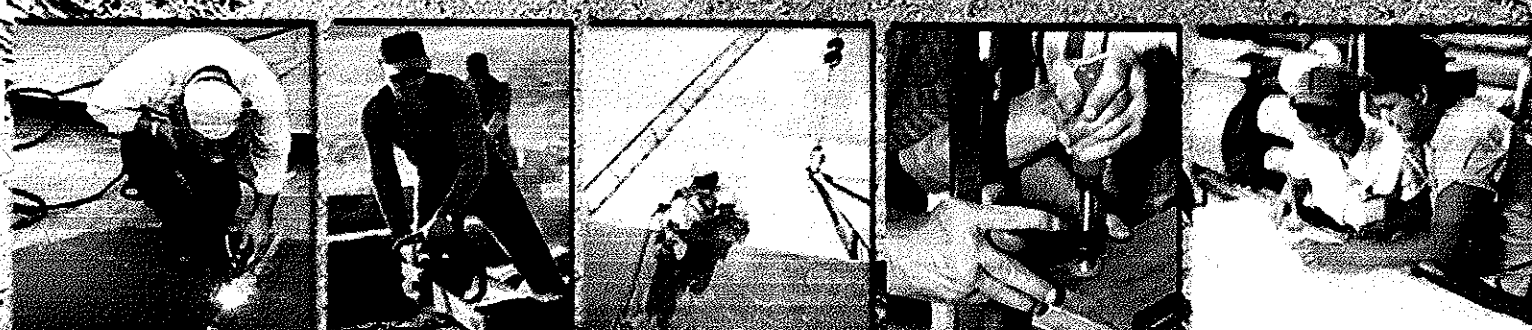


Proceedings of the First American Conference on Human Vibration



DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

National Institute for Occupational Safety and Health
NIOSH

Proceedings of the

First American Conference on Human Vibration

June 5-7, 2006

Waterfront Place Hotel
Morgantown, West Virginia, U.S.A.

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DHHS (NIOSH) Publication No. 2006-140
June, 2006

Foreword

It is my pleasure to welcome the First American Conference on Human Vibration to Morgantown, West Virginia. This meeting showcased the most recent research regarding the physiological effects of vibration. It explored the etiology of vibration-induced disorders and illuminated opportunities for their diagnoses, treatment, and prevention.

Vibration-induced disorders, such as work-related Reynaud's disease, are serious and potentially disabling. They may result in loss of feeling and interfere with one's ability to work. NIOSH has long sought strategies to prevent vibration-induced disorders. In 1983 the Institute published a Criteria Document describing the risk of vibration syndrome from the use of hand-held machinery. Since that time the body of knowledge in this field has continued to expand. We now better understand the risk faced by workers who drive on or off road vehicles, operate marine or aircraft, or are exposed to continuous building vibration.

This conference provided us with a historic opportunity to exchange information regarding this critical occupational health issue. The agenda promised a rich and diverse scientific program as researchers and medical professionals from around the world have gathered to examine human responses to hand-transmitted vibration and whole-body vibration.

NIOSH is pleased to have hosted the first U.S. conference to examine human vibration, and I would like to thank the many scientific presenters from both the U.S. and abroad who have come to share their work with us. Together, we will advance the science further and achieve safer and healthier workplaces.

I congratulate you on a successful conference.

John Howard, MD
Director, National Institute for Occupational Safety and Health

Acknowledgments

The convening of the First American Conference on Human Vibration was supported by the Health Effects Laboratory Division of the National Institute for Occupational Safety and Health (NIOSH). Many thanks to Frank J. Hearl (Chief of Staff, NIOSH) for delivering the opening address. Assistance with the organization of the conference was provided by Jamie Long (West Virginia University -- Continuing Education) and Barbara Elbon, Thomas McDowell, Daniel Welcome, and Christopher Warren (NIOSH). Editing, cover design, graphics, and layout were provided by Kimberly Clough Thomas (NIOSH). Tanya Headley (NIOSH) provided assistance with the final editing.

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Board of Scientific Advisors (in alphabetical order)

Table of Contents

Introduction

Vibrations caused by power tools, machinery, vehicles, and heavy equipment are a ubiquitous feature of modern work environments. In the U.S., an estimated six million workers are in occupations exposed to whole-body vibration and more than one million workers are in occupations exposed to hand-transmitted vibration (U.S. Bureau of Labor Statistics, 2004). Since Alice Hamilton's seminal report in 1918 on vibration-induced hand disorders in quarry stonecutters, the potential health risks associated with prolonged and repeated vibration exposure have been well recognized and documented. Efforts to understand the exposure risk factors and adverse health effects of occupational vibration exposure have waxed and waned over the years. Despite numerous studies and technological advances in vibration measurement and control, the exposure risks and etiology of the adverse health effects are not well understood. Human exposure to vibration remains a major risk factor associated with vascular, neural, and musculoskeletal disorders.

The First American Conference on Human Vibration (ACHV) was held in Morgantown, West Virginia, June 5-7, 2006. It was organized by the Health Effects Laboratory Division of the National Institute for Occupational Safety and Health and West Virginia University Department of Continuing Education. This conference provided a unique opportunity for a multidisciplinary group of national and international experts to exchange current information on all aspects of segmental and whole-body vibration exposures. The attendees included industrial hygienists, engineers, physicians, epidemiologists, scientists, psychologists, physiologists, health and safety specialists, consultants, students, and other individuals from Government, industry, and academic institutions from the U.S., Canada, and more than seven other countries.

Four keynote lectures and more than 60 papers were presented at this conference. Topics included vibration exposure measurement and quantification, biodynamic responses of whole-body and hand-arm system, subjective perceptions of vibration, physiological and pathological mechanisms, health effects, clinical diagnoses, epidemiological studies, prevention effectiveness, standard development and implementation. Presentations also described recent technological advances that may improve vibration measurement, tool and vehicle seat designs and tests, personal protection devices, and clinical diagnosis and assessment methods.

The ACHV was intended to prompt the convening of future, biennial conferences on human vibration in North America. We hope that the publication of these conference proceedings will help encourage new research and technological advances so that the health hazards associated with occupation vibration exposures will be significantly reduced.

Ren Dong
Kristine Krajnak
Oliver Wirth
John Wu

Morgantown, West Virginia

Keynote Speakers

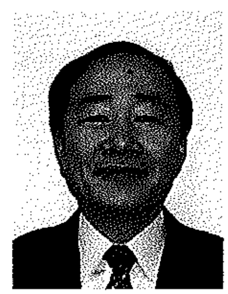
Michael J. Griffin

Michel Griffin, BSc., Ph.D., is the head of the multi-disciplinary Human Factors Research Unit in the Institute for Sound and Vibration Research at the University of Southampton in England. Professor Griffin is the Chairman of the British Standards Institution Sub-Committee concerned with human response to mechanical vibration and shock. He is also a member of relevant committees of the International Organization for Standardization and the European Committee for Standardization. Professor Griffin has particular research interests in biodynamics, human performance, ride comfort in vehicles, vibration-induced injuries, and motion sickness.

Setsuo Maeda and Neil J. Mansfield

Setsuo Maeda, Dr.Eng., Dr.Med.Sci. is the Director of Department of Hazard Assessment at Japan National Institute of Occupational Safety and Health in Kawasaki, Japan. His research interests include human response to multi-axis whole-body vibration and multi-axis hand-arm vibration. Neil Mansfield, B.Eng., Ph.D., is a Senior Lecturer in the Department of Human Sciences at Loughborough University in the U.K. He is Technical Director of OPERC hand-arm vibration test centre (HAVTEC) and heads the Vibration, Biomechanics and Noise research group of Loughborough University's Environmental Ergonomics Research Centre. He has worked in the area of human response to vibration and noise for 15 years as a consultant.

Hisataka Sakakibara



Hisataka Sakakibara, M.D., Ph.D. is a Professor at Nagoya University School of Health Sciences in Nagoya, Japan. His major research focuses on the pathophysiological effects of hand-arm vibration.

Chris Nelson

Chris Nelson, Ph.D. is a Specialist Inspector (Noise and Vibration) with the U.K.'s Health and Safety Executive (HSE). He has recently been involved with the development of British legislation, and supporting guidance, to implement the European vibration directive. He is also convener of the ISO and CEN working groups on hand-arm vibration. Prior to joining the HSE, Chris spent some years involved in research and consultancy work at the Institute of Sound and Vibration Research, Southampton University, gaining a Ph.D. for his study of vibration-induced white finger in dockyard employees. He then joined the Institute of Naval Medicine as Head of Acoustics and Vibration, moving to the HSE in 1997.

Keynote Presentation

HEALTH EFFECTS OF VIBRATION – THE KNOWN AND THE UNKNOWN

Michael J. Griffin
Institute of Sound and Vibration Research, University of Southampton, U.K.

Introduction

Science involves the study of the nature and behaviour of natural things and the knowledge we obtain about them. Scientific endeavour leads to the unfolding of new knowledge and adjustments to our understanding and our behavior. To indicate that we 'know' something may merely mean we do not feel able to, or that we do not wish to, disagree with others who claim to know; or it may mean we have either heard about it, or studied it, or understand part of it, or accept that it is true, or have seen evidence to be convinced of its veracity. What do we 'know' about the health effects of vibration?

There are many unknowns in the field of human responses to vibration. Not all would agree on what is known and what is unknown. This paper seeks to summarize what we know that we know, what it is sometimes claimed that we know, and what we know that we do not know about the relation between exposures to vibration and our health. It also speculates on what we do not know that we do not know.

Hand-transmitted vibration

What we know we know

We know that exposures to hand-transmitted vibration result in various disorders of the hand, including abnormal vascular and neurological function. Not all frequencies, or magnitudes, or durations, of hand-transmitted vibration cause the same effects.

What we may claim to know

To enable exposures to be reported and compared, they are 'measured' and 'evaluated' using defined (e.g. standardised) procedures. This involves identifying what is to be measured and specifying how it is expressed by one (or a few) numbers. Summarising a vibration exposure in a single value involves assuming the relative importance of components within the vibration (e.g. different magnitudes, frequencies, directions, and durations), so standards define 'weightings' for these variables. The importance of the weighted values may also be suggested, allowing 'assessments' according to a criterion (e.g. the probability of a specific severity of a specific disease).

Standards for the measurement and evaluation of hand-transmitted vibration define a frequency weighting and time dependencies that allow the severity of vibration exposures to be assessed and the probability of finger blanching to be predicted [1].

What we do not know

We do not know that the frequency weighting in current standards reflects the relative importance of different frequencies and axes of vibration in producing any specific disorder. We do not know whether the energy-based daily time-dependency inherent in A(8) reflects the relative importance of vibration magnitude and daily exposure duration. Consequently, the relation between A(8) and the years of exposure to develop finger blanching, as in an appendix to ISO 5349-1 (2001), is not well-founded.

We do not know, or at least there is no consensus on, the full extent of the disorders caused by hand-transmitted vibration (e.g. vascular, neurological, muscular, articular, central), or the pathogenesis of any specific disorder caused by hand-transmitted vibration, or the roles of other factors (e.g. ergonomic factors, environmental factors, or individual factors). We know that acute exposures to hand-transmitted vibration cause both vascular and neurological changes analogous to the changes seen in those occupationally exposed to hand-transmitted vibration, but we do not yet know how the acute changes relate to the chronic disorders.

Whole-body vibration

What we know we know

We know that many persons experience back pain and that some of these are exposed to whole-body vibration. We know that in the population at large, occupational exposures to whole-body vibration are not the main cause of back problems, and that ergonomic factors (e.g. lifting and twisting) and personal factors are often involved. We know vibration and shock can impose stresses that could supplement other stresses.

What we may claim to know

Measurement methods and evaluation methods have been defined in which the frequencies, directions and durations are weighted so as to predict the relative severity of different vibrations and indicate the magnitudes that might be hazardous [2].

What we do not know

We are not able to predict the probability of any disorder from the severity of an exposure to whole-body vibration. We do not know whether there is any disorder specific to whole-body vibration, or what disorders are aggravated by exposure to whole-body vibration. We do not know the relative importance of vibration and other risk factors in the development of back disorders.

Discussion

Providing guidance to others involves compromises – a perceived need, or other argument, may outweigh the cautious interpretation of scientific evidence. Standards for measuring and evaluating human exposures to vibration use uncertain frequency weightings and time dependencies but allow legislation for the protection of those exposed [3]. The standards may appear useful, but it is prudent to distinguish between standards and knowledge – between what is accepted to reach a consensus and what can be accepted as proven. Standards may guide actions but not understanding.

Where reducing risk solely involves reducing vibration magnitude or exposure duration, ill-founded evaluation methods will not increase risk. Where prevention involves a redistribution of vibration over frequencies or directions, or balancing a change in magnitude with a change in duration, an inappropriate evaluation method can increase risk. For example, the hand-transmitted vibration frequency weighting, which may be far from optimum, implies that gloves give little beneficial attenuation, whereas a different weighting might indicate that gloves can be a useful means of protection [4].

What do we not know that we need to know? Not all appreciate the benefits of placing more reliance on traceable data than on consensus. Traceability is fundamental to quality systems but deficient in current standardization. Standards can comfort their users – justifying actions without resort to understanding – while concealing assumptions that may prevent the minimization of the risks of injury from exposures to vibration.

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Keynote Presentation

EVALUATION OF WHOLE-BODY VIBRATION COMFORT

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Introduction

The purpose of using experimental subjective and/or perception methods is: (a) to understand human subjective impressions of the physical characteristics of vibration; (b) to determine the relationship between the subjective perception of some aspect of the vibration and an evaluation index of the physical vibration characteristics; and (c) the establishment of target values for design of vibration environments in terms of human sensation of vibration characteristics. In order to understand the relationship between a physical measure of the mechanical vibration and the subjectively perceived aspect of the vibration environment, experimental methods shown in Table 1 have been used[1].

Table 1. Psychophysical methods.

Constant measurement methods	Constant stimulus method Method of adjustment Method of limits Adaptive psychological method
Subjective scaling methods	Interval scale Paired comparison method Category judgment method Proportional scale Magnitude estimation

The constant measurement methods of Table 1 are mainly used for measurement of the threshold of human sense. The subjective scaling methods are mainly used for obtaining subjective (or proportional) scaling between the perceived quantity and physical quantity.

In this review, the fundamental approach of experimental methods for obtaining the target values used in the design of vibration environments, and the different findings between the subjectively perceived methods for evaluating human response to vibration characteristics and the physical quantity of the vibration environment are summarized.

Fundamentals of Subjective Scaling

The relationship between the experimental psychological methods for providing target values in the design of the vibration environments and the physical quantities is illustrated in Fig. 1. Vehicle mechanical vibration can be characterized using many metrics, and these can be considered the 'input' to the human. In order to predict subjective responses to the vibration, it is necessary to link the characteristics of the source of vibration and human reactions, the 'output'.

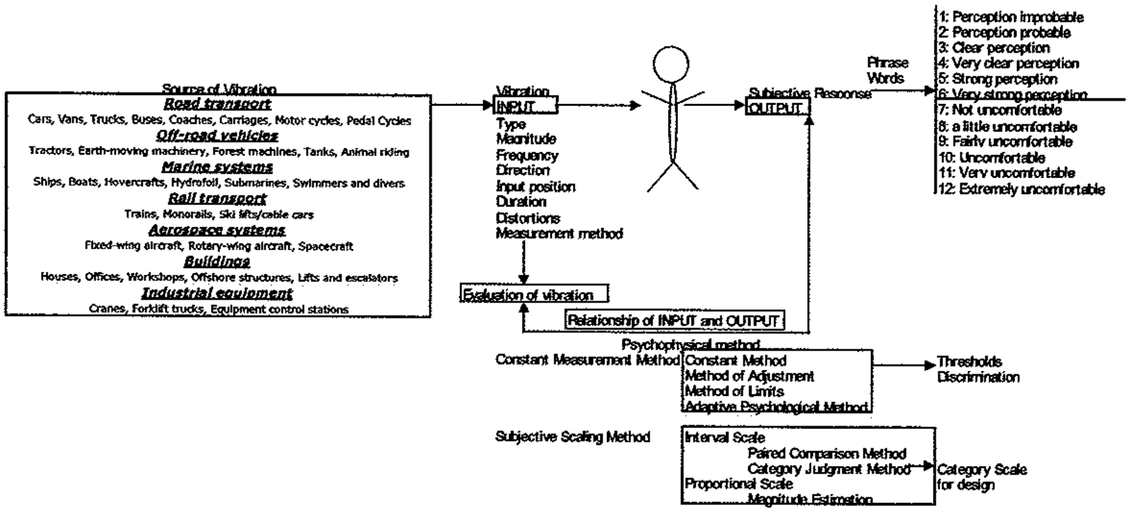

Fig.1 Relationship between vibration and subjective responses.

The constant measurement methods are usually used when the aim of the research is to understand human sensation in response to changes in the nature of the vibration (e.g. changes in frequency). The constant method uses an array of predetermined stimuli at discrete magnitudes above and below the expected threshold; the method of adjustment allows the experimental subject to control the magnitude such that they can set it to their threshold; the method of limits alternates the magnitude between detection and non-detection thresholds; adaptive methods use stimuli with magnitudes which step up and down, crossing the threshold, in response to subjective responses. In all of these cases the threshold could be absolute perception or some form of difference threshold.

Subjective scaling, such as using interval scales or proportional scales, has usually been used when the aim of the research is to understand human sensation in response to changes in the perceived magnitude of vibration. Paired comparisons requires subjects to choose one of two stimuli (e.g. greater intensity); category judgment requires subjects to select from a range of text descriptors (e.g. describing levels of discomfort); magnitude estimation requires subjects to give a numerical score to each stimulus. Some methods are used that try to combine qualities from more than one technique (e.g. Borg CR-100).

Each experimental method works in a different way and has its own advantages and disadvantages. Therefore, researchers must carefully choose the most appropriate experimental method. It is also essential to include enough information for readers to understand and assess the methods used when presenting and publishing results.

It will be necessary to conduct new experiments for the design of vehicles in the future, possibly requiring new psychophysical approaches. For example, new methods might be required to investigate the relationship between the human biodynamic response and subjective responses to multi-axis whole-body vibration.

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Keynote Presentation

SOME ASPECTS OF PATHOGENESIS OF VIBRATION-INDUCED WHITE FINGER

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Introduction

Although the pathophysiology of vibration-induced white finger (VWF) is still under discussion, evidence has been accumulated to understand the underlying mechanism.

VWF is pathophysiologically characterized by an enhanced vasospastic response to cold, which can result from an imbalance between vasoconstriction and vasodilation in the digital arteries in response to cold (i.e., vasoconstriction-dominant). The imbalance is supposed to be due to faults in vascular vessels and sympathetically mediated vascular tone.

Enhanced vasospastic response to cold

Structural factors for enhanced vasoconstriction (and vasodilation)

- Narrowing of arterial lumen with medial smooth muscle hypertrophy.

Possible functional factors for enhanced vasoconstriction

- Increased sympathetic nervous activity to cold (e.g., norepinephrine)
- Increased release of endothelin-1 (ET-1; an endothelial-dependent vasoconstrictor) from the endothelium
- Increased reactivity of alpha2-adrenoreceptors to cold

Possible functional factors for decreased vasodilation

- Decreased release of nitric oxide (NO; an endothelial-dependent vasodilator) from the endothelium
- Decreased release of calcitonin gene-related peptide (CGRP; a vasodilatory neuropeptide) from sensory afferents

The question is how their interrelations or imbalances among them are.

Vibration and arterial damage

The next question is, how does hand-arm vibration exposure induce such pathophysiological changes in VWF patients? Recent morphological evidence from animal experiments shows that vibration acceleration stress (including shear stress) and smooth muscle contraction contribute to arterial damage of smooth muscle and endothelial cells. The vibration-induced arterial damage is frequency-amplitude-dependent.

Repeated vibration exposure may damage smooth muscle cells to medial hypertrophy leading to lumen narrowing and injure endothelial cells to impaired vasodilation, resulting in vasospastic response to cold. The enhanced vasospastic response might in turn exaggerate vasoconstriction in response to cold.

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Keynote Presentation

EUROPEAN LEGISLATION AND STANDARDISATION FOR THE CONTROL OF RISKS FROM VIBRATION AT WORK

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Introduction

Two pieces of European Union (EU) legislation together establish requirements for protection against risks from vibration at work. The vibration directive[1] specifies duties of employers to protect workers from risks from exposure to vibration; the machinery directive[2], specifies duties of manufacturers and suppliers regarding the safety of machinery marketed in the EU. This paper discusses both directives and the standardisation programmes that support them. It also addresses the implementation of these requirements in Great Britain.

Employers' duties: the vibration directive

This directive requires employers to assess and control risks to health and safety arising from hand-arm vibration (HAV) and whole-body vibration (WBV). Member States were required to implement the directive in national legislation by 6 July 2005.

Employers are required to eliminate vibration risk at source, or reduced to a minimum. The duties include: assessing risk and exposure; planning and implementing the necessary risk control measures; providing and maintaining suitable work equipment; providing workers with information and training on risks and their control; and monitoring and reviewing the effectiveness of the risk control programme. Daily exposure exceeding a specified action value triggers a requirement for a programme of technical and organisational measures to minimise vibration exposures and the resulting risk, and the provision of health surveillance. Exposures above a specified limit value are prohibited.

When conducting their risk assessments, employers are required to "assess and, if necessary, measure" the vibration exposure of workers, for comparison with the action and limit values. Vibration measurement in the workplace is not expected in all cases and the use of vibration information from equipment manufacturers is specifically mentioned. This provides a link with the machinery directive (see below).

Manufacturers' and suppliers' duties: The machinery directive

The machinery directive, first introduced in 1989, is intended to remove barriers to trade. It puts duties on manufacturers and suppliers who place machinery on the European market to design their products to eliminate or reduce risks to health and safety and to warn the user of any residual risks, providing information required for safe use (for example, operator training, maintenance and selection of consumables). There are specific requirements for minimising risk from vibration in the design and construction of the machine and, in the case of hand-held, hand-guided and mobile machines, for declaring the vibration emission. If the declared emission of a machine is representative of the vibration in real-world use, it can be adequate to inform the user of residual vibration risks.

Standards supporting the two directives

The vibration directive contains two annexes (for HAV and WBV respectively) which define the metrics for daily vibration exposure by reference to ISO 5349-1:2001 for HAV and ISO 2631-1:1997 for WBV. The European Standards bodies (CEN and CENELEC) have no mandate from the European Commission to produce any standards in support of the vibration directive. However, CEN had, in 2001, adopted both parts of ISO 5349, and has also chosen to prepare a new standard providing guidance on assessing daily WBV exposures using the "A(8)" method.

The machinery directive is supported by a set of harmonized standards, mostly prepared by CEN and CENELEC under a work programme mandated by the European Commission. Where appropriate, this is done in partnership with ISO so that the relevant international standard is used to support the directive in Europe. The harmonized standards define safety requirements for various categories of machine (including the provision of user information); conformity with the relevant standard carries a presumption of conformity with the directive. The standards include test codes for vibration emission; some of those dealing with hand-operated equipment do not adequately describe the vibration in typical use and require revision.

Controlling risks from vibration at work in Great Britain

Both directives are implemented as regulations in the British legal system and are enforced by the Health and Safety Executive (HSE). HSE's work programme includes targeted inspections of high-risk activities (currently focusing on construction, foundries and steel fabrication) to ensure that HAV risks are properly controlled. Visits to tool manufacturers and suppliers are also undertaken, to secure improved provision of information on vibration risks. This front-line work is supported by the production of guidance material and activities to communicate HSE's messages on preventing vibration-related ill-health[3].

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Podium Presentations

Session I: Exposure I

Chairs: Suhbash Rakheja and Logan Mullinix

USING AN AIR BLADDER SEAT SHOCK ISOLATION SYSTEM TO PROTECT MILITARY VEHICLE OCCUPANTS FROM MINE BLASTS

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Introduction

Landmines are a great threat to military vehicles and their occupants. Mine blasts can completely destroy vehicles and kill all the occupants or disable the vehicle and leave the occupants severely injured. Injuries sustained during a landmine blast come from fragmentation that enters the vehicle through a hull breach, hot gasses expanding through the vehicle, or shock created from the extreme pressure of the blast (Lafrance, L.P. 1998). Mitigating the high acceleration experienced by the occupants during survivable mine blasts is the focus of the research being addressed in this paper.

Method

The objective of the project reported in this paper was to prove the feasibility that pneumatic seat technologies that employ light-weight, foam-filled, inflatable air bladder seats and seat backs can be used to protect the crews of lightweight combat vehicles against the detrimental and injurious effects of mine blasts. This protection includes reducing the shock energy experienced by seated vehicle crews during mine blast initiation and at vehicle slam-down to below potentially injurious levels. Figure 1 shows a schematic representation of the proposed lightweight, foam-filled, inflatable mine blast attenuating seat. It will consist of specially designed interconnected seat and seat back lightweight, foam-filed, air bladders that are supported by a rigid frame.

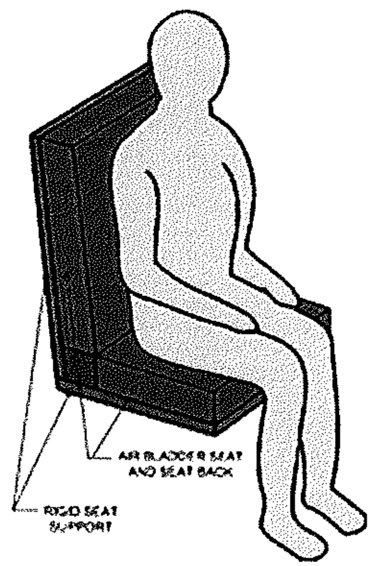

Figure 1 Schematic of Lightweight, Foam-Filled Inflatable Mine Blast Attenuating Seat

Results

Air gun tests and finite element analyses were conducted to determine the effectiveness of a light-weight, foam-filled, inflatable air bladder seat shock isolation system in isolating a vehicle occupant from the injurious effects of a mine blast. Figures 2 through 5 show analytical and experimental results associated with a 65.8 kg mass resting on an inflatable air bladder that is exposed to a shock input.

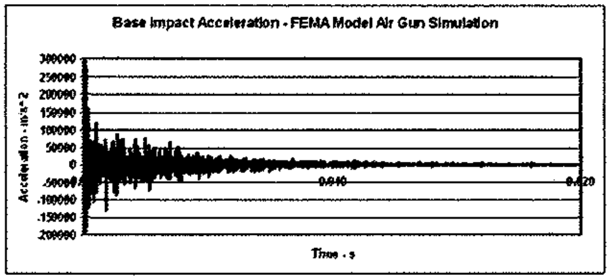

Figure 2 Simulated Air Gun Test Shock Input

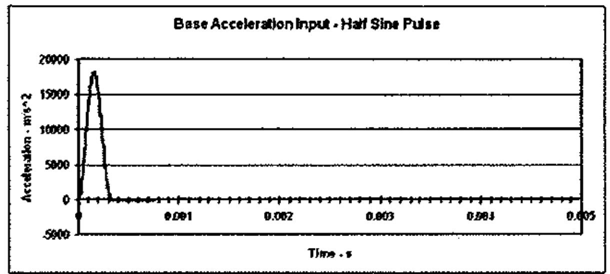

Figure 3 0.32 ms 8,000 m/s^2 Half-Sine Shock Input

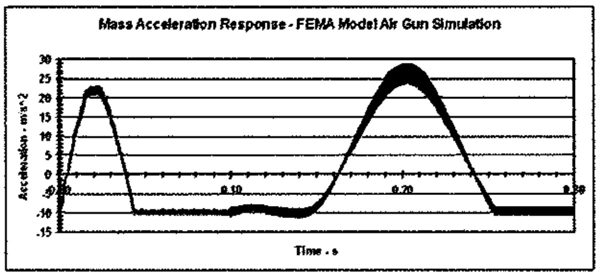

Figure 4 Supported Mass Acceleration – Air Gun Simulation

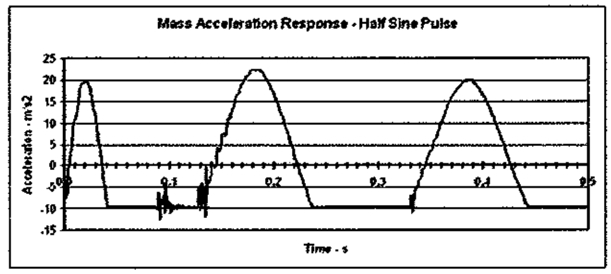

Figure 5 Supported Mass Acceleration – 0.32 ms 18,000 m/s^2 Half-Sine Pulse Input

Discussion

Table 1 shows that seat bladder reduced the peak acceleration response of the 65.8 kg mass relative to the peak shock input acceleration by three orders of magnitude for the air gun test and the half-sine shock pulse simulation.

The seat bladder shock isolation system has the potential when properly and fully developed to significantly reduce the injurious effects of mine blast shock inputs to seated individuals in lightweight combat vehicles.

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VIBRATION SPECTRAL CLASS CHARACTERIZATION OF LONG HAUL DUMP MINING VEHICLES AND SEAT PERFORMANCE EVALUATION

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Introduction

Long-haul dump (LHD) vehicles used in underground mining are known to expose workers to important levels of whole-body vibration[1]. These vehicles are generally designed without suspension and may be categorized as small or large LHDs depending on whether their respective load capacities are lower or larger than 3.5 cubic yards. While the majority of older vehicles are equipped with a rigid or unsuspended seat, more recent LHDs often incorporate a suspension seat.

The objective of this study was to define the vibration spectral characteristics of most commonly encountered large and small LHD vehicles operating in mining operations. This was done in an effort to categorize the vehicles in terms of vibration spectral classes to be reproduced on a laboratory whole-body vibration simulator to assess the vibration attenuation performance of a typical LHD suspension seat.

Methods

Vertical vibration measured at the seat attachment point of 8 small and 8 large LHD vehicles operating underground in typical mining operations under loaded and unloaded conditions was considered as the basis for defining the spectral classes. By regrouping the data collected for each LHD vehicle size and load condition, the overall distribution of acceleration power spectral density (PSD) of measured floor vibration was determined over the 0.5 to 20 Hz frequency range. Mean and envelopes of maximum and minimum values of PSD spectra were computed to define the spectral classes, along with the corresponding values of frequency weighted rms acceleration determined in accordance to the ISO 2631-1 standard[2]. These spectra were further used to calculate the displacements needed to drive a whole-body vibration simulator consisting of a platform supported by two servo-hydraulic actuators having a total stroke of ±100 mm. For validation purposes, the vibration acceleration spectra measured on the simulator were compared with the target spectra representing the spectral classes. Finally, the vibration transmissibility characteristics of a typical suspension seat were determined under sine sweep excitation using both a rigid mass load and a human subject having a mass of 62 kg and 85 kg, respectively. The SEAT value, representing the ratio of seat to base frequency-weighted rms acceleration, was further measured under each of the defined LHD vibration spectral classes by loading the seat with an 85 kg subject. Tests were repeated three times and the mean SEAT values were determined to assess the seat's ability to reduce exposure to whole-body vibration in LHD vehicles.

Results

Three spectral classes applicable to both loaded and unloaded conditions were defined as shown in Figure 1: one for large and two for small LHDs. The influence of load on frequency-weighted rms acceleration was found to be negligible for large and Class I small LHDs, while a shift of the peak acceleration PSD to lower frequencies was noted for the loaded vehicles. The influence of load was found to be more important for Class II small LHDs. Table 1 provides a comparison of frequency weighted, a_w, and unweighted, a, accelerations and dominant frequencies for the mean, maximum and minimum spectra associated with the different spectral classes. These were reproduced on a vibration simulator and used to assess the performance of a typical LHD suspension seat. The results obtained suggest that the seat cannot provide attenuation of the vibration at the dominant frequencies of the vehicles which range from 2.6 to 3.4 Hz . The measured SEAT values ranging from 1.25 for large LHDs to 1.35 for Class II small LHDs confirm that the seat is not adapted to these vehicles.

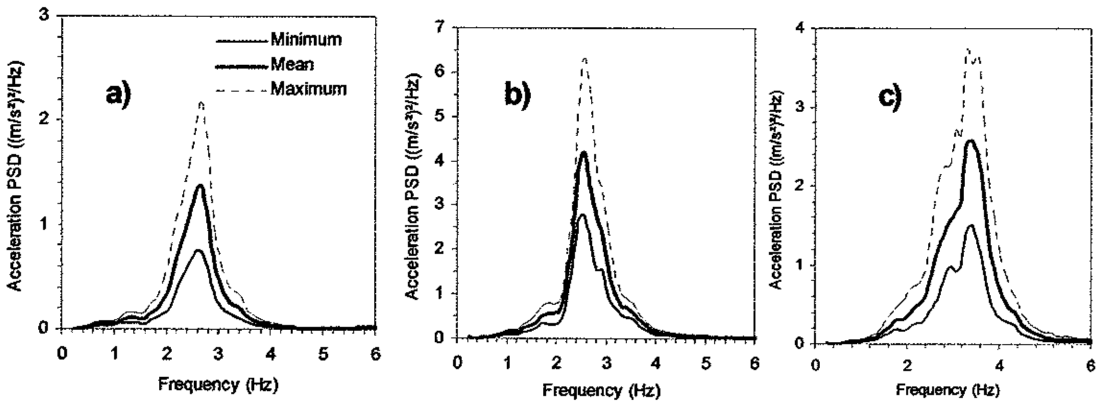

Figure 1 : Vibration spectral classes :a) Large LHDs; b) small LHDS Class I ; c) small LHDs Class II

Table 1: Characteristics of the spectral classes for large and small LHDs.

Spectrum	Large LHDs		Small LHDs-Class I		Small LHDs-Class II	
	a	a_w	a	a_w	a	a_w
Minimum (ms^{-2})	0.89	0.62	1.63	1.16	1.38	1.13
Mean (ms^{-2})	1.20	0.85	2.03	1.45	1.88	1.55
Maximum (ms^{-2})	1.52	1.09	2.45	1.76	2.36	1.95
Dominant frequency	2.7 Hz		2.7 Hz		3.4 Hz	

Discussion

The vibration measured in LHD vehicles can be categorized into three spectral classes, two of which apply to small LHDs. In general, small LHDs lead to much higher vibration levels than large LHDs and the spread of values is more important, particularly for class II vehicles for which the dominant vibration frequency is considerably higher than that of the other categories. Laboratory evaluation of a typical suspension seat recommended for use in these vehicles has shown that it is more likely to provide amplification of whole-body vibration under normal operating conditions.

Acknowledgment

The authors would like to extend their gratitude to the WSIB of Ontario and IRSST for funding this part of the research project.

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TIME-FREQUENCY ANALYSIS OF HAND-TRANSMITTED VIBRATION OF IMPACT TOOLS USING ANALYTIC WAVELET TRANSFORM

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Introduction

Prolonged, extensive exposure to hand-transmitted vibration could cause a series of vibration-induced disorders in the vascular, sensorineural, and musculoskeletal structures of the human hand-arm system, which have been collectively called hand-arm vibration syndrome (HAVS).[1] To assess the risk of HAVS the international standard ISO 5349-1 (2001)[1] recommends using the root-mean-square (rms) acceleration of the measured vibration with a frequency weighting. While a few epidemiological studies have reported results consistent with the predictions made according to the recommendation, many other studies have reported results with large discrepancies.[2] This may be partially attributed to the time-averaging effect involved in calculation of the frequency components, especially for impact type tools. Because the spectral characteristics of impact tools change dramatically with time, a time-frequency (T-F) analysis can provide better characterizations of such highly transient vibrations. The analytic wavelet transform (AWT) is an ideal T-F analysis tool because it possesses the advantages of both the Fourier transform and the wavelet transform.[3] The objective of this study was to explore the application of the AWT method for characterizing the impact tool vibrations and assessing their exposure risk.

Methods

Five tools (two chipping hammers, two riveting hammers, and one concrete cutting saw) were used in this study. The saw vibration was measured when it was used to cut a section of road pavement during a repair. The vibrations on the other tools were measured by the procedure specified in ISO 8662-2 (1992).[4] A sampling rate of 16,386 Hz was used in the measurement. The AWT and Fourier analysis were applied to these signals and to identify their characteristics.

Results

Figure 1 compares the T-F characteristics of the accelerations measured from the relatively steady concrete saw and a riveting hammer. The frequency weighting specified in ISO 5349-1[1] was applied in the calculations. The comparison clearly shows that the two tools have completely different T-F characteristics.

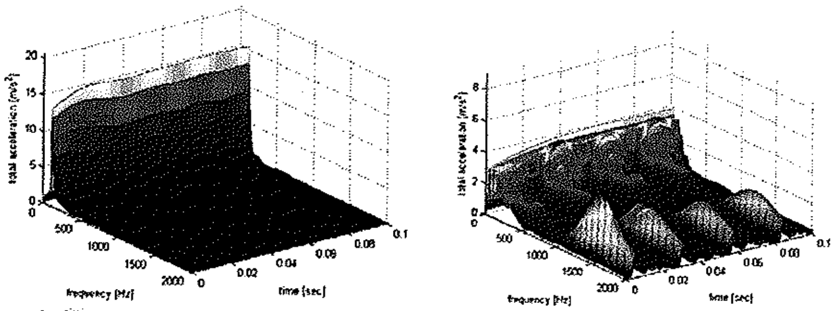

Figure 1: T-F characteristics of a concrete saw (left) and a riveting hammer (right).

Figure 2 compares the frequency-weighted and un-weighted 1/3 octave band spectra of the tools used in Figure 1. The spectra, especially in weighted forms, are not as strikingly different as those in Figure 1.

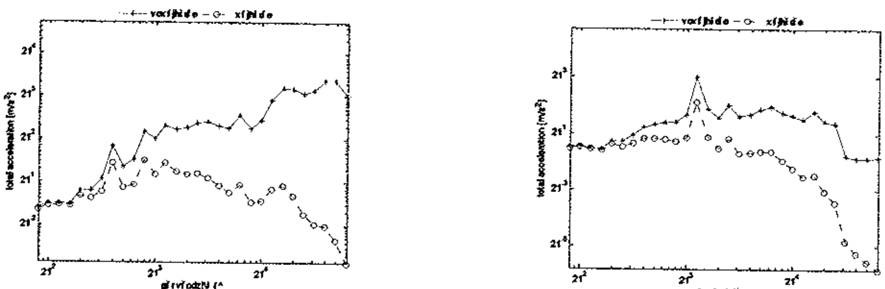

Figure 2: 1/3 octave band spectra of a concrete saw (left) and a riveting hammer (right).

Discussion

The frequency-weighted spectrum such as shown in Fig. 2 is used as the basis to calculate the vibration exposure dose in the standardized method.[1] The time averaging effect evens out the effect of sharp peaks that can be observed in Fig. 1. The health effects or thresholds of vibration exposure may be non-linear with respect to vibration magnitude, which may not be fully taken into account by the standard time-averaging- based method. The time-frequency-weighted acceleration can be calculated from the T-F spectra shown in Figure 1. Because the temporal changes of the frequency components can also be taken into account, the T-F method is believed to be a better approach than the conventional method for assessing the risk of impact vibration exposure.

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VARIATION IN THE VIBRATION EMISSION OF ROTARY HAMMER DRILLS UNDER SIMULATED WORK-SITE CONDITIONS

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Introduction

Tool manufacturers are required to provide declarations of vibration emission values in order to sell their tools within Europe. To ensure that users can compare results obtained from different manufacturers, the declared values must be obtained using a methodology as specified in the relevant test code (such as in the ISO 8662 series of standards). In most cases, the vibration emission values obtained using test codes under-estimate the vibration that an operator will be exposed to when using the tool on a work-site. A further problem with manufacturers' data is that usually only a single value is provided for a tool. This is despite many factors affecting the vibration emission, including inserted tool type, work piece, operator technique, tool condition. New improved test codes are in the process of being developed.

In order to provide guidance to users on how to interpret manufacturers' data, a Draft CEN Technical Report (Draft CEN/TR 15350 (2005)) was developed. Part of the CEN/TR provides multiplication factors for combinations of task and tool type. For example, data obtained from electrical hammer drills (tested according to EN 60745-2-6:2003) should be multiplied by 2, for hammering applications, in order to obtain an estimate of the vibration emission during work.

In response to concerns from industry, the UK trade association OPERC have, in collaboration with hire companies and tool manufacturers, established a freely accessible online database of tool emission values based on independent tests carried out under simulated work-site conditions. This paper reports some of the data obtained from electrical hammer drills, highlighting the range of emission values that can be obtained for a tool. Data from many other tool types are also included in the database.

Methods

Tri-axial hand-arm vibration was measured at both handles of each of 19 electrical hammer drills, in accordance with ISO 5349-1 (2001). Each tool was measured with three experienced operators and at least 5 runs were completed for each operator. Tools were tested using a range of appropriate new bits from 4 to 40 mm diameter. The minimum number of bits for a tool was 3; the maximum number was 29. 146 tool / bit combinations are reported here, representing about 2200 individual 6-axis measurements. Operators were required to drill vertically into a concrete block with a compressive strength after 28 days of 40 N/mm^2. Two drills (1 and 15) were battery powered; others were powered using a 110V transformer supply.

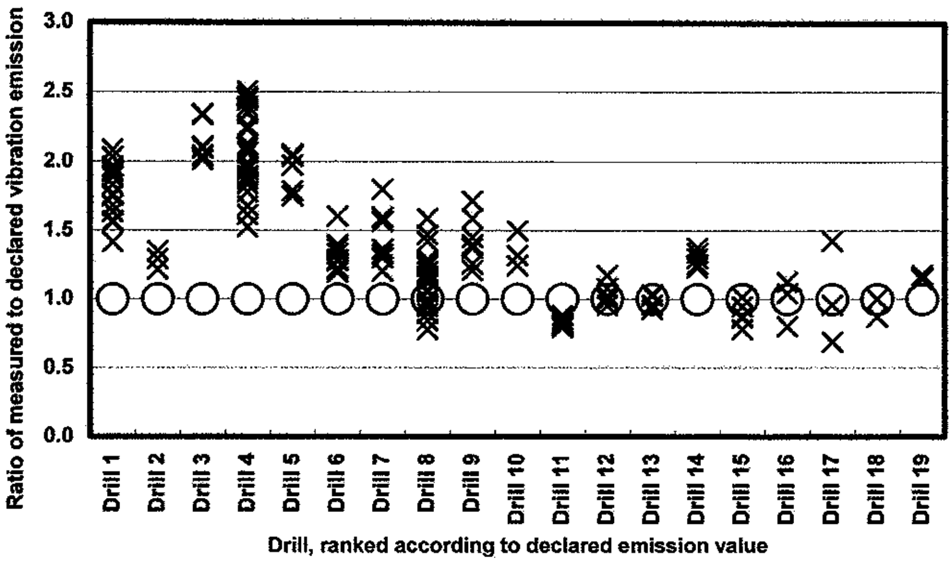

Fig 1. Ratio of measured emission to declared emission for 19 tools.

Results and Discussion

The relationship between the measured vibration and the declared vibration is illustrated in Fig 1. For those tools declaring vibration emission values less than 10 m/s^2 (Drills 1-10), work-site data were generally greater than declared values; for those tools declaring vibration emission values greater than 10 m/s^2 (Drills 11-19), work-site data were generally similar to declared values. Thus, if the scaling factors are used, those tools reporting higher but closer to simulated work-site values would be penalized.

In agreement with individual tool trends, there was a positive correlation between vibration emission and drill diameter (Fig 2, $p < 0.01$, Pearson). This indicates that provision of specific tool / bit data should improve applicability of risk assessments.

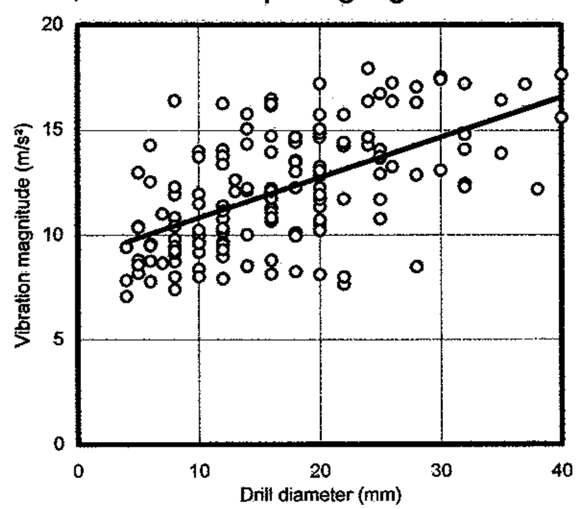

Fig 2. Relationship between drill diameter and vibration magnitude

Acknowledgements

Data in this abstract were drawn from the HAVTEC database (www.operc.com). The contributions of Dr David Edwards and Dr Andrew Rimell are acknowledged.

Reference

Draft CEN/TR 15350 (2005), Mechanical vibration – Guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery.

DEVICE FOR MEASURING DAYLONG VIBRATION EXPOSURE AND GRIP FORCE LEVELS FOR DURING HAND-TOOL USE

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Introduction

Over the past two decades, there have been significant reductions in industrial exposures to hand-arm vibration, especially when specific tools and work processes have been redesigned to incorporate anti-vibration and ergonomic principles. Nevertheless, Hand-Arm Vibration Syndrome (HAVS) remains a significant occupational health problem as disease symptoms continue to occur even when vibration exposure levels believed to incur low risks have been reached[2]. This inconsistency may be related to the methodology that is typically used to estimate workday vibration exposure levels, involving laboratory and/or very short duration field measurements coupled with estimates of overall eight-hour tool operation times determined from brief observations of tool tasks and/or self-reported surveys. One solution is to use small, commercially-available, personal vibration dosimeters to calculate, record, and display long-duration vector sums and energy equivalents of vibration. However, since these devices are attached to the worker and require tool-mounted accelerometers, they are incompatible with the worker performing normal duties involving putting down or changing tools. In addition, these commercial systems do not allow for the characterization of the transmission of vibration to the hand such as monitoring the mechanical coupling between the hand and the tool handle (e.g., grip forces). O'Boyle and Griffin showed that variations in applied force can alter vibration transmission characteristics by 50% or more indicating that the measurement of grip force is essential for modeling vibration transmissibility and vibration exposures[5]. In summary, a need exists for the development of a method and device that will more accurately characterize workday-long vibration exposures.

Methods

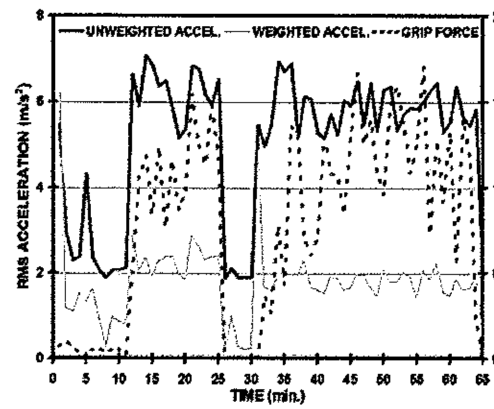
A portable, light-weight, Vibration Exposure Monitor (VEM) system was developed to record user-specific tool-operating times, vibrations, and grip forces throughout all, or a representative part, of a workday. It monitors frequency weighted and unweighted accelerations from a palm-mounted uni-axial accelerometer (Model 352C22, PCB Piezotronics, Depew, NY) and calculates exposure levels using the root-mean-square (RMS) and higher power mean values, such as the root-mean-quad (RMQ) and the root-mean-oct (RMO). Grip forces are also monitored using a palm-mounted force sensor (Model 400, Interlink Electronics, Camarillo, CA) from which average grip force levels and exerted grip extrema are calculated.

At the core of the VEM system is a commercially available, battery-powered microcomputer (Tattletale, Model 8v2, Onset Computer, Onset, MA) with one megabyte of memory and eight analog channels using 12-bit sampling at a single-channel maximum of 100 kHz. Analog signal processing (i.e., anti-aliasing, with cutoffs at 4 and 1250 Hz, and ISO 5349-1[3] frequency weighting) is accomplished using custom circuitry that is directly interfaced with the microcomputer. An embedded C-based protocol governs the data collection from each channel at a 3 kHz sampling frequency and performs all vibration and grip force calculations. The entire VEM system, including the ICP-type accelerometer, is powered using three 9 V batteries and can provide measurements for up to 12 hours, while retaining data in the RAM for up to 72 hours.

Results

Measures of acceleration and grip were validated through laboratory studies involving an electro-dynamic shaker outfitted with a handle and actual power tools. The frequency response of the palm-mounted sensors was measured at a 100 N grip and showed a flat response up to 3 kHz. Results for weighted and unweighted vibration and grip force are presented in Fig. 1 for a 65-minute window of debrushing operations during forestry work.

FIG. 1: DEBRUSHING VIBRATION EXPOSURE



Discussion

Given the nature of the root-mean and averaged calculations, the measurements made using the VEM system only provide estimates of the time histories of accelerations entering the hands and for the grip forces exerted throughout the workday. These estimates have been seen to be more accurate than traditional methods and can be used to assist in the subsequent construction of vibration exposure metrics for the development of exposure-response relationships as described in ISO 5439-2[4] and more complex metrics involving biologically plausible models of tissue burden and dose[1]. These metrics may also assist in determining why deviations from ISO's energy-based exposure-response models occur.

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CHALLENGES AND UNCERTAINTIES IN DESIGNING FIELD STUDIES TO MEASURE HAND VIBRATION

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Introduction

We encountered several areas of methodologic uncertainty during development of a data collection method for use with vibrating hand tools in metal assembly. A local manufacturer sought our assistance designing a data collection method for evaluating and predicting risks of upper extremity disorders associated with use of vibrating hand tools. Current methods of vibration measurement are described in ISO 5349 [2]. However, the complexity of measuring vibration along with other exposures such as force and posture has limited the number of workplace-based studies of upper extremity disorders that have included direct measurements of vibration. Data from this preliminary study was used to look at two issues: a comparison of vibration values between production and non-production workers when performing the same task, and a comparison of worker ratings of vibration comfort to direct measurement of tool vibration.

Methods

Eight experienced production workers used each of six metal fastening tools to install fasteners. Vibration was collected by 3 tri-axial accelerometers, one attached to the tool handle following ISO 5349 recommended locations, one attached to the hand dorsum on the 3rd knuckle and one to the thumb side of the wrist. Data sampling rate was 10,000 samples/second. Hand grip and feed forces were obtained using a Novel pressure sensing mat on the palm. Each trial consisted of installing 10 fasteners per tool for each of the 6 tools. The test set-up placed the wrist in the position typically used by the operator during production. Each worker documented subjective comfort and effort ratings on a seven point scale following each series of fastener installations. One series of testing was completed by three non-production workers inexperienced in fastener installation to simulate use of alternative employees for data gathering. Vibration data for each trial were acquired, digitized, and stored using LabView. The X, Y, & Z axes were used to calculate the vector sum response for each tri-axial accelerometer. The tool data were digitally filtered following ISO recommendations. Calculated data consisted of the mean RMS over the tool's on- time, the starting and breaking peak impulses, and the peak of the frequency response.

Results

Production workers (n=8) were right hand dominant males with a mean age of 55 years and normal hand strength (mean right grip = 106 lbs). Non-production workers (n=3) had similar characteristics.

We found large and statistically meaningful differences in hand force during tool use between production and non-production workers (mean production workers = 9.77 lbs, mean non-production workers = 43.30 lbs, p = 0.0001). Vibration values obtained from the hand also showed a statistically meaningful difference (mean in production workers = 0.67 Gs, mean in non-production workers = 1.48Gs, p = 0.0014, figure 1). Experienced worker ratings of comfort during tool use demonstrated a moderate correlation with measured vibration (r=0.63). Worker ratings trended with direct recordings from the tool handle as shown in figure 2.

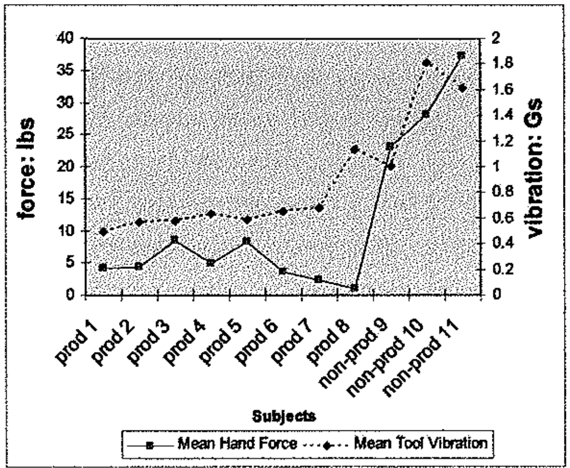

Figure 1. Comparison of hand force and vibration in production and non-production workers.

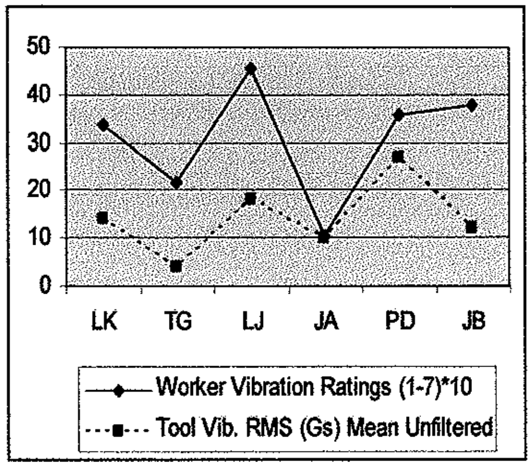

Figure 2. Comparison of worker ratings to vibration values produced for six different tools.

Discussion

This study highlights some of the issues that should be considered during vibration field studies. The striking differences in hand force and vibration between production and non-production workers suggest that vibration measures should be performed in the worker population actually using the tools. As workers become more adept at operating tools, they may use less hand force to perform a task, thus affecting vibration values. In our study, workers who were not experienced with daily use of the tools used higher hand force resulting in unreliable vibration values. The conditions of the field study should mimic real work conditions as much as is feasible, and deviations from normal work conditions should be considered when interpreting study results.

Our results also showed that worker ratings of tool vibration had reasonable correlation to measured vibration [1, 3]. This indicates that at least in a qualitative sense, experienced workers can estimate the magnitude of the vibration incurred during tool operation of familiar tools. Field studies may use worker rating data to identify problems or document the effectiveness of interventions. These data may supplement direct measures, particularly in large cohorts where direct measures on all subjects are impractical. Development of methods to estimate vibration under realistic work conditions will greatly enhance our ability to better understand the relationship between vibration and upper extremity disorders.

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Podium Presentations

Session II: Health Effects I

Chairs: Suzanne Smith and Oliver Wirth

SJEF!N PUJP O!F GGF DUT!P O!UI F!BDDVSBDZ!P GSBQJE!QP JOUJOH!UBTL T

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Introduction

Reaching movements are planned and subsequently executed [1] using visual and somatosensory feedbacks [2], where absence of visual feedback is known to increase endpoint variability [3]. Visual occlusion decreases the ability to make rapid online compensatory movements, which results in initial radial deviations that are highly correlated with radial dispersion at the target. Perturbations of rapid, visually-guided reaches are compensated on-line and result in endpoint dispersions poorly correlated with initial deviations, emphasizing the strong effect of visual feedback in temporally-constrained reaching tasks. In control conditions (no vibration), these uncompensated, rapid reaches serve as estimates of the individual's intended trajectory. When ride motion is present, trajectories of rapid, visually-occluded reaches provide a measure of the natural biodynamic response of the cantilevered spine-arm-hand linkage. These intended movement trajectories and the biodynamic response (vibration feedthrough) are used to predict the effect of ride motion on the performance of rapid reaching tasks. Goals of this study are to investigate the influences of vehicle motion on human reaching and pointing, and to reveal movement strategies used in visually-occluded reaching tasks.

Methods

A six degree of freedom human-rated Ride Motion Simulator (RMS) was used to generate a dynamic vehicle environment. Participants performed discrete, rapid pointing tasks to targets presented on three touchpanel displays under stationary and random whole-body vibration. Reach instructions included ***successfully*** reaching identical circular targets (Ø = 0.25") with the right index fingertip ***as fast as possible***. Targets were presented on resistive-touch displays mounted approximately 60 cm from the participant's nasion. The touchpanel displays were located in the forward and lateral directions at eye level, and forward at 45° of elevation. These displays measured the spatial error of the reach destination. A ten-camera VICON motion capture system recorded the upper body kinematics of the participant. Reflective markers were placed on the participant's torso, head, and arms. Initial kinematics of the fingertip (i.e. time and magnitude peak tangential velocity) and tangential velocity at target were used to estimate the planned endpoint of the reach.

Results and Discussion

Ride motion resulted in increased endpoint variability compared to reaches performed in the stationary condition. Reaches to the elevated touchpanel consistently resulted in the largest variability across all motion conditions, suggesting that a vehicle occupant would not be capable of accurately activating a control in that location. Principal axes of endpoint ellipses were along and perpendicular to the direction of fingertip movements. Example graphs of endpoint variability with ellipses containing 95% of the data points are shown in Figure 1. These ellipses might be used to enhance vehicle cockpit designs, where controls and displays could be shaped and oriented within the vehicle with respect to the operator and the probable reach direction.

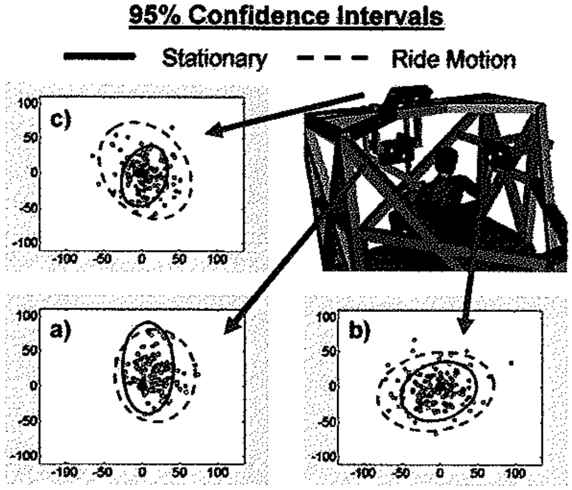

Figure 1. Comparison of 95% confidence ellipses of endpoint variability due to ride motion.

Analysis of the endpoint accuracy is illustrated using the circular representation in Figure 2a, where the deviations at peak velocity (PV, Figure 2b) are correlated with the deviations at the target (Figure 2c) with respect to the mean trajectory. If visual feedback mechanisms are not being utilized, than the dispersion of fingertip positions at PV (Figure 2b) should be replicated at the target. However, figure 2c shows that the actual endpoint dispersion at the target are poorly correlated (R^2 = 0.07) to values at PV for visually-occluded reaches, suggesting the interaction of proprioceptive feedback control.

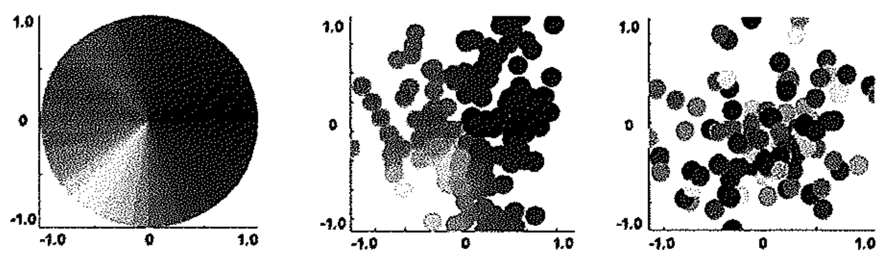

Figure 2. a) Illustration of the radial deviation of fingertip position at peak velocity (b, relative to the mean path) and reach endpoints (c, relative to the target center).

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THE EFFECTS OF VIBRATION ON PSYCHOPHYSICAL GRIP AND PUSH FORCE-RECALL ACCURACY

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Introduction

Workers using vibrating hand tools have the potential for developing health problems associated with repeated forceful actions and exposures to hand-transmitted vibration. Hand-arm vibration syndrome (HAVS) and other hand-arm system disorders have been associated with such exposures.[1-2] To better assess health risks, comprehensive evaluations of these exposures must include quantitative assessments of hand-tool coupling forces; unfortunately, no standardized method for quantifying hand forces exists. Handle instrumentation may be ill-suited for some field environments. Psychophysical force-recall techniques may provide alternatives to handle instrumentation. A thorough understanding of the effects of vibration and other factors on force-recall accuracy and reliability is important before such methods are applied in risk assessments.

Methods

In this study, the effects of vibration and other factors on the accuracy of psychophysical force-recall were explored in two experiments. Twelve male subjects participated in the first experiment. The second experiment employed 20 participants (10 female, 10 male). In each experiment, participants applied specific grip and push forces to an instrumented handle mounted on a shaker system. Participants were exposed to sinusoidal vibration at frequencies that ranged from 0 Hz to 250 Hz. Three levels of applied force (low: grip = 15 N/push = 25 N, medium: grip = 30 N/push = 50 N, and high: grip = 45 N/push = 75 N) and two levels of vibration magnitude (low: ANSI 4-8-hr limit and high: ANSI <0.5-hr limit)[3] were examined. During the vibration exposure period, participants were provided with visual feedback while they attempted to "memorize" the applied grip and push forces. At the conclusion of the vibration exposure/force memorization period and a controlled rest period, the participants tried to duplicate the grip and push forces on a non-vibrating handle without the aid of visual feedback. The effects of different vibration frequencies, vibration magnitudes, and grip and push force levels were tested in a random order from trial to trial.

Results

Participants tended to overestimate grip and push forces. Depending on exposure conditions, error means ranged from 2 N to 10 N. The ANOVA revealed that force-recall errors for exposures between 31.5 Hz and 63 Hz were significantly higher than those at other vibration frequencies ($p < 0.05$). The frequency effect is depicted in Figure 1. Error means were greater when participants were exposed to the higher vibration magnitude (mean = 9.1 N, 95% CI = 8.2-10.1 N) when compared with the lower vibration magnitude (mean = 4.9 N, 95% CI = 3.9-5.8 N) ($p < 0.05$). The effect of vibration magnitude is shown in Figure 2. The average error for females (4.9 N, 95% CI = 4.0-5.8 N) was significantly less than that for males (8.3 N, 95% CI = 7.4-9.2 N) ($p < 0.05$). The effects of force level were mixed.

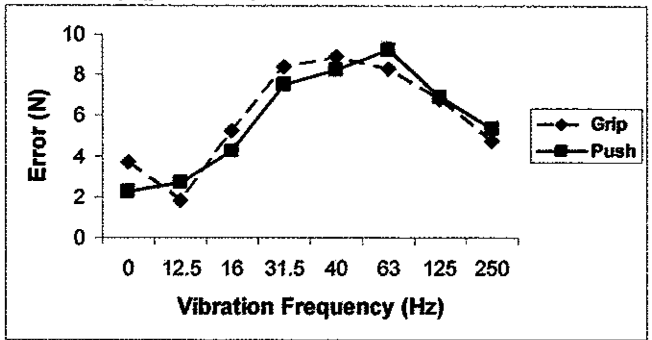

Figure 1. Grip and push force-recall error means plotted vibration frequency across all conditions of the two experiments.

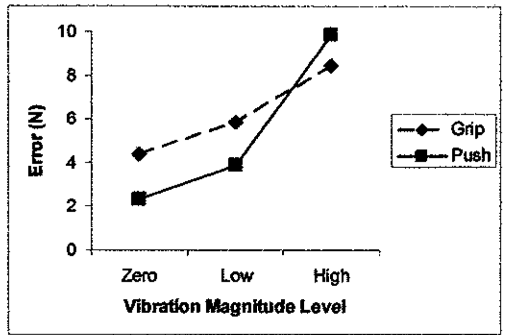

Figure 2. Force-recall error as a function of against vibration magnitude (Low = ANSI 4-8 -hr limit, High = ANSI <0.5-hr limit)[3] and exertion type.

Discussion

Overall, recalled force errors were relatively small over the range of operationally-relevant hand-handle coupling forces and vibration exposure conditions. Vibration exposure significantly affected grip and push force-recall accuracy. This result is consistent with previous research.[4-5] The vibration effect was particularly pronounced with vibration exposures between 31.5 Hz and 63 Hz. This frequency range coincides with that of hand-arm system resonance.[6-7] The effect of vibration was greater at higher levels of vibration magnitude. This force-recall technique shows promise as an alternative to expensive and fragile force-sensing instrumentation. For example, to account for anticipated force-recall errors due to vibration effects, weighting functions can be developed to yield accurate force estimates. Once refined, this psychophysical force-measuring technique can be incorporated into various risk assessments of hand-transmitted vibration.

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COMFORT EVALUATION FOR MINE SHUTTLE CAR SEAT DESIGNS

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Introduction

Industrial equipment exposes individuals to whole-body vibration (WBV) and mechanical shock. This exposure can negatively impact their health, safety, comfort, and working efficiency and performance. Accordingly, proper seat design is an important consideration in reducing the adverse effects of WBV exposure to vehicle operators. Since the human body is sensitive to low frequency WBV, ride quality is a basic and important element of good seat design. When designing a suitable seat, it is essential to understand vibration exposure environment of workers and how well they can tolerate this environment [1]. This is particularly true in the mining industry.

Mayton et al. [2] reported on a low-coal shuttle car seat design that underwent limited, yet successful underground mine trials. Building on this work, a follow-up study compared NIOSH and existing seat designs on low- and mid-coal seam shuttle cars. The NIOSH seat designs included viscoelastic foam, which has properties similar to those found in a mechanical spring/damper suspension system. The seats also included an adjustable lumbar support and a fore-aft seat adjustment. The NIOSH seat designs contrast with the existing seat design, which have little or no lumbar support and include inexpensive foam padding of the type commonly used in furniture.

This paper will focus on the seat designs for the mid-coal seam shuttle car and compare subjective comfort data collected from five vehicle operators with ISO 2631 – based reduced comfort boundary (RCB) analysis of recorded vibration levels.

Methods

Experimental data were collected using three different tools: triaxial accelerometers, pre-amplifiers, and filters connected to a data recorder; a visual analog scale (VAS); and a short questionnaire.

Researchers recorded quantitative or objective vehicle vibration data to determine the input and output acceleration at the operator cab floor and operator seat interface. Qualitative or subjective data, collected with the VAS, allowed researchers to obtain the operators' immediate impressions of shock, vibration, and discomfort levels for the vehicle ride on each of the seat designs. Each shuttle car operator made six round trips with the vehicle each seat. The shuttle car operator marked the VAS on the first, third, and sixth round trip of the trials for each seat. A round trip consisted of traveling to the coal face with no load and returning to the load discharge location with a full load of coal.

Results

Total overall average ratings for the five vehicle operators of the mid-coal seam shuttle car, showed that operators sensed from 45 to 87% <u>less</u> discomfort with NIOSH seat designs compared to the existing seat design. Using a 95% CI, researchers computed a strong positive correlation for discomfort.

Figure 1 illustrates the RCB analysis method for one of two NIOSH seat designs.

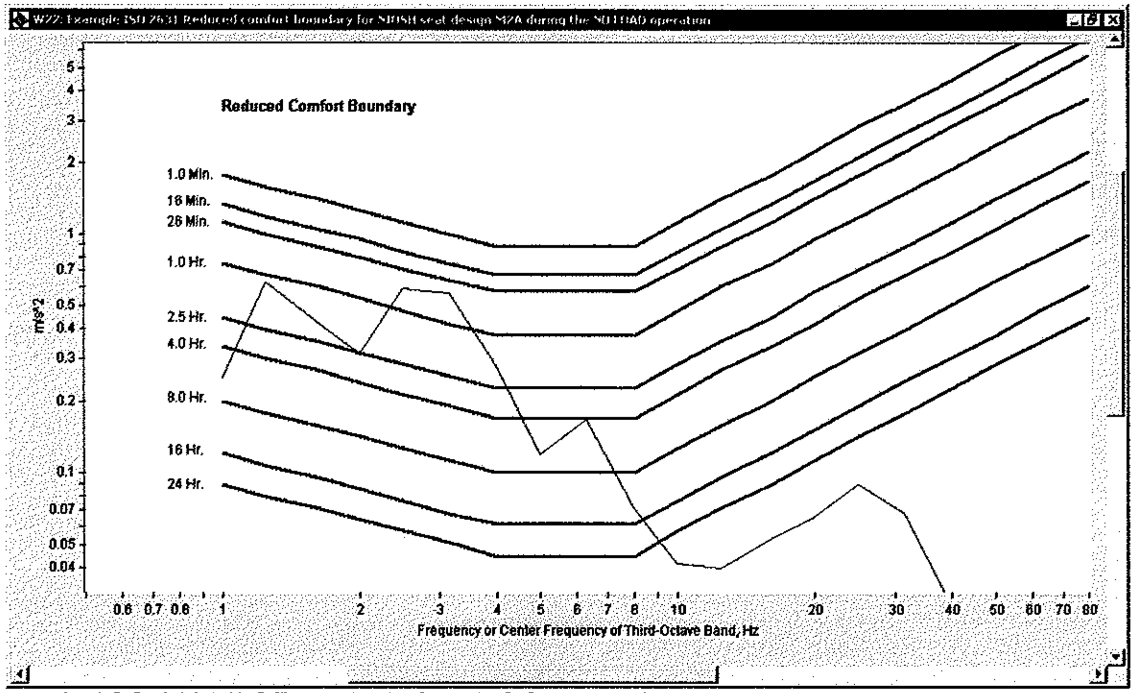

Figure 1. ISO 2631 RCB analysis for NIOSH seat design during *no load* operation.

Discussion

The RCB analysis during no-load operation showed that NIOSH seat designs, compared to the existing seat design, generally provided an increase in allowable exposure time for the vehicle operator, in the 4 to 8 Hz range. During full-load operation, the RCB analysis showed little difference in allowable exposure time for either the NIOSH or the existing seat designs. The natural frequency of the vehicle decreases for full-load operation as shown by the equation, $\omega = \sqrt{k/m}$ where, ω is the natural frequency, k is the spring constant, and m is the mass. Foam- or air-filled tires provide primary damping or attenuation of jars/jolts when the vehicle mass is increased with the full load of coal. Seat performance in attenuating of jars/jolts is thus secondary. The RCB acceleration-based analysis appears inadequate for correlating operator perceptions of discomfort. Vehicle operators' perceptions of discomfort are based more on the energy they sense transmitted to their bodies through the seat from the floor of the vehicle. So, the use of the absorbed power analysis reported by Mayton et al. [3], on the other hand, may provide a better means of correlating operator perceptions of vibration energy rather than the acceleration levels of the ISO 2631 RCB method.

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A METHOD OF EVALUATING VEHICLE SEAT VIBRATION WITH CONSIDERATION OF SUBJECTIVE JUDGMENT

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Introduction

Vibration magnitude and frequency of the z-axis vehicle seat are time-variant, which are influenced by not only vehicle vibration characteristics themselves but also road surfaces, speeds and the human body. There is little in the current reporting about evaluating and analyzing automobile seat vibration that focuses on the time-variant.

Yaguchi et al.[1] has proposed a method to evaluate automobile seat vibration that is based on judgments using a subjective mental state. Their method focuses on the time-variant magnitude of the peak frequency on a power spectrum density. However, their method has no consideration of all the frequency contents of the discomfort, nor comparison between different peak frequency vibrations. Suzuki[2] has emphasized that the vehicle vibration should be judged by a series of vibration stimuli to evaluate, because the vehicle vibration is time-variant, which isn't a matter of the relationship between a single vibration stimulus and a subjective response. He clarified that the human sensation to the vehicle vibration discomfort changes every moment showing the relationship between the frequency-weighted r.m.s. acceleration calculated every 5 seconds and the category judgment to vehicle vibration discomfort every 5 seconds. However, his study doesn't show what parameter connects to the subjective final judgment to vehicle vibration.

Therefore, we applied the method similar to ISO10056[3] considering the time-variant to the vehicle seat z-axis vibration evaluation. The new method for the vehicle seat vibration considering the time-variant was examined on the hypothesis that the final subjective evaluation must be conducted from the judgment summarizing a series of vibration stimuli.

Methods

The vibration bench system, which reproduces the movement of a vehicle floor, was used for the experiment with the single-axis (vertical direction) four-post road simulator system, which is usually used for a car, as shown in Fig.1. The experiment was done on the right side of the vibration bench using the floor vibration which was 5.5 minutes, 0.822 m/sec^2 (Wk) over the range 0.5-20Hz with 4 male subjects (age ave21.5, SD0.5, weight ave75kg, SD7.91kg, height ave166.8cm, SD5.2cm) and 4 suspension seats. As Fig.2 shows, subjects evaluated the degree of discomfort every 5 seconds to each seat vibration measuring the seat z-axis vibration acceleration.

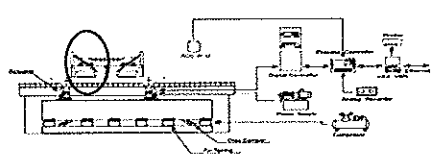

Fig1. Road simulator system

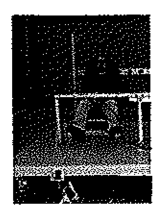

Fig 2. Right side of vibration bench system

Results

Fig.3 shows the discomfort evaluated every 5 seconds by 4 subjects matched up to frequency-weighted r.m.s. acceleration calculated every 5 seconds. Other seats also had the same tendency. As Table1 shows, evaluations by ISO2631-1[4] didn't fit final judgments by each subject. Table2 shows statistical parameters from cumulative distribution histogram of frequency-weighted r.m.s. acceleration calculated every 5 seconds applied the method of ISO10056. Seat A and Seat B had larger frequency weighted r.m.s. acceleration of the 90% band range than Seat C and Seat D. Seat A, which had the least discomfort, as judged by most of the subjects, had smaller values over all than Seat B had.

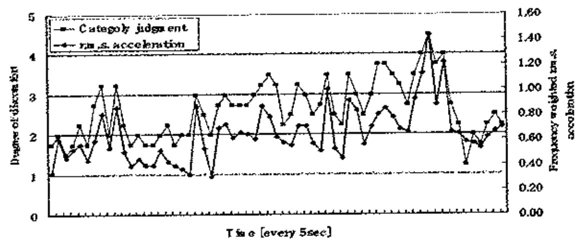

Fig.3 Seat A results of Frequency weighted r.m.s. accelerations and category judgments every 5 seconds.

Table 1. Evaluations by ISO2631-1 and subjective final judgments

	Seat A	Seat B	Seat C	Seat D	Least Discomfort seat
Subject1	0.694	0.675	0.665	0.65	Seat A
Subject2	0.673	0.728	0.647	0.66	–
Subject3	0.674	0.743	0.688	0.638	Seat A
Subject4	0.645	0.76	0.626	0.647	Seat A
Average	0.671	0.727	0.656	0.649	
SD	0.017	0.032	0.023	0.008	

Table 2. Statistical parameters of Wk r.m.s. acceleration cumulative distribution histgram

	Seat A	Seat B	Seat C	Seat D
Average	0.647	0.697	0.647	0.631
SD	0.216	0.244	0.166	0.191
Max	*1.456*	*1.552*	1.274	1.351
99%tile	*1.425*	*1.525*	1.225	1.325
95%tile	*1.045*	*1.17*	0.975	1
5%tile	*0.362*	*0.375*	0.416	0.375
1%tile	*0.287*	*0.3*	0.375	0.312
Min	*0.27*	*0.28*	0.36	0.294
80%band	*0.5*	*0.604*	0.416	0.45

Discussion

It was shown that the human sensation of discomfort to vehicle seat vibration changes every moment influenced by the time-variant seat vibration. It clarified the new evaluation and analysis method for seat vibration that was based on the hypothesis that the final judgment was conducted from summarizing a series of time-variant vibration stimuli. An additional study is required to investigate the applicability to different types of vehicle vibration using a larger number of subjects.

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PERCEPTION THRESHOLDS FOR LATERAL VIBRATION AT THE HAND, SEAT, AND FOOT

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Introduction

Discomfort, annoyance, or interference with activities due to exposure to vibration is only expected if the vibration exceeds the threshold for the perception of vibration. When there is more than one vibration input to the body (e.g. at the hands, seat and feet), the sensation is first experienced at the location with greatest sensitivity. Knowledge of differences in the thresholds of perception for vibration at the hand, seat, and feet should assist the identification of sources of discomfort caused by vibration.

Perception thresholds for vibration have been determined in several studies, but only a few studies have investigated perception thresholds in the horizontal direction for hand-transmitted vibration [2-4,7] or whole-body vibration [5,6], and there has been little consideration of perception thresholds for the foot resting on a vibrating surface.

This study determines absolute thresholds for the perception of sinusoidal lateral vibration, examining the effect of vibration frequency (8 to 315 Hz for the hand and foot; 2 to 315 Hz for the seat) and the effect of input location (the hand, the seat and the foot).

Methods

Three groups of twelve males aged between 20 and 29 years participated in the experiment. Subjects in each group attended an experiment to determine perception thresholds for lateral vibration via either a rigid handlebar (30 mm diameter) at the left hand (left hand), or a rigid contoured seat (250 mm x 150 mm), or a footrest at the left foot (30.5 mm x 10.5 mm with 10-degree inclination). For the non-exposed hand (right hand) or foot (right foot), a stationary handle and footrest with the same dimensions as the vibrating handle and footrest were provided so that the same body posture was adopted among the three groups of subjects.

An up-down (staircase) algorithm was employed to determine thresholds in conjunction with a three-down one-up rule. A single test stimulus (2.0 seconds) was presented with a cue light illuminated during this period. The task of the subjects was to indicate whether they perceived the vibration stimulus or not. The threshold was calculated from the mean of the last two peaks and the last two troughs, omitting the first two reversals.

Results

The median absolute thresholds of the 12 subjects determined at each frequency for the hand, seat and foot are shown in Figure 1. A frequency dependence of the threshold contours within the investigated frequency range is evident, with similar shape to the threshold contours determined in other research [4,7]. Among the three locations (hand, seat and foot), the thresholds between 25 and 63 Hz did not differ significantly. The seat was the most sensitive to lateral vibration at 8 and 10 Hz among the three locations (Mann-Whitney, $p<0.05$). The hand was less sensitive to lateral vibration than the seat and foot at 12.5, 16 and 20 Hz (Mann-Whitney, $p<0.05$), but more sensitive than the seat and foot at frequencies greater than 100 Hz (Mann-Whitney, $p<0.05$).

Discussion

It is evident from Figure 1 that the vibration threshold contours derived from the present study are inconsistent with the reciprocals of the relevant frequency weightings (e.g. W_h, W_b, and W_d) in current standards [2,3], indicating greater sensitivity at high frequencies relative to low frequencies than implied by the standards for predicting perception thresholds at the hand, the seat, and the foot.

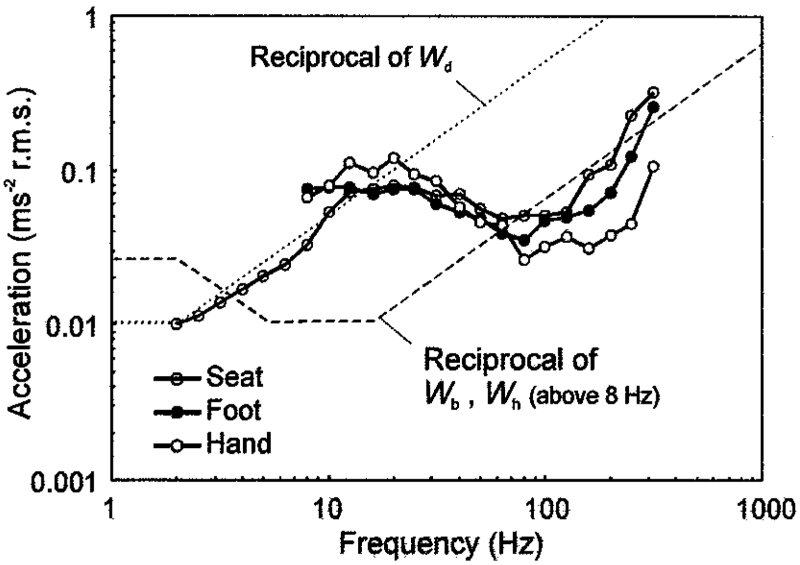

Figure 1 Median perception threshold contours for lateral vibration at the hand, seat and foot. The reciprocals of W_b, W_d, and W_h frequency weightings [2,3] normalized to 0.01 ms^{-2} r.m.s. are overlaid.

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NEUROMOTOR HABITUATION AS A MECHANISM FOR VIBRATION INDUCED LOW BACK PAIN

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Introduction

Occupational exposure to whole body vibration has long been associated with increased incidence of low back pain and low back injuries[1]. A number of studies have investigated transmissibility of seat pan vibration [5, 6]. While transmissibility has been well researched, the mechanism by which vibration may induce injury has not been thoroughly studied. Winter et al. identified increased reflex response delay after vibration exposure and speculated that muscular fatigue may be the cause of this increase[9]. However, a mechanism has yet to be demonstrated completely.

A potential mechanism that may explain the increased risk is neuromotor habituation. Muscle spindle organs have been shown in the extremities to be sensitive to muscle and tendon vibration. Rapid length changes in muscle have been shown to result in kinesthetic illusions as the regular firing of the muscle spindles is interpreted as muscle lengthening[4, 7]. These illusions have also been demonstrated in the paraspinal musculature[2]. With removal of vibration, research in the extremities has demonstrated increased positioning errors, probably due to neuromotor habituation[8].

In this research, it has been hypothesized that neuromotor habituation after exposure to occupational vibration will increase positioning errors. It is further hypothesized that these errors can be shown to be linked to increased reflex response time. Such increased reflex response time could, in turn, decrease spinal stability and increase low back injury risk.

Methods

Both positioning error and sudden load response were measured before and after exposure to 20 minutes of 5 Hz, 0.223 m/s^2 RMS seat pan vibration. Subjects were asked to sit on an unpadded seat without a backrest. Throughout the whole body vibration period, subjects were instructed to put their hands on a stable hand rest and feet on an adjustable stable footrest. The subjects were instructed to assume a comfortable and relax sitting posture for the duration of the exposure.

Positioning error was measured using an active-active reposition sense protocol. Electromagnetic markers (Motionstar, Ascension Tech, Burlington, VT) were used to track trunk motion. With markers attached to the skin at the T10 vertebra, the S1 vertebra and manubrium, trunk flexion (the angle from vertical of the line connecting T10 and S1) and lumbar curvature (the difference in inclination of the T10 and S1 markers) were tracked. In the reposition sense protocol, subjects were asked to maintain an upright trunk flexion and to rotate their pelvis and lumbar curvature to assume a target lumbar curvature. In the protocol subjects completed training trials, where they were asked to match their lumbar curvature using a visual display, and assessment trials, where they were asked to reproduce the lumbar curvature from memory. After two initial training trials, training trials and assessment trials were alternated for a total of 3 assessment trials. Reposition error was defined as the absolute difference between the target lumbar curvature and the lumbar curvature the subject assumed during the assessment trials.

For sudden loading trials, subjects were asked to stand on a force plate with their pelvis fixed with a belt. A sudden impulse load was applied by dropping a weight of 4.5 kg a height of 10 cm. The weight applied a sudden flexion moment through a chest harness. Electromyographic (Delsys, Boston, MA) data was recorded from the erector spinae, rectus abdominus and internal and external oblique muscle groups. Trunk motion was collected with the electromagnetic sensors.

A simulink model (MATLAB, Natick MA) was created in which the trunk was modeled as an inverted pendulum and muscle reflex response was modeled as a feedback with a detection threshold, a fixed time delay, and a linear gain. Overall trunk stiffness and trunk inertia from Cholewicki et al. were used[3]. An increase in positioning errors was modeled as an increase in detection threshold.

Results

Both reposition error and erector spinae muscle activity delay were found to increase significantly after exposure to vibration, returning close to baseline after approximately 20 minutes. This pattern was also reflected in the significant increase after vibration in trunk flexion in response to sudden loading.

By increasing detection threshold for reflex response in the model, it was possible to show that changes in the detection threshold (position error) would indeed increase response delays and increase trunk flexion. It was shown that altering gain did not change these delays suggesting that muscular fatigue may not explain the data.

Discussion

From the model, it can be predicted that loss in proprioception (position sense) can lead to increased muscle response times and increased trunk flexion in response to a sudden load. This was also demonstrated experimentally. This association supports the hypothesis that neuromotor habitation from vibration can lead to loss in proprioception and in turn alter low back stabilization. Future work will examine occupational factors such as seating configuration and vibration frequency on these neuromotor changes.

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Podium Presentations

Session III: Biodynamics I

Chairs: Douglas Reynolds and Farid Amirouche

PNEUMATIC ACTIVE SUSPENSION DESIGN FOR HEAVY VEHICLE SEATS AND OPERATOR RIDE COMFORT

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Introduction

Handling of heavy vehicles such as tractors, trucks and buses require a large roll stiffness which causes large high accelerations at the seat level during impacts. To provide comfort and minimize the energy transfer from the chassis and the seat a pneumatic active seat suspension is proposed. An active seat suspension design and control algorithm under development at the University of Illinois at Chicago, UIC, is being developed and tested. Preliminary results are presented in this paper.

The design of a passive suspension typically consists of optimizing the value of two parameters: the stiffness and the damping of the suspension. The general dynamic performance of the suspension is limited to the conditions under which these parameters were obtained. A change in the input conditions might lead to poor suspension and an amplification of the vibration transmitted to the body. The focus of this paper is a robust, semi-active suspension system with a variable controlled damping and using the body response an index measure to minimize the acceleration at the interface of the seat and operator.

A summary of existing suspensions, such as MR and ER fluids, and spring loaded and dual valve shock absorbent will be discussed to highlight the need of a semi-active pneumatic suspension system design.

Methods

A model of the proposed suspension was developed in MATLB (Simulink) and different control strategies for the valve position in relation to the cylinder pressure tested. The effects of stiffening and softening resulting from pressure changes in the cylinder were examined. The vertical accelerations of the seat was computed for different control strategies and configurations of the suspension and compared to the response of a passive seat suspension.

A lump -mass model was created to represent the human body including the head, the upper, middle and lower torso as well as the legs. The connective forces between body segments were modeled through modal analysis techniques from previous experiments at the Vehicle Technology Laboratory. ISO standards and absorbed power were used to evaluate the different configuration of the seat suspension system in relation to the dynamic response of the operator.

Results

Initial results of the semi-active suspension system show a significant reduction in the RMS value of the acceleration of the seat. A reduction of the total absorbed power by the operator is expected to provide an insight into the control strategies adapted in the active suspension.

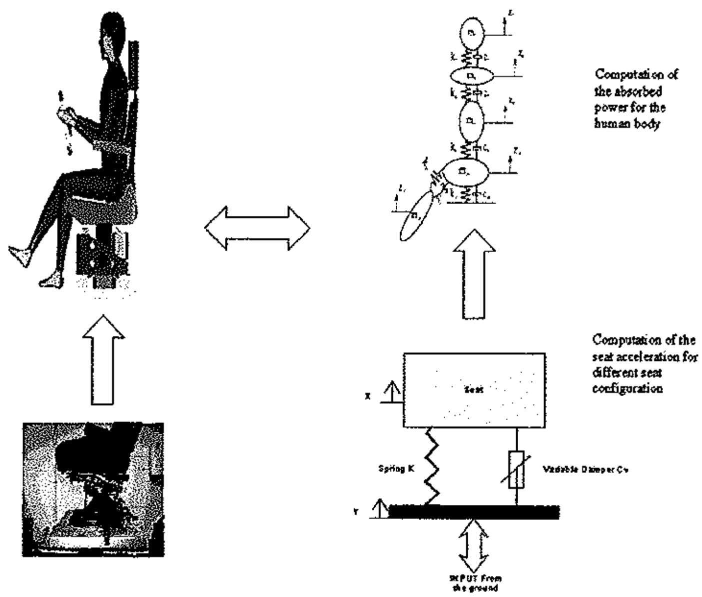

Figure 1 : Scheme of the general method applied in the study

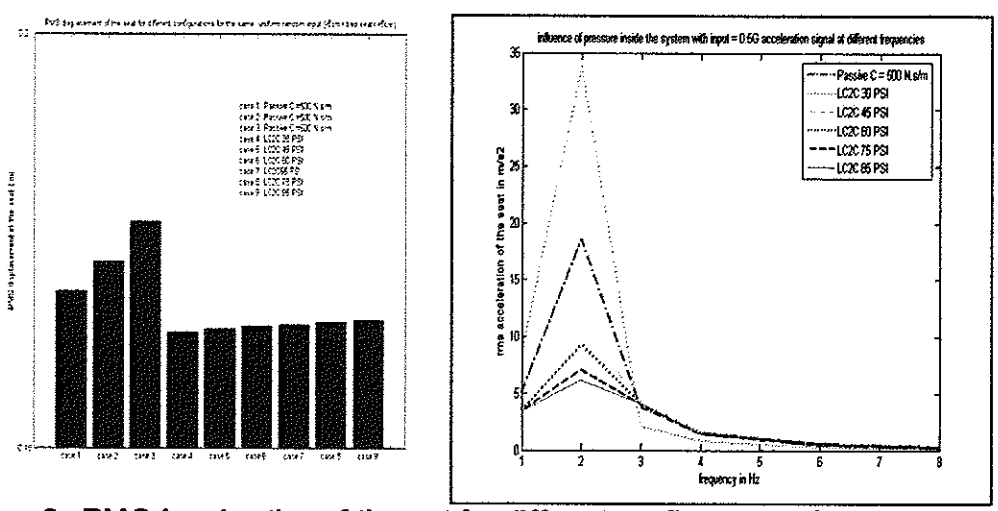

Figure 2 : RMS Acceleration of the seat for different configuration of the suspension

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HAND FORCE-DEPENDENT MODELING OF THE HAND-ARM UNDER Z_H-AXIS VIBRATION

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Introduction

A number of biodynamic models of the hand-arm system have evolved on the basis of measured driving-point mechanical impedance (DPMI) responses to facilitate analyses of the coupled hand-tool system [1]. The parameter identifications in such models are based upon minimization of an error function of the model and the target impedance data, which may not yield a unique solution. Consequently, a number of model structures and parameter sets could be realized that would equally satisfy the target curve. Moreover, the vast majority of the reported models exhibit acute deficiencies due to excessive static deflections of model masses, presence of a low frequency mode and very light masses in the order of 1.2- 4.8 grams. The models also do not characterize the dependency of the biodynamic responses on many factors, namely the hand forces, hand-arm posture and vibration intensity. This study aims at development of a hand-arm biodynamic model with considerations of the hand forces, and both the DPMI and power absorption measures, to enhance the uniqueness of the model.

Methods

Two different model structures are chosen for identifying the model parameters on the basis of measured DPMI and absorbed power characteristics of the hand-arm system under z_h-axis vibration over a range of hand-grip and push forces. Owing to the strong influence of the hand-handle coupling forces, the models were initially derived for fixed hand forces, namely 30 N grip and 50 N push forces, as suggested in the ISO 10068 standard [2]. The equations of motion for the model are formulated and solved to compute both the DPMI and absorbed power responses. A constrained minimization function comprising weighted errors of both the DPMI and absorbed power is formulated and solved to identify the parameters. Alternate functions corresponding to different combinations of hand forces are then applied to identify hand-force dependent model parameters.

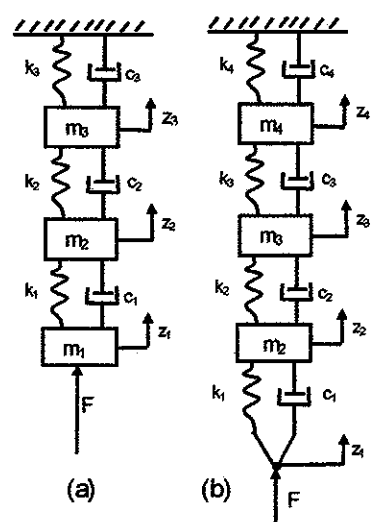

Fig. 1: hand-arm vibration models

Variations in the model parameters are investigated as functions of the grip, push and coupling forces through linear regression analysis. Regression-based models are formulated for deriving the hand-handle forces dependent model parameters. The validity of the model is also examined under selected combinations of hand forces.

Results and Discussions

Comparisons of models results with the measured data suggested that both model structures could predict the DPMI as well as absorbed power reasonably well, when variations in the hand forces are neglected. The model with the visco-elastic interface (b), however, provided relatively poor agreements and large static deflection under a static push force. The model stiffness and damping parameters identified on the basis of measured responses for nine different combinations of hand forces revealed linear variations with the hand forces, particularly the coupling force. The model masses, however, revealed only minimal sensitivity to variations in the hand forces. The resulting relationships between the model parameters and the coupling force (CF) were thus used to formulate a hand force-dependent mechanical-equivalent model of the human hand-arm system using model (a). These relationships suggest linear increase in stiffness and damping coefficients with increasing coupling force, and assume the general form:

$$k_i = a_1 CF + a_0 \text{; and } c_i = b_1 CF + b_0 \quad \text{for } i=1,2,3$$

where a_0, a_1, b_0 and b_1 are constant coefficients. Multiple linear regressions between parameters and the grip and push forces (F_g and F_p) as independent variables, were also performed, which resulted in higher correlation factors (>0.88). These are expressed as:

$$k_i = a_2 F_p + a_1 F_g + a_0 \text{; and } c_i = b_2 F_p + b_1 F_g + b_0 \quad \text{for } i=1,2,3$$

Comparisons of model responses with the measured data revealed reasonably good agreements in both the DPMI and absorbed power magnitudes for the hand forces combinations considered. Consideration of parameters as functions of grip and push forces would also be more desirable than that based upon the coupling force only.

While the DPMI magnitude is known to exhibit negligible sensitivity to variations in excitation magnitude, the absorbed power increases considerably under a higher vibration magnitude. The validity of the resulting model under different magnitudes of excitation was thus explored by comparing the model results with the data acquired under $a_{h,w}$= 2.5 and 5 m/s^2. The model results revealed reasonably good agreements with measured absorbed power and the DPMI under both levels of excitations.

The vibration properties of the proposed models could be considered appropriate in view of the practical issues related to model implementation, namely static deflection, damping ratio and resonant frequencies. The eigen-frequencies of the proposed model also revealed good agreements with the frequencies corresponding to the peaks observed in the DPMI magnitude data, while the static deflections of masses were relatively small.

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DYNAMIC RESPONSES OF A FINGERTIP TO VIBRATION - 3D FINITE ELEMENT ANALYSIS

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Introduction

Although the exact mechanisms underlying vibration white finger (VWF) are not clear, it has been speculated that VWF is associated with variations of the blood flow patterns due to the physical damage and/or degeneration in neural and vascular tissue caused by vibration loading [1]. Excessive dynamic deformation of the soft tissues in the fingertip under vibration loading is believed to induce multiple occupation-related hand/finger disorders. However, the in vivo distributions of the dynamic stress/strain of the tissues in the fingertip under vibration conditions have not been studied because they cannot be measured experimentally to date. The goal of this study is to analyze, theoretically, the location and frequency-dependent dynamic deformation of the soft tissue in the fingertip during vibration exposures.

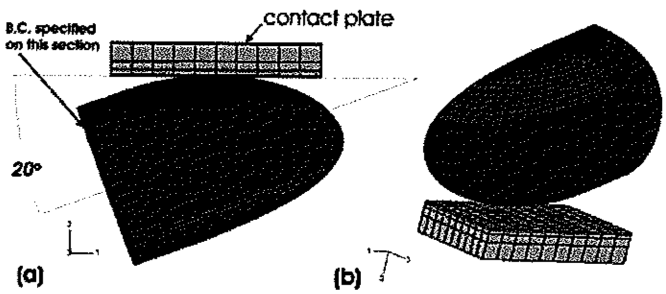

Figure 1: FE model of the fingertip in contact with a flat surface. (a): side view. (b): perspective view. The fingertip is in contact with a flat plate with a contact angle of 20°.

Methods

The fingertip considered in the model is the distal phalanx, the portion from the distal end of the fingertip to the distal interphalangeal (DIP) joint articulation (Fig. 1). The external shape of the fingertip was determined using a smooth mathematical surface fitting to the observed fingertip shapes. The fingertip surface was then scaled to the dimensions of a typical male index finger: length 25 mm, width 20 mm, and height 18 mm. The fingertip was approximated to be symmetric, such that only a half of the fingertip was considered in the FE modeling. The fingertip was assumed to be composed of outer and inner skin layers, subcutaneous tissue, bone, and nail. The soft tissues (inner skin layer and subcutaneous tissues) were assumed to be nonlinearly elastic and viscoelastic, while the bone, nail, and outer skin layer were considered as linearly elastic. The simulations were conducted using a displacement-controlled protocol in two stages. First, the fingertip was statically pre-compressed. The contact plate was first displaced towards the finger to achieve a predetermined value of tissue deformation (i.e., 0.5, 1.0, 1.5, and 2.0 mm). Second, the steady-state dynamics responses of the fingertip were analyzed using a linear perturbation procedure. The fingertip was subjected to a continuous harmonic excitation (magnitude 0.5 mm) from the contact interface. The dynamic analysis was performed in a frequency domain ranging from 16 to 2000 Hz. The frequency-dependent distributions of the vibration magnitude and dynamic strain magnitudes in the soft tissues are investigated.

Results

Typical simulation results for the frequency-dependent distributions of the vibration magnitude in the soft tissues are shown in Fig. 2 (figures show the results with a pre-compression of 2.0 mm). The vibration magnitude at the contact surface is 0.5 mm (specified) for all frequencies, while the vibration magnitudes in the soft tissues are location- and frequency-dependent. It is clear that the fingertip has a major resonance around 125 Hz, at which the vibration magnitudes in the soft tissues are over four times greater than that of the contact plate (0.5 mm). It is interesting to observe that, at this resonant frequency (125 Hz), the soft tissues at the tip has the maximal vibration magnitude while the regions near the contact

NUMERICAL MODELS AND HARDWARE DUMMIES FOR SIMULATING WHOLE-BODY VIBRATION OF HUMAN - AN OVERVIEW

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Introduction

The goal of biodynamic models is to simulate the vibration behaviour of the human body. In combination with experimental studies biodynamical models can be a powerful tool for the analysis of the effects of vibration exposure on health [1] and comfort. This paper gives an overview of the state of the art of biodynamic whole-body vibration models of humans, addressing both numerical models and hardware dummies.

Method

Two approaches are distinguished, the phenomenological and the anatomical, as illustrated in Figure 1.

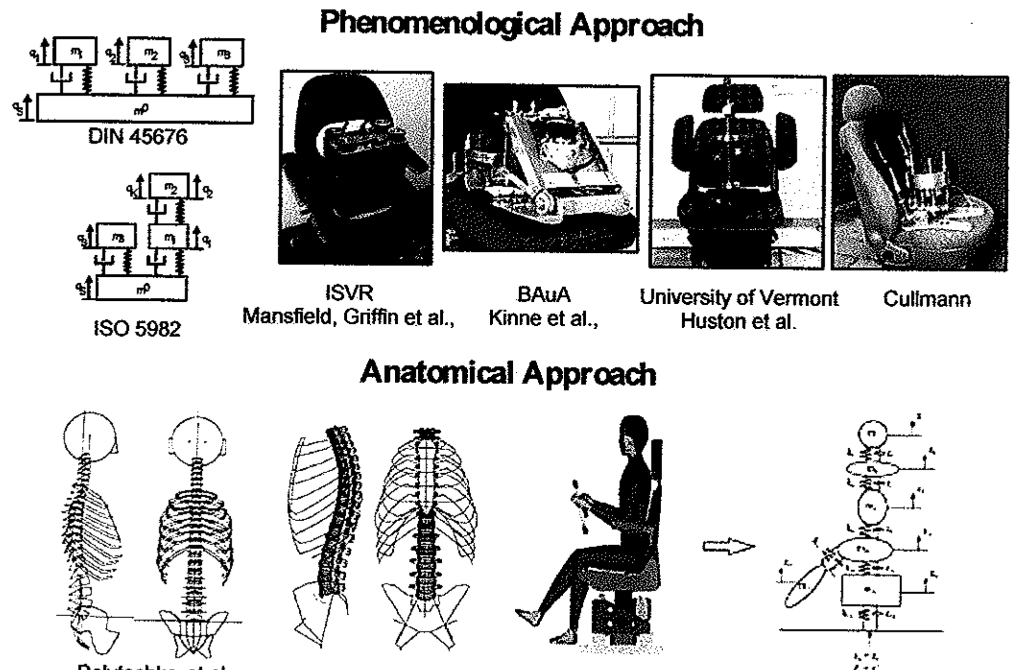

Figure 1: Two modelling approaches.

Phenomenological models aim to reproduce the vibration behaviour of humans with respect to particular physical quantities, chiefly the driving-point impedance at the interface to the seat, and partly with respect to other transfer functions. Discrete systems of masses, springs, and dampers with several degrees of freedom whose topology and parameters are determined by structure- and parameter identification methods are used in the sense that the functions derived from measurements are reproduced as well as possible. This paper provides an evaluation of this methodology and defines its range of application as well as its limits.

The aim of anatomical models, on the other hand, is to simulate numerically all quantities potentially relevant for the evaluation of vibration behaviour, as well as to calculate those unknown quantities not accessible from experimentation, e.g., the loading of the lumbar spine. The basis for these models is human anthropometry and physiology [2]. Multi-body systems and finite element models are utilised as mathematical models. Because of the complexity of the claim, the validation of anatomical models with the help of experiments on test persons is important. This paper gives an overview of various types of anatomy-based models, their range of application, and the current trends in this field.
Two types of hardware vibration dummies have been developed so far: Passive and active dummies. Both types of dummies aim to reproduce the driving-point impedance at the interface to the seat. Passive dummies consist of a system of masses, springs and dampers. They are based on phenomenological models. Active dummies additionally use an actuator to meet given response functions in a more flexible way.

Results

There is a broad variety of biodynamic models used to simulate human whole-body vibrations [3]. The use of these models requires a critical check of the biodynamic properties employed to describe the models, as well as how they were validated [4].This is most important for numerical models, but also valid for hardware dummies.
In order to accurately simulate motions and loads numerically, including the effects on health and comfort sensations of an individual exposed to vibration, a high level of research is essential. In particular, this necessitates the extension and systematisation of the experimental database needed for the validation of spatial vibration behaviour, and to what extent the dependence of the factors of posture, anthropometric properties, age, gender and potential pre-damage can be systematically calculated.
For anatomy-based models, there is an urgent need for research on the modelling of the lumbar spine, especially with regard to the development of damage models, the modelling of muscles, the influence of muscle activity, and finally the modelling of the inner organs and soft tissue involved in the man-seat interface.

Conclusion

Numerical biodynamic models are needed for any systematic analysis of the relationship between vibration exposure, health and comfort. But the range of their application must be carefully limited to the range in which they are validated. Numerical models and hardware dummies will help to support the development of technical systems for the reduction of vibration impact.

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SIMULATION OF HUMAN MOTION, MUSCLE FORCES AND LUMBAR SPINE STRESSES DUE TO WHOLE-BODY-VIBRATION: APPLICATION OF THE DYNAMIC HUMAN MODEL CASIMIR FOR THE DEVELOPMENT OF COMMERCIAL VEHICLES AND PASSENGER CARS

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Introduction: Occupant modeling

In the development of commercial vehicles as well as of passenger cars, the effects of vehicle vibrations on operating safety, health and comfort can only be predicted by numerical simulation when appropriate occupant models are available. Such models must be based on human anatomy and have dynamic properties of real humans in order to achieve realistic results. Since human dynamic behavior depend on posture and percentile, the occupant model needs to be adjustable to these parameters with respect to geometry and dynamic properties [1,2].

Dynamic Human Finite-Element-Model CASIMIR

CASIMIR is a non-linear, dynamic finite-element-model of the human body. It consists of a dynamic model of the upper torso with head, neck, shoulders and arms as well as of a dynamic model of the lower extremity with pelvis and legs. The most important part is the lumbar area with dynamic non-linear models of the lumbar spine and of back and abdominal musculature. The frequency-dependent characteristics of the intervertebral discs and the effects of muscle activation and non-linear frequency-dependent muscle properties are included. In the latest stage of development, CASIMIR has been equipped with a compliant model of the body surface in the contact areas to the seat. This results in a very realistic transmission of static and vibrational forces into the human body, see fig. 1. Intense model verification and validation has been performed in all stages of model development, starting with validation of small components like intervertebral disc, ending with validation of whole-body-vibrations using measurements of the dynamic mass / mechanical impedance [4]. For an in-detail examination of stresses in the vertebral bodies and discs, a non-linear submodel of the lumbar spine with an increased number of degrees of freedom can be coupled to the whole-body-model, enabling the researcher to examine local effects of vibrations and single shocks on the lumbar materials.

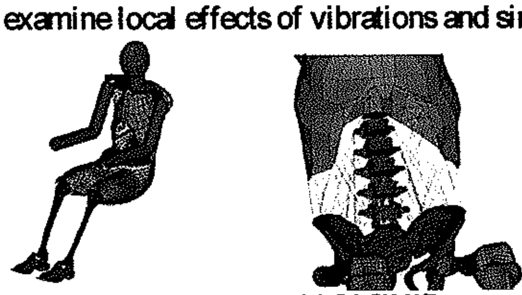

Fig. 1: Dynamic human model CASIMIR

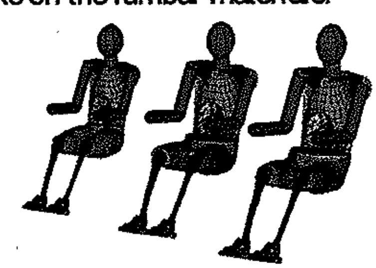

Fig. 2: CASIMIR f05, m50, m95

Since it is well known that human dynamic behavior is significantly affected by anthropometric data and posture, CASIMIR can be individualized to the anthropometric status of single individuals or to the mean values for specific percentile groups. Furthermore, posture can be adjusted to the seating conditions applicable to a specific vehicle. Posture modification capabilities include the variation of the lumbar lordosis [3].

Static Seating: Muscle Activation and Static Forces in the Lumbar Spine

Due to non-linearities of human body and seat a qualified simulation of the static seating procedure is a prerequisite of any simulation of dynamic responses of the human body and seat. During static seating simulation, the human model takes the desired posture on the seat, muscles are activated in order to maintain this posture and thus the non-linear biomaterials of the human body as well as the non-linear foam materials in common seats of commercial vehicles and passenger cars are loaded in an appropriate trim point. This ensures automatic selection of the correct tangent stiffness for the succeeding vibration analysis. A static seating simulation gives a number of valuable results with respect to the human body:

- muscle activation / muscle forces: ergonomic judgment of the body posture
- static forces and static stresses: relevant for damage in the vertebral discs
- pressure distribution (comfort, fig. 3) and H-point-location (package, safety)

Multiaxial Dynamic Excitation: Motions, Forces and Stresses

After static seating simulation, dynamic excitations in multiple axes (x,y,z) can be applied on the human model or the model of the occupied seat (seat + human). Usually, an excitation is selected that is typical for the seat slide (or the seat surface) of the specific vehicle under investigation. For commercial vehicles with higher amplitudes of excitation, a non-linear solution procedure has to be applied while comfort simulations may be covered with linearised procedures. Results to be analysed are motions of the body with respect to operational safety of commercial vehicles, dynamic forces in the musculature with respect to operational performance and dynamic forces / stresses (with submodel) in the lumbar spine with respect to health, fig. 4.

Fig. 3: Static seat pressure

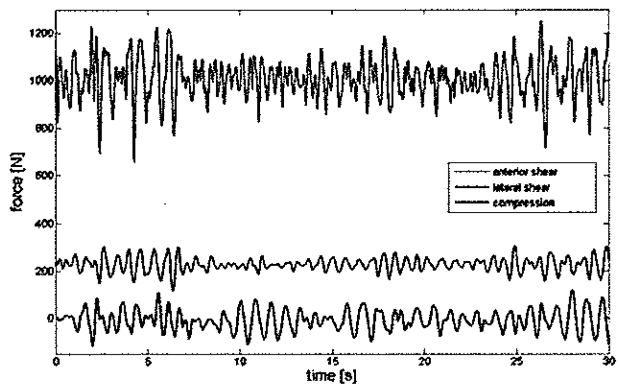

Fig. 4: Dynamic disc forces, spinal level L4L5

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A CASE STUDY OF WHOLE-BODY VIBRATION EXPOSURES ASSOCIATED WITH ORDINARY PASSENGER AND RECREATIONAL VEHICLES

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Introduction

Measurements and analyses were conducted of whole-body vibration aboard seven commercially available passenger and/or recreational vehicles: sedan; sport-utility vehicle (SUV); pickup truck; moving truck; motorcycle; all-terrain vehicle (ATV); and boat. The purpose of the testing was to measure and assess whole-body vibration exposure in a range of typical vehicle environments in order to gain understanding of typical exposure levels characteristic of activities of daily living.

Vehicle models tested (and model year) were: Ford Taurus (1995); Jeep Cherokee Sport (2000); Toyota Tundra SR5 (2002); Ford F-350 (1997); Harley-Davidson Electra Glide Classic (2004); Yamaha Kodiak 400 4x4; and Steiger Craft Model 21 Montauk. All vehicles were tested with their standard factory-installed seats and were operated under a range of normal operating conditions and speeds typical of intended vehicle use.

Methods

The measurement, processing, analysis, and exposure assessment methods follow the guidance of generally accepted, national and international consensus standards relevant to the evaluation of whole-body vibration, including ISO 2631-1 [1] and ANSI S3.18 [2].

Seats were instrumented with low-mass triaxial accelerometers mounted in seat pads. Accelerometers used in the test are specified to have flat frequency response over the frequency range of 0.5 to 80 Hz, and all accelerometers were recently calibrated traceable to the National Institute of Standards and Technology (NIST). Seat pads were installed following guidance in the relevant standards [1, 2], with sensitive axes of the accelerometers following the standard coordinate system with respect to the seated occupant. (The x-axis represents fore-aft motion; the y-axis represents side-to-side motion; and the z-axis represents vertical motion with respect to the occupant.)

Vibration data processing and analysis, including filtering, sampling, frequency-weighting, averaging, summation, and determination of basic and additional metrics followed procedures in the relevant standards [1, 2]. Digitized time series data were acquired and stored using a PC-based data acquisition system. Whole-body vibration exposure analyses were conducted via post-processing. During data processing, recorded periods of seat acceleration that were identified and verified as resulting from occupant-induced motion rather than vehicle motion were excluded prior to exposure analysis.

The basic evaluation metric for whole-body vibration is the frequency-weighted root-mean-square (r.m.s.) acceleration, a_w. The primary additional evaluation metric is the fourth-power vibration dose value, VDV. The VDV measured for a period of time can be normalized to a standard eight-hour time period using a standardized calculation process.

Testing of on-road vehicles was conducted on public roads. The routes included a variety of road surfaces and features that are typical of road travel in urban, suburban and/or rural areas. Testing of the ATV was conducted off-road, on rural trails. Testing of the boat was conducted in a bay and estuary in calm conditions with waves of less than one foot. The total duration of vibration measurements during vehicle operations ranged from approximately 1½ hours for the ATV and boat to approximately 4½ hours for the SUV.

Results

Results of basic and additional exposure metrics are summarized in the table below. Basic r.m.s. acceleration is expressed in m/s^2. Measured VDV for the duration of the test and VDV normalized to an 8-hour exposure period (VDV_8) are expressed in $m/s^{1.75}$.

Vfi jdfh	bxy	bxz	bx{	VEVy	VEVz	VEV{	VEV8y	VEV8z	VEV8{
Sedan	0.27	0.21	0.38	4.6	3.8	7.4	6.2	5.2	9.9
SUV	0.14	0.20	0.33	2.9	3.9	6.8	3.4	4.6	7.9
Pickup Truck	0.16	0.19	0.30	3.0	3.8	6.3	3.7	4.7	7.8
Moving Truck	0.22	0.21	0.53	3.8	3.5	11.3	5.2	4.8	15.4
Motorcycle	0.23	0.87	0.61	4.8	14.5	13.9	5.9	17.8	17.1
ATV	0.69	0.67	1.02	9.2	8.9	14.2	14.2	13.7	21.7
Boat	0.66	0.47	1.01	10.0	8.2	22.0	15.0	12.3	33.1

Discussion

Measurements and exposure analyses conducted in accordance with consensus standards may be compared with guidance for the assessment of whole-body vibration and impact with respect to health, as published in Annex B of the standards [1, 2], in order to address questions regarding potential health effects of vehicle operation.

It is also instructive to compare whole-body vibration exposures determined for these typical passenger and recreational vehicles with exposures measured in other vehicle types, including those driven by professional operators, and with other occupational exposures to whole-body vibration and impact. Comparisons may also be made with exposure assessments of vehicles measured by other investigators, in accordance with relevant standards, for example, locomotives and road vehicles, e.g., as reported in [3].

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PROSPECTIVE STUDIES OF VIBRATION EXPOSED COHORTS: HAND-ARM VIBRATION INTERNATIONAL CONSORTIUM (HAVIC)

M Cherniack[1], AJ Brammer[1,2], R Lundstrom[3], JD Meyer[1], TF Morse[1], G Neely[4], T Nilsson[4,5], D Peterson[1], E Toppila[6], N Warren[1],
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Introduction

HAVIC is a collaboration of investigators from North America, Sweden, and Finland having a scientific mandate from NIOSH, to study the exposure response relationship between vibratory tool exposure and adverse health effects. Five cohorts, the Suomossalmi forest workers cohort, Volvo truck cab workers, Connecticut shipyard workers, and matriculating dental hygiene students and experienced dental hygienists have been under study. In the case of shipyard workers, there was survey and tool exposure data from 1988, although detailed subject testing was only available within the timeframe of the study. The truck cab assembly workforce was an inception cohort that had been followed from 1994 along with age-matched controls. The Finnish forest workers had cumulative health data on a cohort (n=52) that had been studied from 1976. For a subset of these subjects, there was detailed tactometry testing in 1990, 1995, and 2003. Accordingly, there was historical as well as new prospective data for the industrial cohorts. The Suomossalmi cohort was reassembled only for our study, which precluded follow-up evaluation and because of retirement is almost certainly the last time this historic group will be studied. The study features are:

- Characterization of the exposure response relationship for hand-arm vibration through a study design, incorporating multiple cohorts, some having existing historical data,
- Selection of cohorts to include different types of vibration: oscillatory (forest workers) impact (truck cab workers), high frequency (dental hygienists) and mixed (shipyard workers),
- Inclusion of two inception cohorts: dental hygiene students and Swedish truck cab workers,
- Methods for multi-site and historical integration

A description follows.

	Participants	Design	Duration	Populations	Health Assessment	Exposure Assessment
HAVIC	North America, Sweden, Finland	Longitudinal, historical data inclusion, variable re-test intervals	2000-2006	217 shipyard worker; 56 automotive workers/34 controls; 61 forestry workers; 94 dental hygienists/ 56 trainees	Questionnaire, Physical exam, cold challenge test, tactometry, segmental nerve conduction	Diaries, questionnaire, data logging, simulation, biomechanical analysis (PATH)

Methods

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Results

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There are interesting results related to exposure monitoring. In Figure 1, data logged tool operating time is graphed against energy equivalent hand absorption. At the individual level, the association is weak. In Figure 2, there is little correspondence between self report of exposure, data logged exposure, diary based exposure accounting, and observation by a skilled observer.

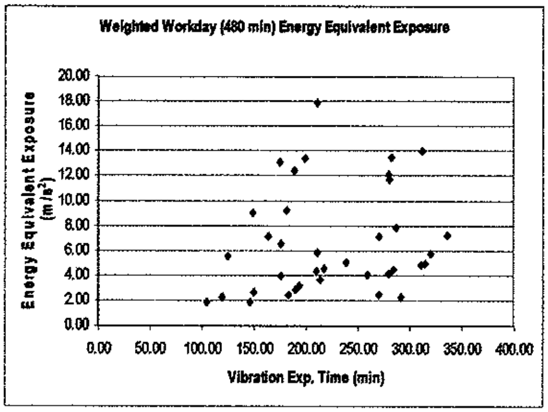

Fig. 1 Exposure magnitude and time

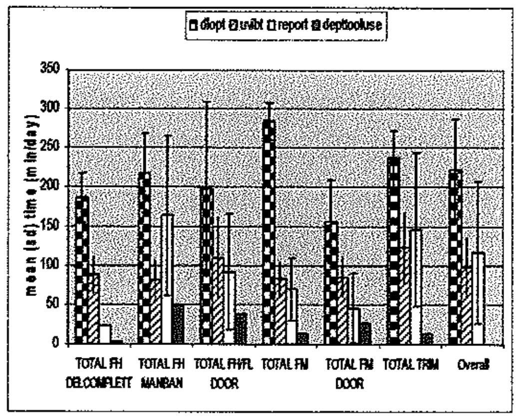

Fig.2 Exposure assessment: different modalities

Discussion

To date, the results demonstrate the importance of exposure monitoring methods. Mixed longitudinal designs or repeated cross-sections have advantages over traditional prospective cohort construction for studies of this type.

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CLINICAL ASSESSMENT AND CHARACTERISTICS OF MEN AND WOMEN EXPOSED TO HIGH LEVEL OF HAND-ARM VIBRATION

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Introduction

While the neurological and vascular aspects of Hand-Arm Vibration Syndrome (HAVS) has been generally accepted as a medical condition, the medical criteria and the clinical findings used to establish the diagnosis has been more difficult to bring to consensus. The criteria was first quantified by the Taylor-Palmear scale.[1] This criteria was subsequently modified in 1986 at the 1st Stockholm Workshop[2,3] to included more acceptance for the neurological effects that characterized the predominate findings in some workers. The relationship between hand-arm vibration and Carpal Tunnel Syndrome was defined in NIOSH 97-141[4].

While the aforementioned documents have defined the clinical entities associated with hand-arm vibration exposure, agreement on the clinical findings and test to confirm the diagnosis has be been more difficult to bring to consensus. Clinicians assessing HAVS has relied on a number of varied neurological and vascular tests. The neurological testing has focused on assessing damage to the sensory capability of the fingers for the neurological component including tests to measuring ability to sense vibration, cold or other end point finger sensor functions. However, the vascular testing has been traditionally focused on the ability to either measure vascular function or to reproduce the vascular blanching that occurs in HAVS with cold water provocation. Recent assessment of this testing in the United Kingdom Coal Miner's study has questioned the value of this testing especially in reviews by McGeoch.[5] In an attempt to provide some type of definitive testing to substantiate vascular damage from hand-arm vibration exposure, angiography is an alternative or adjunct to cold water provocation testing.

The standards that have been established to predict the level, type and incidence of HAVS have been based on clinical studies and reports that have essentially been all male populations. However, the recent entry of women into more vibration intensive jobs has brought about the exposure of some women to high levels of vibration previously only previously experienced by men. However, there have been only few studies that look at HAVS in women[6]. Although exposed the same vibration levels, it has not been clear that the latency and type of pathology of HAVS in women will be the same as for men.

The purpose of this study is to look at recent case studies of men and women exposed to jobs with high levels of hand-arm vibration with extensive clinical testing for both the neurological and vascular components of HAVS as well as other associated upper extremity conditions such as Carpal Tunnel Syndrome.

Methods

Clinical cases referred for evaluation with neurological testing including, vibrometry, Simmes-Weinstein mono filaments, 2 point discrimination, Purdue peg board testing and nerve conduction testing. Vascular testing included Allen's testing, Doppler studies of both upper extremities, cold water provocation testing and angiograph. Additional laboratory blood work and clinical examination was done to rule out alternative disease conditions that could confound results such as diabetes, collagen-vascular disease, etc.[8]

Results

Although the study was too small for statistical significance, review of the cases show that when exposed to the same high levels of hand arm vibration, women develop HAVS symptoms sooner than might be expected and early onset of Carpal Tunnel Syndrome.. In contrast men take longer to develop the same symptoms and are more likely to develop other finding such as tendonitis before they develop the constellation of symptoms and findings found in women.

Comparison of the vascular testing techniques indicates that the angiography can be helpful in confirming the vascular damage from hand-arm vibration exposure in both men and women. Furthermore, angiography may help localize areas of damage from specific exposure. The study proved to be too small to compare the effectiveness the various vascular testing techniques but suggest that further study is warranted.

Discussion

The study shows that there is a suggestion that present standards for the latency of HAVS and other vibration related disorders may be different for women then for men. Also review of clinical cases shows that angiography is useful tool in confirming and defining the level of vascular pathology in case of significant HAVS. Further enlarged studies to confirm both of these findings are recommended.

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CHACTERISTICS OF VIBRATION INJURIES IN PERIPHERAL NERVES

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Introduction

This experimental study was done to determine pathological feature of vibration injury to the peripheral nerves in the hind limbs of rats exposed to 7 days of vibration.

Materials and Methods

Animals: Twenty four male Sprague-Dawley rats weighing 350-400 grams were randomly divided into two groups: sham control group and vibrated group. To document vibration-induced changes in the experimental model, the sciatic nerve was used because it contains both motor and sensory fibers and is relatively superficial in the posterior thigh.

Customized Vibrating Platform: The hind limbs of the rats in the vibrated group were exposed to vibration in a custom-built vibrating apparatus consisting of two platforms: a smaller vibrating platform on which the hind limbs of the rat are secured, and a larger platform on which the remainder of the body rests. The vibration parameters (frequency 43.5 Hz, amplitude 1.5mm, acceleration 4.75G, velocity 6cm/sec., and displacement of 3.0mm) of this model were measured.

Methods: Rats were anesthetized with 35mg/kg of intraperitoneal Nembutal (phenobarbital) and their hind limbs fixed to the vibrating platform by Velcro loops. Both hind limbs rest on the vibrating platform while the remainder of the body rests on the larger platform. The rats were vibrated 4 hours a day, for 7 days, with close monitoring of the vibration parameters. The 4-hour duration of hazardous vibration was based on recommendations from the British Standards Institution. The sciatic nerve of rats not exposed to vibration, but similarly anesthetized and secured to the vibrating platform, acted as controls. At the end of seven days of exposure to vibration, nerves from both the vibrated rats and the control rats were harvested after perfusion of the lower half of the body using glutaraldehyde as described below.

Neural Fixation: The aorta was cannulated, and the inferior vena cava was nicked and the animal was initially perfused with 0.9% buffered sodium chloride. This was followed by perfusion of a filtered mixture of 3% glutaraldehyde and 3% paraformaldehyde fixation solution, The tissue was subjected to post fixation by routine. The neural tissue was then submitted for light and electron microscopy.

Results

While light microscopy showed minimal histological differences between vibrated (n=12) and control nerves (n=12), the changes revealed by electron microscopy were dramatic. These included thickening of the epineurium, as well as thickening of the myelin sheath as compared with normal nerve. Also, the axon plasma was detached from the myelin sheaths, and many vacuoles were seen between the myelin laminae(Fig.1); These changes were found in all vibrated animals, and in the whole segment of each vibrated nerve. Myelin balls, consisting of destroyed myelin rolled into wool-like threads, were located inside the myelin layers (Fig. 2); Axonal damage was seen in both myelinated and nonmyelinated axons (Fig. 3). In addition, nonmyelinated axons were edematous. An interesting finding was the circumferential disruption of several myelin layers, leaving a large circular space around the impacted myelin with central axonal constriction, this characteristic finding, giving the appearance of a finger ring, was found in every vibrated nerve (Fig. 4). Many microtubes and microfilaments were ruptured or had disappeared (Fig. 2-4).

Fig. 1

Fig. 3

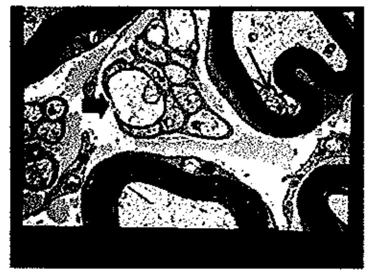

Fig. 2

Fig. 4

Fig. 1. Arrow indicates a big vacuole in myelin laminae; **Fig 2.** Arrow indicated a huge myelin ball, wool-like thread consisting of destroyed myelin; **Fig. 3** Axonal plasmadamage was seen in both myelinated (arrow) and nonmyelinated axons (arrow head); **Fig. 4.** Arrows showed a large circular space between the myelin layers.

Discussion

The vibrated nerves show definite pathologic changes in the form of axonal damage and myelin fragmentation[1-4]. We therefore conclude: Myelin disruption, myelin balls, myelin "finger ring" changes, and axonal de-attachment are identifiable characteristics of the neuropathological changes due to vibration injury. Further research to identify the hazardous components of vibration (amplitude, frequency, etc.) is in progress in our laboratory.

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MEASURING PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN WORK-RELATED VIBRATION

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Introduction

Until now there has been controversy about which tests should be performed to diagnose early Hand-Arm Vibration Syndrome (HAVS). Initial screening questions, especially about tingling and numbness, routinely given to patients prior to examinations proved to be a very important tool in the diagnostic process[1, 4]. However, standardized tests that are simple, quick, valid and reliable are needed to support a diagnosis of HAVS. **Purpose:** To find the most valid and reliable tests to diagnose HAVS.

Material and Methods

Five major tests were performed on Group I and Group II. Group I: Control group of 12 volunteers including students, nurses, secretaries and physicians with no history of using vibrating tools (age 20 to 50y, mean age 38.5y; 5male, 5 female.) Group II: 12 workers (age 17 to 65y, mean age 39y; 9 male, 3 female) were sent by a local trade union with a history of using vibrating power tools on their jobs for varying amounts of time (mean 12.2y, from 0.5 to 35y.) Pre-enrollment survey showed that each had more than 4 complaints commonly associated with use of vibrating tools (including numbness, tingling, weakness, pain, finger color or nail changes, temperature change, and difficulty moving.)
1. Sensory nerve conductive tests: Amplitude and nerve conductive velocity (NCV) were evaluated. 2. Cold Stress-Temperature recovery time tests were done on the index finger of the dominant hand following these steps: Confirm water bath is within 4-5° C. Place the finger temperature probe on pad of the index finger of the dominant hand. Record temperature every 15 seconds. Place subject's hand in the cold- water bath for exactly five minutes. Record temperature every 15 seconds for ten minutes. 3. Blood test: Venous blood was taken by a 21-gauge needle with the yellow collection tube adapter. S-ICAM, Sera Thrombomodulin, Norepinephrine levels were evaluated by Henderson Research Centre, Canada. 4. Finger Sensory Evaluation: Semmes-Weinstein monofilament test and 2-point discrimination tests were performed on bilateral fingers. 5. Digital blood pressure test: blood pressure was measured in bilateral index fingers.

Results

1. Median nerve sensory conductive amplitude from palm to wrist :
   GI: mean 96 ± 31μm; GII: mean 43± 30μm; for dominant hands.

   GI vs GII: P<0.001

Motor nerve conductive velocity (NCV) from elbow to wrist:

GI: mean 60.8± 8.5m/s; GII: mean 48.3± 5.9m/s; GI vs GII: P<0.001

2. Cold-Stress Test: Temperature Recovery Rate (TRR) = T before test / T after 10 minutes. GI: mean: 85.36% ± 14.22 GII: More three years of using vibrating tools was a critical point, with vibration for 3 years, the TRR was 70% and as time of use increased, the correlation to TRR also increased. Two subjects' TRR was 52% with 15 and 35 years of using vibrating tools.

3. Sera Chemical Test: A. sICAM: Standard Reference Range is 132.5-344.2ng/mL. GII: The value of 3 workers > 344.2ng/mL (385.2, 346.4 and 381.4), Positive rate was 25.0%; B. Norepinephrine: Standard Reference Range is 0.8-3.4; 4 workers' value was <0.8 nmol/L (0.5, 0.7, 0.3, 0.6). Positive rate was 33.3%.

4. Hand Sensory Evaluation:
   A. Semmes-Weinstein monofilament test: Standard criterion: Normal: 1.65-2.83; Diminished light touch: 3.22-3.61; Diminished protective sensation: 3.84-4.31; Loss of protective sensation: 4.59-6.65.
   Results: 3 workers (3.5years) were normal; 9 workers (>5 years) were diminished. Positive rate was 66.98%.
   B. Two-point discrimination test: Normal is < 6mm. GI: 119/120 tested fingers were less than 6 mm; GII: 20/120 were < 6mm. Positive rate was 16.7 %.

5. Digital blood pressure test: Normal cut-off point: < 70 mmHg was abnormal. Results: GI: none was < 70; GII: 8/23 fingers (n=23, index fingers in both hands, 1 n/a); positive rate was 35%.

Conclusions

1. Semmes-Weinstein monofilament test is a sensitive and simple test to assess HAVS. 2. Cold stress test gave a lower positive rate but did indicate later damage; however, it causes patient discomfort.3. Sensory nerve conductive and NCV were useful but need a control group value.4. The S-ICAM increased in 25%, and NE decreased in 33% of vibrated workers. 5. Digital BP test and 2-point discrimination test both have cut-off point value; they could be used to differentiate HAVS from simple carpal tunnel syndrome.

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However, at 2000 Hz (Aβ fibers), restrained animals displayed an increased sensitivity to the stimulus following exposure (i.e., lower CPT value, $F(1, 28) = 23.71$, $p < 0.001$). In contrast, the CPT was significantly higher in vibrated rats immediately following the exposure, indicating that the Aβ fibers were less sensitive to stimulation. However, 24 h later, the CPT at 2000 Hz returned to pre-exposure values (Figure 1A-C). At 5 Hz, there were no group differences in pre to post CPT values. However, about one third of the animals did display a post exposure increase in CPT values. The increased CPT in this subset of animals accounts for the large variability in the post exposure measure at 5 Hz. None of the CPT values were affected by temperature. (Figures 1D-F).

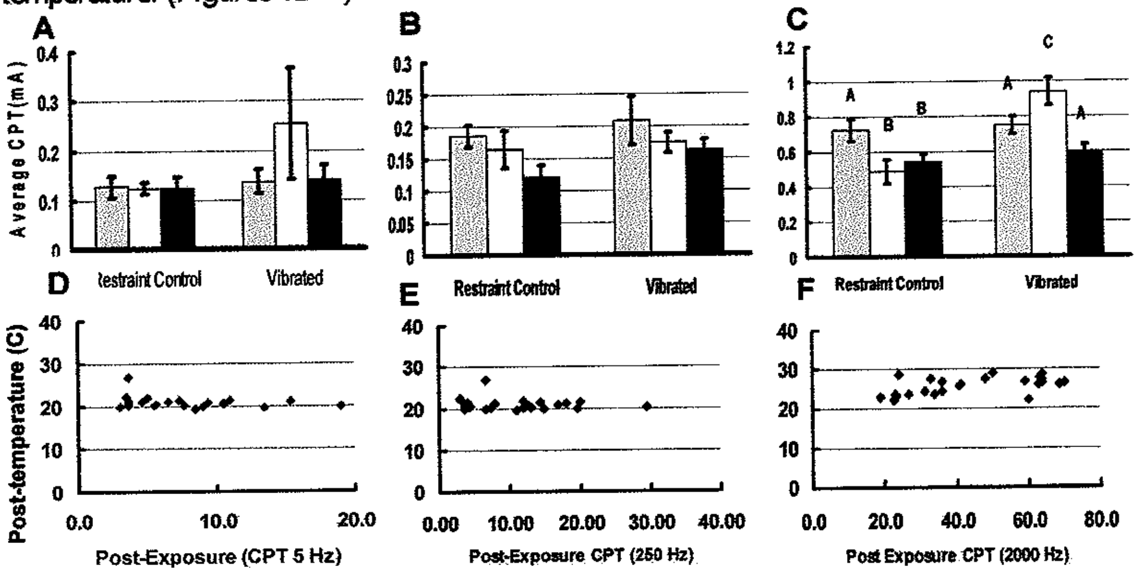

Figure 1. CPT measures (mA) at 5 (A), 250 (B) and 2000 Hz (C), and correlations between temperature and CPT values (D-F). Bars represent the means ± sem. Gray bars are pre-exposure, white immediately after exposure and black 24 h after exposure. In 1-C, different letters are significantly different from each other ($p < 0.05$). R^2 values for the correlation between temperature and CPT are 0.085 for 5 Hz, 0.042 for 250 Hz and 0.009 for 2000 Hz.

Discussion

- Exposure to a single bout of vibration results in a transient reduction in the sensitivity of the Aβ fibers to stimulation. This shift in sensitivity is comparable to the transient shift in vibrotactile thresholds seen in humans after an acute vibration exposure (2,4,5).
- The vibrotactile test is affected by the skin temperature of the subject (1,3). The results of this study demonstrate that the CPT is not affected by skin temperature. In addition, the CPT allows the tester to determine which nerve fiber subtype is affected. Thus, the CPT may serve as reasonable test for diagnosing vibration-induced changes in tactile sensitivity.

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ACUTE EFFECTS OF VIBRATION ON RAT-TAIL NERVES

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Introduction

Hand arm vibration syndrome (HAVS) affects industrial workers exposed to long term hand-transmitted vibration from powered-tools. Peripheral neuropathy is a major component of the symptom complex of HAVS. Long term exposure to vibration causes myelin damage in peripheral nerves and reduces nerve conduction velocities in rats[1]. This study addresses the effects of acute vibration at constant acceleration of 49 m/s^2 on myelinated fibers in peripheral nerves in Sprague-Dawley male rats using the 'rat-tail vibration model,' which simulates hand-transmitted vibration[2].

Methods

Male Sprague-Dawley rats (~300 g) were assigned to vibration groups: 1 hr continuous vibration at 60 Hz; 4 hr continuous exposure at frequencies of 30, 60, 120 or 800 Hz; immediate and 24 hr following a 4-hr cumulative exposure of continuous and intermittent vibration at 60 Hz. Unanesthetized rats were restrained in cages on a nonvibrating platform with their tails placed on a vibrating stage accelerated by a B&K motor type 4809 and vibrated. Intermittent vibration was delivered in bouts of 10 min vibration alternating with 5 min rest periods repeated over 6 hr. Sham controls were restrained without vibration. After vibration exposure, the rats were anaesthetized, and the ventral nerve trunks from the proximal tail segment 7 were fixed in glutaraldehyde, embedded in epon-araldite and sectioned at 0.5 µm thickness and stained with toludine-blue for morphological quantitative analysis. The total number of myelinated axons in each cross-section of the nerve was counted using the Image J software. Myelin damage was identified by focal increase in area and intensity of toludine-blue staining and unraveling of the myelin sheath. Statistical analysis for comparing sham and the different vibration groups was done using Dunnett's test. Animal treatment and all surgical procedures were approved by the institutional review board and compiled with the Laboratory Animal Welfare Act.

Results

The rats tolerated continuous vibration very well and exhibited no behavioral signs of stress. When exposed to intermittent vibration, there was increased vocalization, a startle reflex at the beginning of each bout of vibration, deposition of porphyrin around the eyes and transient hypersensitivity to touch.

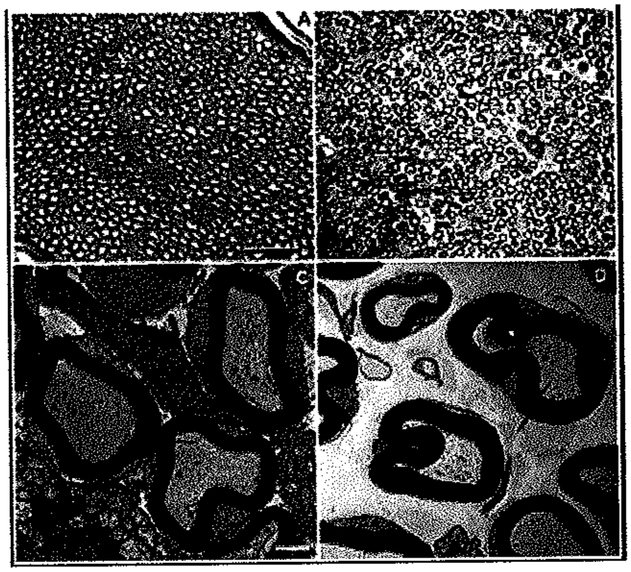

Fig 1: A. The semithin cross section of the tail nerve from a sham control rat demonstrates that the myelin is evenly stained with toludine blue. B. When vibrated, the myelin stains darker and exhibits focal thickening. C. At the electron microscopic level, the myelin membranes are compact, except for tiny foci of separation in the sham-vibrated control nerves. D. Vibrated nerves exhibit larger and more extensive areas of separation of the myelin membranes (arrows), and frequently the myelin sheaths show decompaction (*). Bar in A equals 40 µm for A, B. Bar in C equals 0.5 µm for C, D.

Table 1: There was an average of 1187 ± 50 myelinated axons in the ventral tail nerve at the level of segment 7. The numbers of myelinated fibers showing delamination are expressed as % of total fibers ± SEM. All vibration groups were significantly different from the sham vibrated, *$p<0.05$. CI- Continuous immediate, CS- Continuous 24 hr survival, II- Intermittent immediate, IS- Intermittent 24 hr survival.

Exposure	Myelin disruption %
Sham, 4hrs, CI	5.0 ± 0.6
60Hz, 1hr, CI	15.6 ± 2.2*
30Hz, 4hr, CI	24.5 ± 3.4*
120Hz, 4hr, CI	28.0 ± 1.7*
800Hz, 4hr, CI	16.9 ± 1.6*
60Hz, 4hr, CI	28.6 ± 1.8*
60Hz, 4hr, CS	36.2 ± 1.8*
60Hz, 4hr, II	47.7 ± 1.9*
60Hz, 4hr, IS	45.3 ± 5.7*

Discussion

1. Vibration exposure duration as short as 1 hr at 60 Hz can cause myelin disruption.
2. Damage is not limited to a single frequency.
3. Frequent rest periods do not reduce, but exacerbate, damage as evidenced by increased myelin disruption and transient hypersensitivity.

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Podium Presentations

Session V: Health Effects III

Chairs: Thomas Jetzer and Danny Riley

SEATED HUMAN RESPONSE TO SIMPLE AND COMPLEX IMPACTS

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Introduction

The human lumbar spine is inherently an unstable structure and requires sophisticated neuromuscular control to maintain its stability and for performing physical tasks. As a consequence, it is important to understand the potential health effects on human operators of mechanical stimuli such as shock and vibration.[1] Impact applied to a vehicle operator combines the risk of sudden, unexpected load with the mechanical stress of the seated posture.[2] Because many work environments contain the potential for multiple, unexpected impacts, it is important to understand how the trunk muscles respond to complex conditions. We believe the results have implications for isolation design and standards development.

Methods

Muscle activity was recorded during simple and complex impacts, applied randomly and without warning, while subjects sat on an air-suspension truck seat located on a man-rated 6-DOF motion platform (Rexroth-Hydraudyne). Simple (single) impacts consisted of 100 ms quarter-sine jolts in the side-to-side (L and R) and vertical upward (V) directions with peak amplitude at 0.4 g. Complex impacts consisted of combinations of two simple (single) impacts in sequence (LV, RV, VL, VR), separated by 100 ms. Twelve right-handed males (23.7 ± 7.8 years old) were tested without a blindfold under 2 posture conditions (supported while leaning back and unsupported, sitting upright) and 2 seat suspension conditions (present or absent). Each type of impact was repeated three times under each posture and suspension condition, resulting in 84 impacts in total. Surface EMG signals from the left and right erector spinae (ES), rectus abdominis (AR), external obliques (EO) and internal obliques (IO) were recorded and transformed to 25ms RMS values. The response time, defined as the time the muscle activity exceeded the mean + 2 STD of the pre-impact resting period, peak response amplitude, and time were then derived. A mixed-model repeated measures analysis of variance was used to evaluate statistical significance, where type I error rate was set at .05.

Results

One question we asked of these data was whether there were differences in responses related to simple single strike impacts (L, R, or V) and complex, double-strike impacts (LV, RV, VL, VR). There are 21 possible combinations of comparisons of simple and complex impacts to each other. The differences found are listed in Table 1.

Table 1. Number of significant contrasts in muscle response to different impact types (the format below is: Peak response amplitude (response start time, time at peak response)

	Muscle Groups				
Comparison	ES	AR	EO	IO	Total
Simple vs. Simple	1 (0, 0)	0 (0, 0)	1 (0, 1)	3 (2, 2)	5 (2, 3)
Simple vs. Complex	3 (3, 4)	2 (0, 0)	1 (3, 1)	5 (5, 6)	11 (11, 11)
Complex vs. Complex	0 (3, 2)	0 (0, 0)	0 (2, 0)	2 (4, 5)	2 (9, 7)
Total	4 (6, 6)	2 (0, 0)	2 (5, 2)	10 (11, 13)	18 (22, 21)

The contrast between impact types shows differences in the muscles. Overall differences occurred more often in the Simple vs. Complex comparisons. The analysis also showed that posture had a significant effect but the suspension had little effect.

Discussion

These results corroborated prior work showing that the back muscles play an important role in balancing the trunk in seated impact environments and confirmed that abdominals and external obliques are less able to discriminate between impact types and are likely unable to respond effectively. This study shows, for the first time, that the behavior of the internal obliques is more sensitive than that of the erectors to impact types. Just as a bent beam has one side under tension and the other side under compression, the act of sitting for a human lengthens the posterior aspect of the body and shortens the anterior aspect. During sitting, the lengthened (posterior) muscles are more sensitive and the passively shortened and hence, loose anterior muscles are less sensitive. In the standing posture, all trunk muscles play a role in postural control, however in the sitting posture, a demand on the internal obliques was observed. Long-term exposure to this unbalanced condition may retrain the muscles and control system in an undesirable fashion. Concern about responses to a complex strike is because the first impact may displace the body and the second may further destabilize it, especially with the first strike being an asymmetric impact. These results suggest that a single strike from the side may not be a simple mechanical stimulus, as has traditionally been hypothesized, because it is asymmetric and fundamentally different from a vertical strike. There was one limitation of the study. The low level of the impacts might have contributed to a lack of suspension effect.

Acknowledgements This project entitled "Reducing Injury Risk from Jolting/Jarring on Mobile Equipment" was partially supported by CDC order # S0265112 from the NIOSH-Spokane Research Lab, Centers for Disease Control and Prevention. This investigation was conducted in a facility constructed with support from The University of Iowa vice president for Research and the University of Iowa, College of Engineering. Assistance was provided by Logan Mullinix (CVGrp, Columbus, OH) in determining subject impact exposure and in supplying a KAB seat.

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RESPONSE TO SUDDEN LOAD BY PATIENTS WITH BACK PAIN

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Introduction

As mechanical shock and vibration environments evolve, it is important to understand their potential effect on human operators. Human beings are sophisticated mechanisms comprised not only of passive components with mass, damping, and stiffness characteristics, but also of components that can actively affect apparent mass, stiffness, and damping. Because the lumbar spine can exhibit local, short-column buckling, stability of the human trunk depends on the responsiveness of the neuromuscular control system.[1-2] We have been evaluating the ability of patients with back pain to respond to a series of sudden loads. We believe the results have implications for isolation design and standards development.

Methods

153 patients, aged 21 to 55, presenting with back pain agreed to enroll in a research study that randomly assigned them to one of three treatment arms: high velocity low amplitude spinal manipulation, low velocity variable amplitude spinal manipulation, or wait for 2 weeks and then be randomized to one of the above groups. Response to sudden load testing was one of a battery of baseline evaluations performed upon entry into the study and prior to treatment. EMG electrodes were attached to the skin over the paraspinal muscles of the standing participant bilaterally 3 cm from midline at the L3 level. While standing upright on a force plate (Bertec), participants were fitted with a strap around their back and hooked to a load cell in front of their chest. An accelerometer was rigidly attached to the load cell. Impact was applied to the chest using a cord attached to a falling weight. The weight's fall distance was varied between 9 and 13 inches to account for the size of the subject. The subject was blindfolded and wore headphones playing white noise to prevent cueing of when the weight was dropped to apply the load. Hence, although the participant knew a load was about to be applied, he or she did not know the instant it would occur. Just before the weight was dropped, a 4 second data collection process was started for the two EMG electrodes, load cell, accelerometer, and force plate. The load drop was repeated 6 times, at irregular intervals, over a period of 2 minutes. The raw data thus collected was reduced to obtain several values: 1) length of time from the pull on the harness to the beginning of the response of the left and right paraspinal muscles (LES, RES), 2) time and magnitude of the maximum response, 3) force and acceleration experienced at the chest, and 4) the time and magnitude of the center of pressure location (COP). A general linear model was used to evaluate the results.

Results

For the EMG data, of the 1,824 observations made, 90% of them indicated a response. Prior to the sudden load, resting muscle activity was different between left and right sides ($p=0.0001$) and between males and females ($p=0.0001$). Female subjects began to respond to the sudden load within 92 to 110 ms and males from 101 to 109 ms. Females exhibited more variation in starting their responses than did males. Females began to respond to the second sudden load significantly sooner (92 ms) than the males (109 ms) with $p=0.0027$, otherwise they were similar to the males. There was no significant effect of sudden load trial (1^{st}, 2^{nd}, 3^{rd}, etc) on the amount of time taken to create the peak EMG response to the sudden load (179-193 ms LES, 186-198 ms RES), but the muscle side responding more quickly had a trend of an effect ($p=0.0568$). Peak muscle response was not affected by gender, but was affected by trial. The first peak response differed significantly from the rest (2^{nd} $p=0.0108$, 3^{rd}-6^{th} $p<0.0001$). Thereafter, only the peak response at trial 2 was different from that at trial 6 ($p=0.0498$). Females exhibited greater variation in their peak responses than did males. The females experienced significantly lower forces at the chest during the sudden pull than did the males (121.1 v 131.4 N, $p<0.0001$). The females experienced significantly larger accelerations at the chest during the sudden pull than did the males (1.76 v 1.39 ms^{-2}, $p<0.0001$). In response to the sudden load, subjects counteracted the overturning moment by shifting forward the center of pressure (COP) under their feet. The shift was larger in the first trial (84mm) and decreased over the trials (79, 77.2, 75.4, 74.7, and 73.7 mm). The time to shift the COP forward was smallest in the first trial (388.0 ms), increased up to the 5^{th} trial (433.4, 444.1, 480.6, and 488.4 ms), and then decreased slightly by the 6^{th} trial (486.5 ms).

Discussion

In a study trying to predict who would respond well to different chiropractic treatment methods, baseline data were obtained on patients that provide insight into the response of people with back pain to sudden loads applied at the chest. The primary observation is that people take finite amounts of time to respond to a sudden load. People are able to adapt to some aspects of exposure to a train of sudden loads: adjusting back muscle activity magnitude, and the speed and magnitude of changing the center of pressure in order to stabilize their stance. There is however, no significant adaptation of the time the back muscles take to respond to the load. Although efforts were made to adjust the suddenly applied load according to subject size, the females presented a more compliant and faster moving trunk to the loading device. In summary, although people with back pain can make some adaptations to a train of similar impacts, their first response is always unique. It always takes a certain amount of time to respond to various aspects of sudden load. The reciprocals of the above response times provide insight into some of the observed psychophysical and mechanical sensitivities to vibration and repetitive mechanical shock.

Acknowledgements Under the leadership of Dr. William Meeker, this project entitled: Predicting Patients' Response to Spinal Manipulation, was supported by Grant Number U19 AT002006 from the National Center for Complementary and Alternative Medicine (NCCAM). This investigation was conducted in a facility constructed with support from Research Facilities Improvement Program Grant Number C06 RR15433-01 from the National Center for Research Resources, National Institute of Health. Several others were also vital to this project: Mr. Lance Corber of the Office of Data Management for organizing the biomechanical data, Dr. Maria Hondras, Project Manager, Caelyn Nagle, Josh Myers, several other assistants in data collection and management, recruitment assistants, and clinicians.

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UPPER BODY JOINT COORDINATION UNDER VIBRATION

Jueun Lee, Jong-Hwa Yoon, K. Rider, Bernard J. Martin

Introduction

Whole body vibration is known to affect movement accuracy [1], however little is known about changes in the organization of movement and movement strategies used to limit the influences of perturbations. The specific aim of this work is to analyze the motion and coordination of upper body segments of seated operators performing reaching tasks under whole-body sinusoidal vibration exposure and simulated vehicle ride motion. The long-term objective is to model reach coordination and predict the dynamic behavior of the upper body motion under vehicle vibration exposure.

Method

The reach task consisted of pointing with the right hand index finger to targets located on touch screens placed in front of the subject, 45° overhead and 90° to the right in the mockup cabin of an HMMWV placed on a 6 DOF ride motion simulator. The task was performed under stable (no vibration) and vibration (sinusoidal vibration or simulated ride motion) conditions. A motion capture system was used to record kinematic data of reflective markers to recreate body link trajectories. Joint angles (torso, shoulder and elbow; Figure 1) were then computed using quaternions. Coordination between body links was defined as a) the joints angle-versus-angle relationships between the upper arm and lower arm, and b) the joint motion onset relationships between torso, upper arm and lower arm in the time domain.

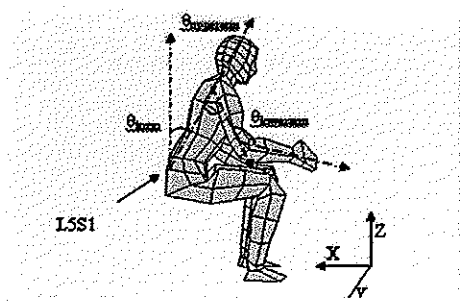


Figure 1. Angle definitions

Results

Angle–versus-angle relationships. The relationship between upper arm vs. lower arm angle and torso vs. upper arm angle for a far forward reaching movement in the stable (solid lines) and vibration conditions (dotted lines) are illustrated in Figure 2. Fig 2A compares the control condition with a 4 Hz lateral vibration while Fig 2B compares the control condition with a 6 Hz vertical vibration. It appears that under vibration exposure the reduced upper arm extension is compensated by an increase in torso flexion. This effect is seen in the last phase of the movements (encircled areas). In addition, the lower arm extension is delayed under 6 Hz vertical vibration (Fig 2B left panel).

Time of joint motion onset. The timing relationship between torso, upper arm and lower arm is largely a function of the target to be reached. Examples of delays between body links are illustrated in Figure 3. The control condition is compared to a 6 Hz vertical vibration for three

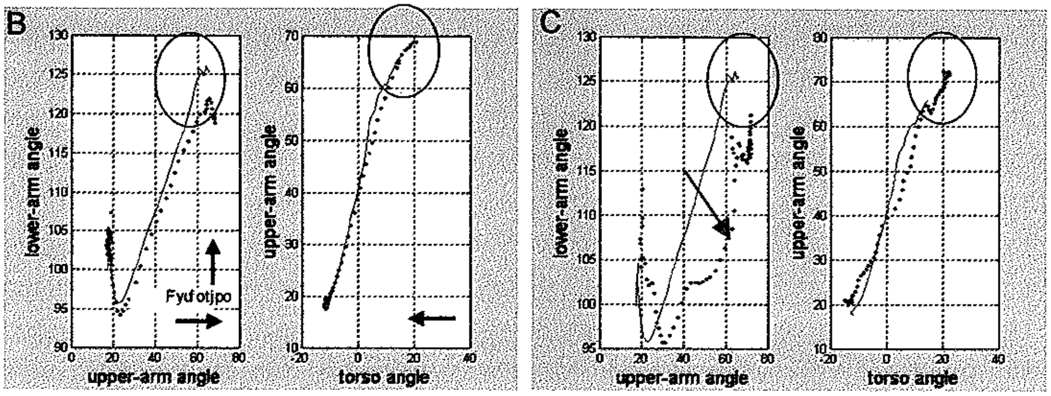
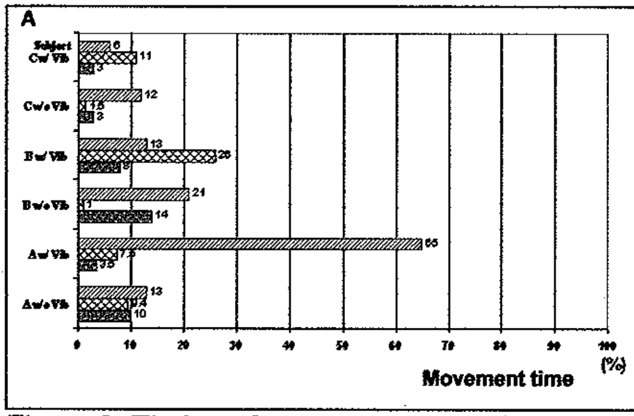


Figure 2. Angle-versus-angle relationships for a far forward reach in two vibration conditions. A: lateral direction, 4 Hz, 0.2g vibration. B: vertical direction, 6 Hz, 0.2g. [control: solid line; vibration: dotted line]

subjects reaching to a lateral target. For this target, the upper arm moves first in the control condition while the torso moves first under vibration exposure.



B

Without Vibration	With Vibration
Torso 1 (0) 2 (3) 3 (0)	Torso 1 (3) 2 (0) 3 (0)
Upper Arm 1 (3) 2 (0) 3 (0)	Upper Arm 1 (0) 2 (1) 3 (2)
Lower Arm 1 (0) 2 (0) 3 (3)	Lower Arm 1 (0) 2 (2) 3 (1)

Figure 3. Timing of movement onsets for a lateral near reach. A) movement onset times (torso: dotted bar; upper arm: bar with the x; lower arm: diagonal bar); B) order of movement onset.

Discussion

Overall the results indicate that the movement strategies (magnitude and timing of joint movements) change under vibration exposure; however, these strategies are dependent on movement direction. It is assumed that the forward flexion of the torso may be used to reduce the influence of vibration on the perturbation of the arm movement.

Reference

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REGIONAL CEREBRAL OXYGENATION AND BLOOD VOLUME RESPONSES IN HEALTHY WOMEN DURING SEATED WHOLE-BODY VIBRATION (WBV)

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Introduction

Landstrom et al. (1985) suggested the possibility of cortical activation during exposure to WBV, however, it is not known how cerebral physiology (oxygenation and blood volume) responds in healthy women during different vibration frequencies. This study examined the role of backrest support and handgrip work on cerebral oxygenation and blood volume responses, during exposure to seated WBV.

Methods

Fourteen women (age: 23.9 ± 3.5 years) were randomly exposed to three frequencies of WBV (3, 4.5 and 6 Hz at approximately $0.9g_{r.m.s}$ in the vertical direction) on a customized vibrating base (Advanced Therapy Products, Inc., USA) in a seated posture on three separate days. On the first day, the subjects completed an aerobic fitness test until volitional exhaustion on an arm cranking ergometer (Cybex, MET 300, USA).

Each WBV session lasted 30 min (6 min baseline without WBV, 8 min WBV 'with' or 'without' backrest support, and 4 min recovery from WBV, 8 min WBV with 'opposite' backrest condition, and 4 min recovery following WBV). During 8 min WBV exposure 'with' and 'without' backrest support, subjects performed maximal voluntary rhythmic handgrip contractions with their right hand for 1 min using a dynamometer. To obtain regional oxygenation and blood volume responses, a NIRS sensor (MicroRunman, NIM, Inc., PA, USA) was placed on the anterior right frontal lobe just below the hair and close to fronto-temporalis region (Maikala et al. 2005).

Results

Baseline oxygenation and blood volume values were recorded during recovery from each WBV session of 'with' and 'without' backrest support. The physiological change in oxygenation and blood volume during each frequency (3, 4.5, and 6 Hz) for both backrest ('with' and 'without' a backrest) and workload (WBV only and WBV combined with rhythmic handgrip contractions) was calculated as the difference between the maximum values identified for each WBV condition of backrest and workload and baseline values (Maikala et al. 2005).

Three-way analysis of covariance with repeated measures (frequency, backrest, and workload) with a fully crossed design was used to evaluate the differences in the oxygenation and blood volume responses (measured in optical density [od] units). Peak oxygen uptake during arm cranking was treated as the covariate. No three- or two-way interactions were significant ($P>0.05$). Only the main effects: frequency and workload reached statistical significance ($P<0.05$). Significant differences were observed in the oxygenation change between 3 and 6 Hz (0.0003 ± 0.04 od versus 0.065 ± 0.09 od, $P=0.022$), but not between 3 and 4.5 Hz (0.030 ± 0.06 od, $P=0.102$) and 4.5 and 6 Hz ($P=0.206$). Corresponding comparisons for the blood volume changes were significant: between 3 and 4.5 Hz (0.017 od $\pm$ 0.12 versus 0.07 $\pm$ 0.06 od, $P=0.008$) and 3 and 6 Hz (0.100 ± 0.09 od, $P=0.004$), but not between 4.5 and 6 Hz ($P=0.247$). Physiological changes were similar 'with' and 'without' backrest support (oxygenation: 0.031 ± 0.07 od versus 0.030 ± 0.07 od, $P=0.79$; blood volume: 0.063 ± 0.07 od versus 0.062 ± 0.12 od, $P=0.80$). Compared to WBV only condition, changes were higher during rhythmic handgrip contractions (oxygenation: 0.020 ± 0.07 od versus 0.042 ± 0.07 od, $P=0.000$; blood volume: (0.048 ± 0.06 od versus 0.078 ± 0.12 od, $P=0.015$)). Subjects' aerobic fitness influenced the oxygenation and blood volume responses during WBV ($P<0.05$).

Discussion

Compared to sitting without WBV, cerebral region showed increase in both oxygenation and blood volume responses at each frequency of WBV, implying an increase in neuronal activity due to WBV. Highest oxygenation and blood volume responses were observed during exposure to 6 Hz, suggesting women respond differently compared to men between the frequencies of 3 and 6 Hz (Maikala et al. 2005). An increase in response during handgrip contractions suggest that exposure to WBV in combination with physical activity might lead to much greater increase in cerebral activity due to functional motor stimulation. During vibration, Weinstein et al. (1988) suggested an increase in axonal transport due to direct stimulation of the brain, similar to the mechanism occurring during peripheral nerve injury, and the current evidence from exposure to WBV in different experimental conditions suggest that, increased neuronal activity subsequently results in increased perfusion to the pre-frontal cortex.

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HEALTH PERCEPTION IN WORKERS EXPOSED TO HAND-ARM VIBRATION: PREREQUISITE FOR PUTTING IN PLACE AN EFFECTIVE PREVENTIVE PROGRAM IN THE WORKPLACE

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Introduction

Knowledge of risks from exposure to hand-arm vibrations is usually presented by clinicians and researchers from a medical and engineering point of view. There is a strong need to develop innovative health promotion programs for exposed workers. Risk perceptions by vibration exposed workers and HAVS (hand-arm vibration syndrome) affected workers are less well known. In 1983, Brubaker demonstrated that 75% of studied fellers thought that whitening of the fingers was part of the job and/or an unrelated nuisance, while only 25% believed it was a disease. [1]Grounds also showed that even though there were a very high number of forestry workers with white fingers, none considered quitting because of their condition. [2] It seems that many workers hesitate to declare the illness or believe they are less affected than they really are, perhaps from fear of losing their jobs and livelihood. [3] Risk awareness, on the part of exposed workers and their employers, as well as knowledge and acceptance of available preventive solutions are necessary steps before installing adequate preventive measures, whether organizational, behavioral or environmental. Workers need to understand fully the hazards and risks in order to be able to make informed decisions under uncertain conditions.[4] Prerequisites include the following: workers knowledge about the risk, their attitude towards it, which in turn, can be influenced by values, needs and interests. Also, knowledge and attitudes towards safety behaviour, organizational or environmental barriers must be taken into account. Our research focuses on these key elements, which help bridge the gap between health promotion research and practice.

Methods

A descriptive exploratory study is in progress with workers exposed to hand-arm vibrations. It uses qualitative methods that include focus group discussions with workers exposed to hand-arm vibrations, as well as individual interviews with other key informants (employers, health care professionals). An open-ended questionnaire was developed to collect qualitative data on perceived risks and solutions to prevent or reduce HAVS. Based on an integrated theoretical framework related to known determinants of behavior change, the analysis will focus on the following[5]:

1) knowledge of health effects, safety, well-being and/or quality of life
2) related beliefs about individual susceptibility and severity of consequences
3) attitude and values related to hand-arm vibration exposure
4) knowledge and attitudes towards exposure reduction, as well as perceptions of barriers and facilitating factors for these measures, in the workplace environment or otherwise.

Results

Preliminary research results indicate that several obstacles exist that need to be addressed, when putting in place preventive measures in the workplace. These include obstacles from the point of view of workers, employers, and health care professionals. We will present the underlying concepts and the theoretical framework necessary for setting up HAVS preventive programs in the workplace as well as the preliminary results of the research.

Discussion

We highlight the importance of taking into account determinants of behavioral change within a theoretical framework, while respecting the workers' and employers' perspective, when setting up HAVS preventive programs. "Health professionals must consult the people who are the intended target of health programs to determine their needs, problems, and aspirations concerning quality of life. If professionals do not take this vital step, health policies will remain sterile technocratic solutions to problems that may not exist or that hold a low priority in the minds of the people."[6]

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Podium Presentations

Session VI: Epidemiology, Standards Applications, and Prevention I

Chairs: Bernard Martin and Paul-Emile Boileau

SHOCK AND IMPACT ON NORTH AMERICAN LOCOMOTIVES EVALUATED WITH ISO 2631 PARTS 1 AND 5

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John J. Gordon, GMH Engineering

Introduction

The International Organization for Standardization (ISO) standard ISO 2631 [1,2] provides three methods for evaluation of human exposure to vibrations that contain occasional shocks or impacts. Part 1 of the standard specifies the running r.m.s. or maximum transient vibration method (MTVV) and the fourth power vibration dose value (VDV). Part 5 of the standard provides a method of computing the stress in the lumbar spine for humans exposed to multiple shocks. Alem et al [3] have reported application of these methods to data for tactical ground vehicles. This paper reports and compares VDV and spinal stress evaluations of more than 90 hours of vibration and shock measurements on North American locomotives engaged in through freight operations.

The measurements evaluated in this paper were obtained for full crew shifts on 19 freight locomotive runs on mainline track in locations from New York to California. The shifts ranged in duration from 187 minutes to 497 minutes. The average speeds for the shifts were from 21.0 mph to 54.6 mph. All measurements were made on locomotives hauling freight trains in regular revenue service.

Data Acquisition and Processing

The results reported here were computed using test data acquired from a tri-axial seat pad, accelerometer at a sample rate of 400Hz with an anti-aliasing filter corner frequency of 100Hz. The VDVs and the lateral and longitudinal spinal stress values were computed directly from the acquired test data according to the procedures specified and described in [1] and [2]. The vertical spinal stress values were computed by converting the as-acquired test data to a sample rate of 160Hz for input to the vertical spine model, as required in [2]. The conversion of the test data from the as-acquired sample rate of 400Hz to the required sample rate of 160Hz involved up sampling or interpolating the test data to an equivalent sample rate of 800Hz, band limiting the resultant data with a low-pass filter corner frequency of 60Hz and finally down sampling or decimating the 800Hz data to a sample frequency of 160Hz.

Discussion

The vertical VDVs computed according to [2] for the 19 shifts ranged from 2.68 to 9.33 $m/s^{1.75}$. In all but one case, the vertical values were greater than the values for the lateral or longitudinal directions. Note that the health guidance in [1] puts the lower boundary of the health guidance caution zone at a VDV value of 8.5 and the upper boundary at 17 $m/s^{1.75}$. The daily equivalent static compression dose computed following [2] ranged from 0.123 to 0.434 MPa. Health guidance provided in [2] states that there is a low probability of an adverse health effect if the daily dose is less than 0.5 MPa.

The daily equivalent static compression dose is plotted against the vertical VDVs for the 19 shifts in Figure 1. As expected, a linear correlation of the spinal stress with VDV is evident in the graph. Also note that although the highest VDV values exceed the lower health guidance boundary, all the compression dose values are well below the boundary for low probability of an adverse health effect with daily exposure over a lifetime of work.

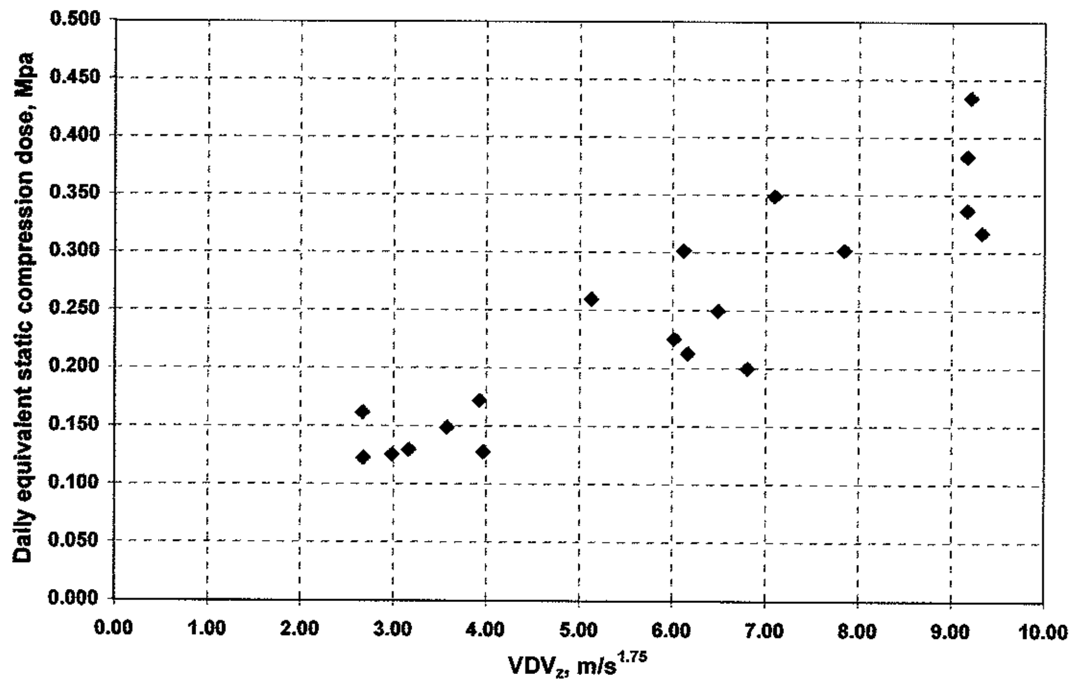

Figure 1. Daily static compression dose vs Vertical Vibration Dose Value

Conclusions

Evaluation of the data collected in the studies reported here following ISO 2631 suggests that the shock and impact exposure for locomotive crew members presents a low probability for an adverse health outcome. These results also indicate that, for locomotive shock and vibration, the health guidance for the VDV given in Part 1 of the standard is more stringent than the health guidance for spinal stress in Part 5.

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REVISION OF ANSI S3.34 (2.70-2006) – GUIDE FOR THE MEASUREMENT AND EVALUATION OF HUMAN EXPOSURE TO VIBRATION TRANSMITTED TO THE HAND

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Introduction

Intense vibration can be transmitted to the hands and arms of workers who use hand-held percussive or vibrating devices, tools, and work pieces. Continued habitual exposure to vibration directed to the hands can cause patterns of various symptoms associated with hand-arm vibration syndrome (HVAS). The International Organization for Standardization (ISO) first published ISO 5349 in 1986.[3] This standard specified methods for measuring and evaluating vibration directed into the hands from hand-held vibrating devices, tools, and work pieces. The American National Standards Institute (ANSI) published ANSI S3.34 the same year.[1] This standard was modeled after ISO 5349-1986 and specified methods for assessing exposure to hand-arm vibration.

The Parliament of the European Union has issued the European Union Human Vibration Directive-2002/44/EC, which specifies vibration daily exposure action values (DEAV) of 2.5 m/s^2 and daily exposure limit values (DELV) of 5.0 m/s^2. These values have generally been accepted by medical experts, scientists, and engineers in governmental agencies, research institutions, and industry in the USA and other countries.[2] When they are achieved, they will reduce the potential for the development of symptoms related to HAVS among workers exposed to hand-arm vibration.

Significant improvements in measurement and analysis instrumentation, miniature and subminiature accelerometers, and medical diagnostic and assessment protocols have being introduced since 1986 when ANSI S3.34 was first published. In response to these improvements and the introduction of the EU Human Vibration Directive, ANSI Working Group S2.39 developed the revision to ANSI S3.34, which has now been published as ANSI S2.70-2006.[2]

Method

ANSI S2.70 specifies the use of the hand-arm vibration measurement procedures outlined in ISO 5349, Parts 1 and 2.[2,4,5] It requires the measurement of ISO frequency-weighted acceleration values in three mutually orthogonal axes of vibration. These values are then vectorially added to obtain the vibration total value, a_{hv}:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad (1)$$

where a_{hwx}, a_{hwy}, and a_{hwz} are the measured r.m.s. ISO frequency-weighted acceleration values in the x, y, and z directions, respectively. If multiple vibration exposure events are experienced during a work day, the overall vibration total value is obtained from:

$$a_{hv} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}\left(a_{hvi}^2\,T_i\right)} \quad (2)$$

where a_{hvi} is the vibration total value of the i^{th} operation, T_i is time duration in hours of the i^{th} operation, n is the total number of operations, and T is total time in hours associated with the n operations. Finally, the daily vibration exposure value, A(8), standardized to an 8-hour reference period, is obtained from:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}} \qquad (3)$$

where T_0 is the reference duration of 8 h.

ANSI S2.70 defines a value of A(8) equal to 2.5 m/s^2 as the Daily Exposure Action Value (DEAV).[2] The DEAV represents the health risk threshold to hand-transmitted vibration. "Health risk threshold is defined as the dose of hand-transmitted vibration exposure sufficient to produce abnormal signs, symptoms, and laboratory findings in the vascular, bone or joint, neurological, or muscular systems of the hands and arms in some exposed individuals.[2]" ANSI S2.70 recommends that a program be designed to reduce worker exposure to hand-transmitted when A(8) exceeds the DEAV to reduce health risks.

ANSI S2.70 defines a value of A(8) equal to 5.0 m/s^2 as the Daily Exposure Limit Value (DELV). [2] Workers who are exposed to hand-transmitted vibration at or above this level are expected to have a high health risk. "High health risk is defined as the dose of hand-transmitted vibration exposure sufficient to produce abnormal signs, symptoms, and laboratory findings in the vascular, bone or joint, neurological, or muscular systems of the hands and arms in a high proportion of exposed individuals.[2]" ANSI S2.70 recommends that workers not be exposed to A(8) values above the DELV.

Discussion

ANSI S2.70 is a timely and needed revision of ANSI S3.34. It gives the U.S. a modern standard that is in agreement with ISO 5349, Parts 1 and 2 and that has vibration assessment criteria that are accepted by medical experts, scientists, and engineers in governmental agencies, research institutions, and industry in the USA and other countries. ANSI S2.70 gives guidance for vibration exposure and health risks assessments, specifies methods for mitigating health risks associated with hand-transmitted vibration, and gives guidance for worker training and medical surveillance.

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STANDARD TESTS FOR SUSPENDED SEATS – CAN THESE CONTRIBUTE TO PROTECTION AGAINST WHOLE-BODY VIBRATION? – COMMENTARY ON HISTORICAL DEVELOPMENT AND CURRENT WORK IN CEN/TC231/WG9 (SEATING)

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Introduction

Suspended seats perform two functions: Reduce effect of occasional large bumps; Reduce more continuous vibration at a lower level. The former needs high damping. The latter needs low damping. For most mobile work machines the inevitable compromise is generally better than a simple cushion seat, because that amplifies vibration at around 4 Hz which is a sensitive frequency for human vertical WBV.

Why have standard tests for seat suspensions?

- Seat suspensions are non-linear so any measure of performance depends on operating conditions. For comparison these need to be defined.
- Seat manufacturers need benchmarks for product development;
- Machine makers choose dynamic characteristics appropriate to their products;
- Occupational health specialists wish to control operator exposure to

Standard tests should be representative, repeatable and reproducible. These requirements are reviewed in relation to the history of seat test standards and the current position.

Current position and history

The current position is that we have standard tests for seats for agricultural tractors, earthmoving machinery, industrial (fork-lift) trucks. These tests comprise measurement of vibration transmission and of the rate of damping.

Current standards developed as the technology developed, starting around 1960:

1. Test on machine driven over standard surface[1].
2. Test on shaker reproducing standard surface.
3. Shaker input replaced by representative spectrum[2].
4. Human subject replaced by dynamic dummy. (Not yet settled).

Are standard tests representative?

The development process has gradually moved seat tests further from reality. 4 hr samples of work exposure suggest that seats do not **on average** provide large reductions of vertical WBV[3]. For **specific magnitudes** of vibration they can work well. For low vibration, performance is reduced by friction and for severe vibration by length of travel. Recent work has led to a new test to quantify how a suspension controls over-travel [9].

Are standard tests repeatable?

Tests involving driving a machine were never very repeatable, because the input could not be controlled very closely. Shaker tests can have very repeatable inputs, e.g. KAB Seating has just run a review that shows consistency over a ten year period.

Are standard tests reproducible?

In Europe, inter-laboratory tests gave unacceptable inconsistencies. Dynamic dummies are being trialled to replace human subjects, but even with these there can be 25% difference between laboratories. Current work of CEN Seating WG is aimed at comparing how different laboratories interpret the standard specifications, with the aim of improving these specifications. Then with dummies we should have reproducibility.

Comments

We have standard tests for seat suspensions that are repeatable. Work is in hand to try to make them more reproducible. The question remains: How helpful are such standard tests in protecting workers against harmful effects that are associated with WBV?

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EVALUATION OF SCRAPER OPERATOR EXPOSURE TO WHOLE-BODY VIBRATION IN THE CONSTRUCTION INDUSTRY: A TASK ANALYSIS

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Introduction

Kittusamy (Kittusamy & Buchholz, 2004) state that there have been few studies conducted to assess exposure to whole-body vibration (WBV) in the construction industry. They suggest that there is very little reliable data from the construction industry that characterizes exposure levels to various hazards including WBV or the health outcomes from such exposure and that there is a need for more exposure data. In a recent exploratory study of heavy construction equipment Cann (Cann, Salmoni, Vi, & Eger, 2003) looked at vibration levels for 14 different types of construction equipment. Eight of the 14 pieces of equipment tested exposed operators to levels of WBV that exceeded the recommended limits for an 8-hour period when comparing the measured VDV to the ISO 2631-1 standards. The purpose of the present research was not only to test a larger number of scrapers but also to investigate scraper operator exposure to whole body vibration (WBV) separately for each task.

Methods

33 scrapers were evaluated for WBV in a variety of residential and road construction projects. Testing equipment consisted of triaxial accelerometers that allowed vibration data collection in all three orthogonal axes, with the x-axis positioned to measure vibration in the anterior-posterior direction, the y-axis in the medial-lateral direction, and the z-axis in the vertical direction. Root mean square accelerations (aRMS), vibration dose value (VDV), crest factor, and maximum transient vibration values (MTVV) were derived from this software and exported to an Excel™ spreadsheet for later data analysis.

Test sessions for each piece of equipment lasted for approximately 20 minutes until at least three work cycles had been completed. Tasks included: idling while waiting for a bulldozer to push the scraper through the scraping phase, scraping, traveling loaded with dirt, dumping and traveling empty.

Results

Task breakdown by time reveals 25% of the work cycle was spent traveling fully loaded with dirt, 19% dumping, 21% traveling unloaded, 17% idling and 18% scraping. Calculation of aRMS vector sums gave values of 2.55 m/s^2 during loaded transport, 2.46 m/s^2 during dumping, 2.31 m/s^2 during unloaded travel, 0.55 m/s^2 during idling and 1.46 m/s^2 during scraping (see Table 1). The highest acceleration values recorded were found in the z-axis during fully loaded transport reaching an average aRMS over three work cycles of 2.55 m/s^2.

Table 1: Summary of WBV aRMS from the x,y,z axes n=33

aRMS (m/s^2)	Loaded	Dump	Unloaded	Idle	Scrape	Overall
X (m/s^2)	0.97	0.94	0.88	0.23	0.60	0.81
Y (m/s^2)	1.04	0.99	0.95	0.21	0.59	0.86
Z (m/s^2)	1.55	1.49	1.39	0.32	0.83	1.28
Vector Sum (m/s^2)	2.55	2.46	2.31	0.55	1.46	2.12

Discussion

The overall vector sum aRMS values exhibit accelerations well beyond the Commission of European Communities (CEC) recommended 8 hour levels. In a review of European Union whole body vibration exposure standards Griffin confirms the 8 hour action limit to be 0.5 m/s^2 and the 8 hour exposure limit of 1.15 m/s^2 (Griffin, 2004). Results are consistent with whole body vibration measurements from previous work. Accelerations are repeatedly in excess of maximal exposure limits recommended by ISO. This leads one to conclude that all scrapers will expose the operator to excessive levels of whole body vibration that may lead to injury or illness. There are researched methods that a scraper operator can do to decrease this risk. First, they can decrease speed while traveling loaded, dumping and unloaded. Second, they can ensure that tire pressure is at optimal levels. Third, they can maintain a healthy posture while driving.
However, the effect of such risk reducing factors is minimal. The solution to harmful vibration does not lie in wasting more money testing construction equipment to determine that it is exposing the user to potentially higher than recommended levels of vibration. The solution lies in the engineer's hands. Attacking this problem through better seat design is thought to enable a decrease of over 50% (Griffin, 1990). In addition, improving vehicle suspension, cab vibration absorption and engine mounts keeps solutions at the source of the problem versus at the operator.

Acknowledgements

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CHARACTERISTICS OF WHOLE-BODY VIBRATION FREQUENCIES AND LOW BACK PAIN IN URBAN TAXI DRIVERS

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Introduction

Occupational exposures to whole-body vibration (WBV) at different frequency domains may differentially affect human comfort and the musculoskeletal system. Under this presumption, a frequency-based weighting scheme has been adapted in many widely accepted standards for WBV measurement. However, there is very little human data showing a direct link between WBV frequency and musculoskeletal disorders. We conducted an epidemiologic study to examine the association between WBV frequency and prevalence of low back pain (LBP) and to identify determinants of specific frequencies associated with LBP in urban taxi drivers.

Methods

The WBV frequency data were collected from 247 professional drivers (aged 44.6±8.3) who participated in an exposure validation study [1] of the Taxi Drivers' Health Study (TDHS) in 2000. [2] In accordance with the ISO 2631-1 (1997) methods, we measured the frequency-weighted acceleration over drivers' seat surface, under conditions representing randomly assigned destinations. We developed a WBV record-replay system at the Liberty Mutual Research Institute (LMRI) in Hopkinton, MA, USA. This system includes two tri-axial accelerometers (PCB Piezotronics, NY, USA), one RD-130T PCM data recorder (TEAC, Tokyo, Japan), and one LMWBV meter 2.0 (LMRI, MA, USA). Only the vertical axis of seat-surface WBV frequency was used in this study. To characterize the WBV frequency curve, we manually identified the presence of any peak within each of the following frequency range: <4, 4-10, 10-20, and >20 Hz. Information about the operating vehicles and driving environment was either collected from the vehicle registration record (manufacturer, year of make, transmission, engine size, etc.) or directly measured (wheel-base length, seat inclination, etc.). Structured interviews were conducted by an occupational physician to gather information on LBP that had led to medical attention or absence from driving in past year. We used multiple logistic regression to estimate the prevalence odds ratio (OR) associated with the presence of each index peak frequency, adjusting for age, body mass index, professional seniority, daily driving hours, seat inclination, and the intensity of predicted root-mean-square WBV exposure in m/sec^2. For any revealed WBV frequency that was associated with LBP, we constructed a multiple logistic regression model to identify the personal and vehicle characteristics associated with the presence of WBV peak within the indicated frequency range.

Results

Of the 236 (96% of 247) all male drivers who had WBV frequency data, 47% complained LBP in the past year. Of all classifiable frequency curves, the proportion of having an identifiable peak, respectively for <4, 4-10, 10-20, and >20 Hz, was 71%, 93%, 47%, and 56% respectively. Drivers whose frequency curves did not reveal the presence of peak frequency < 4Hz had the lowest LBP prevalence (37%). Results of multiple logistic regression showed positive associations between the presence of peak frequency <4 (p=0.06) or 4-10Hz (p=0.35) and increased 1-year prevalence of LBP, with estimated prevalence OR=1.98 (95% confidence [CI]: 0.98-4.01) and 1.74 (95%CI: 0.54, 5.59). No positive associations were found with the presence of peak frequency either at 10-20 or >20Hz. As average driving speed increased, the probability of having a low-frequency (<4Hz) peak on WBV curve increased in a quadratic-linear manner (p<0.001). Other significant determinants of the presence of a WBV peak frequency <4Hz included: engine size <1500c.c. (OR=1.72, 95%CI: 1.46, 9.70) and manufacturer (p<0.001). Our preliminary analyses did not suggest any statistically significant associations with other vehicle or drivers' characteristics.

Discussion

This was the first epidemiologic study linking LBP with WBV frequency profile obtained by directly measuring frequency during the exposure. Our preliminary analyses indicated that the presence of a low-frequency (<4Hz) WBV peak was associated with higher 1-year prevalence of LBP. Although we noted a positive association with the presence of a WBV peak near the resonance frequency of 4-6 Hz, the limited variability of the WBV frequency curve across the 4-10 Hz range, probably as a result of applying the ISO 2631-1 (1997) frequency weighting function, might have precluded the possibility of finding any statistically significant association. We also identified driving speed, engine size, and manufacturer as the most significant determinants of the presence of a low-frequency (<4Hz) WBV peak. Further analyses will examine the association of LBP with the estimated intensity of each WBV peak, and also to identify the determinants of any peak WBV intensity that correlates, if any, with LBP in urban taxi drivers. If the positive association between low-frequency (<4Hz) WBV and LBP was further confirmed, experimental research should look into the biomechanical effects and other pathophysiological changes related to WBV exposure at this frequency range.

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INVESTIGATION INTO THE UNCERTAINTY IN MEASUREMENTS AND EVALUATION OF HAND-TRANSMITTED VIBRATION

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Introduction

Accurate measurement and evaluation of hand-transmitted vibration from a power tool is an important issue for tool manufacturers, because they are obliged to develop low-hazard power tools for workers. The International Standard ISO 5349[1] dictates a systematic procedure for the measurement and evaluation of hand-transmitted vibration. However, the uncertainty in this measurement is too large for manufacturers to apply such data to the design and modification of power tools. There can be several sources of this uncertainty in such measurements; e.g., operator-dependent, power tool-dependent, and operational conditions (see Table 1). For a manufacturer to characterize the exposure of a power tool's use to a given level of vibration, the relationship between these uncertainty factors and the measured vibration must be elucidated. In this study, we investigated the effect of several factors on the uncertainty in measurements.

Table 1. The possible sources of an uncertainty in a measurement.

Tool	Operator	Operating condition	Instrumentations
Tool Grit/Tip/Insert Installation	Stature and weight Muscular strength	Posture Applying forces	Accelerometer Data processing device

Methods

In this study, some of the factors in Table 1 were selected for examination, and their effect on the measured variation was quantitatively investigated. Three tools from the same manufacturer were sampled at random in our experiments, and each of five of the same type of insert (disks or tips) was installed into each tool. Although each of the tools and inserts were of the same design and were made by the same production process, they differed from one to another, which can be a source of the variation in the measured vibration.

Three human subjects participated in our experiments, which were carried out as stated in ISO 5349. The subjects were asked to maintain their posture, and the applied force was kept as constant as possible. The applied force was monitored using an indirect method, where vibration energy was displayed in real time during the experiment using a three-axis accelerometer attached to the work piece at a specified point. The appropriate range of the applied force was predetermined to cover the range of real work operations. The engineering tolerance between the inner diameter of a grit disk and the outer diameter of the tool shaft leads to an eccentricity of the mass at the center of the disk. The degree of eccentricity varies with installation, and this is another source of uncertainty. In our study, the effect of this eccentricity was investigated by carrying out repeated assembly and disassembly of an insert.

Human exposure levels of hand-transmitted vibration were measured in 45 combinations of the three subjects using three tools of the same make, and five inserts of the same make for each of the three types of tool studied: a 7" and a 4" grinder, and a die grinder. Each measurement was performed following the procedure listed in ISO 5349. Data acquisition for each case was made over a period of five minutes involving five repeated one-minute measurements.

Results

Table 2 shows the variation in human exposure levels to hand-transmitted vibration, a_{hv}, for the selected factors. For example, the 7" grinder showed a variation of 13.7% for our subjects using the 15 tool and insert combinations. For the three types of tool, the effect of the variation among the tools, which was closely related to the quality of the product, was the most dominant factor. Variations in the vibration according to subject varied from 11.7% to 13.7%, which seems reasonable, because the applied force was monitored and controlled during the measurement. Variations according to the insert are possibly caused by irregularities in the insert and/or installation. Variations in the measurements according to installation were investigated in a separate experiment.

Table 2. Variations in human exposure levels of hand-transmitted vibration with different tools, inserts, and subjects.

	Factor		
	Subject	Tool	Insert
7" Grinder (plus grit grinding wheel) grinding stainless steel	13.7%	40.3%	14.7%
4" Grinder(plus grit grinding wheel) grinding stainless steel	11.7%	18.6%	9.5%
Die grinder (plus rotary cutter) grinding stainless steel	13.4%	18.9%	16.4%

Discussion

We have investigated the effect of several factors on the uncertainty in measurements of hand-transmitted vibration. Among the three major factors studied, the variation according to the tool used was the most dominant factor, even though this was limited. The variation according to subject showed a consistent value of 11.7% to 13.7% for the three types of tool studied. The variations according to insert had two causes: one was due to the irregularities between the inserts, and the other was due to the eccentricity of the rotation, which is currently under further investigation.

To compare human exposure levels to vibration in different tools, which is necessary for the selection of better tools, more research into the effect of the factors that influence the uncertainty should be carried out.

Reference

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Podium Presentations

Session VII: Biodynamics II

Chairs: John Wu and Kumar Kittusamy

A PORTABLE MEASUREMENT SYSTEM FOR THE ASSESSMENT OF TIME WEIGHTED AND IMPULSIVE EXPOSURES TO WHOLE BODY VIBRATION

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Introduction

Bus drivers represent a large segment of the US transportation industry and research has shown an association between exposure to Whole Body Vibration (WBV) and the high rates of low back disorders. Impulsive WBV exposures have been recognized as a risk factor for low back injury and new guidelines exist for their measurement and assessment (ISO 2631, Part 5). Methods to accurately and better characterize the impulsiveness of WBV along with the temporal patterns of the exposures are needed. The development of a hardware and software system to measure continuous TWA and raw, impulsive WBV exposures and the design of a subsequent study are presented.

Methods

Using two Larson Davis HVM 100 as accelerometer amplifiers, small external batteries, and a Pocket-PC (PDA) with 1 Gb of compact flash memory, we can collect up to 16 channels of data for a full day 600 Hz. Tri-axial WBV exposures will be measured and characterized at the frame of the bus and at the driver/seat interface (seatpad accelerometer). Using a repeated measures design, 20 bus drivers will drive on selected routes which include both city streets and highways, and within and between subject components of variability and exposure determinants related to the bus, bus seat, the bus driver, and the route will be identified. Global Positioning System (GPS) data will also be collected and integrated with the WBV exposure data to facilitate the identification of the location, velocity and type of road associated with high average TWA and impulsive WBV exposures. This system may be used to develop administrative (alter speed and/or route of bus, systematically vary type of routes) and/or engineering controls (identify and trigger the need for street repair) to reduce high WBV exposures.

Results

Our portable Pocket-PC based data acquisition system is up and running and we can collect seven channels of WBV data (seat pan tri-axial accelerometer, bus frame tri-axial accelerometer and GPS data) continuously for a full shift. The software analysis of the data is complex but nearing completion. We have incorporated the vibration dose calculations from ISO 5321, Part 5 and have obtained a Matlab-based routine to appropriately weight the continuous signals.

Discussion

In summary, the measurement of WBV is complex but new technologies open avenues of collecting and assessing WBV exposures that were previously not possible. The standardization of impulsive WBV exposure assessment methods is needed to further the discipline and better enable comparisons across studies.

INFLUENCE OF BACK SUPPORT CONDITIONS ON THE ABSORBED POWER OF SEATED OCCUPANTS UNDER HORIZONTAL VIBRATION

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Introduction

The absorbed power (P_{Abs}) has been suggested as a better measure of human responses to whole-body vibration, since it relates to the cumulative energy dissipated by the body exposed over a given duration. Moreover, unlike the other measures, the P_{Abs} can adequately account for the intensity of exposure. Although, the vast majority of off-road vehicles impose considerably severe vibration along the horizontal axes, the vast majority of studies on biodynamic response characterization consider only vertical vibration. Only a few studies have reported P_{Abs} responses of the seated human body exposed to horizontal vibration and the major contributing factors [1]. This study aims to characterize the P_{Abs} responses of seated human subjects to horizontal (uncoupled x- and y-axis) vibration as functions of the vibration intensity, subject mass, seat height and the, type of back support.

Methods

Experiments were conducted using a rigid seat with an adjustable backrest inclination and seat height. The seat was installed on a horizontal vibration simulator and the forces at the seat base and the backrest were measured by three-axis force plates. Two single-axis accelerometers were installed on the seat back and the platform, oriented along the axis of motion. The experiments were performed using three different seat heights (350, 390 and 410 mm), back support conditions (NB- no back support and sitting erect; Wb0- Upper body supported against a vertical back support; and WbA- back supported against an inclined backrest, while sitting relaxed) and three different magnitudes of broad band excitations in the 0.5-10 Hz frequency range (0.25, 0.5 and 1 m/s^2 rms acceleration under x-axis and y-axis, applied independently). A total of 8 healthy adult male volunteers with total body mass ranging from 59.4 kg to 92 kg and aged between 21-51 years took part in the experiments. The subjects were seated with their hands in lap, and feet supported on the moving platform for each posture. Each measurement was repeated 2 times, while the data were analysed using a bandwidth of 50 Hz and frequency resolution of 0.0625 Hz.

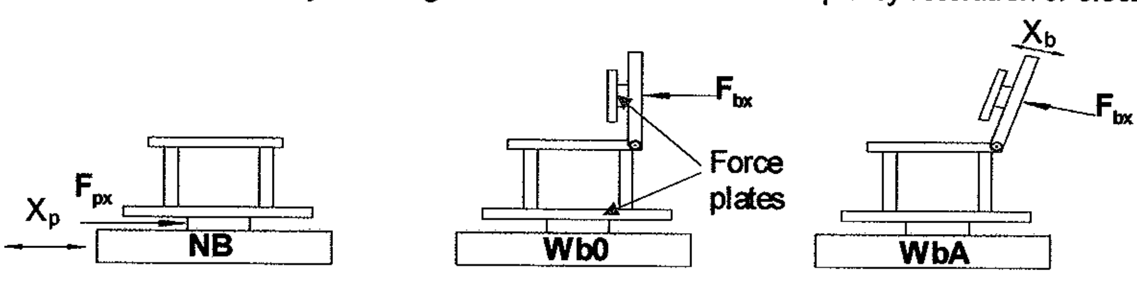

Fig 1: Back support conditions used in the study.

The data were analyzed to derive the absorbed power characteristics of the body at both seat pan and backrest interfaces, while the coherence among the measured forces and accelerations were particularly monitored. The P_{Abs} of the seated body subjected to x- and y-axis vibration were computed in the one-third octave bands, while the total power was derived through integration of the real component of the force and velocity cross-spectrum under each test condition.

Results and Discussions

The measured absorbed power responses suggested significant inter-subject variability, irrespective of the experimental condition employed, while the total P_{Abs} showed nearly quadratic relation with the excitation magnitude. The seat-buttock interface P_{Abs} responses obtained for all the subjects seated assuming the NB posture and exposed to x- and y-axis vibration consistently revealed distinct peaks in the bands with center frequencies of 0.63 and 1.25 Hz. These frequencies are comparable with those observed from reported studies on P_{Abs} and APMS responses [1, 2]. The P_{Abs} responses revealed strong influences of the back support condition, apart from the vibration intensity under x-axis vibration, while the effect of seat height was observed to be small. Under y-axis vibration, the contributions due to back support were relatively small (Fig. 2).

Sitting with inclined back support (WbA) resulted in the peak P_{Abs} response in the 2.5-4 Hz bands under x-axis vibration, while the magnitude of the peak in the 0.63 Hz band diminished most significantly. The P_{Abs} derived at the backrest also revealed similar trends in magnitude and the corresponding frequency under x-axis vibration. The magnitude of the peak P_{Abs} measured at the back rest was around 50-60% of that measured at the seat pan, suggesting important interactions of the upper body with the backrest (Fig. 2). The WbA posture showed lower power absorption by the body when compared to that with the Wb0 posture, which can be attributed to more stable upper body posture when supported by an inclined backrest. Total P_{Abs} derived from the seat pan and the backrest measurements under x-axis motions showed good correlations with the body mass ($r^2 > 0.8$ and 0.7, respectively). The intermittent loss of contact of the upper body with the backrest resulted in relatively lower correlation with the body mass

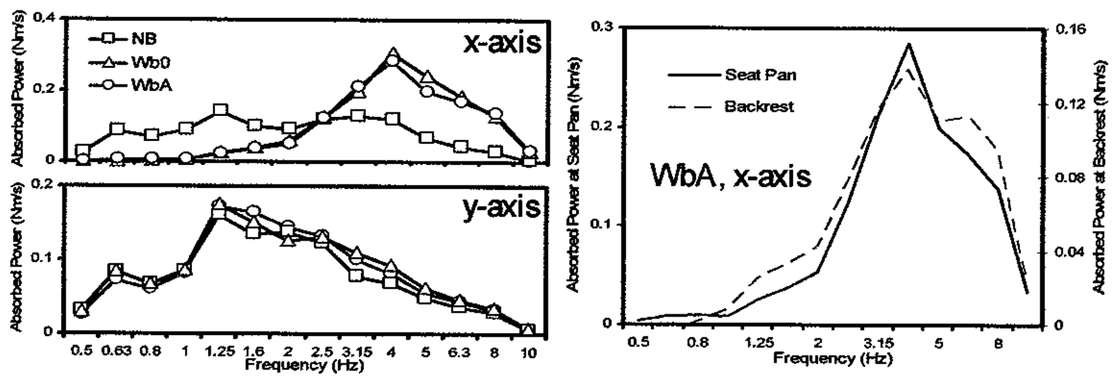

Fig. 2: Influence of back support condition on the absorbed power responses.

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A MULTI-BODY DYNAMIC BIOMECHANICAL MODEL OF A SEATED HUMAN EXPOSED TO VERTICAL WHOLE-BODY VIBRATION

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Introduction

Ethical concerns of in-vivo procedures and poor repeatability of non-invasive techniques have been major limitations in estimating vibration-induced spine loads through experiments. The biodynamic models of seated human body exposed to whole-body vibration (WBV) have evolved for defining the frequency-weightings, enhancement of human responses to WBV, and developing anthropodynamic manikins for seating assessment activities. The widely reported mechanical-equivalent models, solely based on through- or to-the-body biodynamic response functions, do not seem to resemble the biomechanical structure and do not yield information on the dynamic loading and deflections of segments of concern, namely the spine. On the other hand, biomechanical models with representative anatomical structure and anthropometry are being attempted to simulate segmental movements and the coupling effects, using Finite elements (FE) or multi-body dynamics (MBD) formalisms, which could provide important insights into the inter-vertebral forces [1]. While the FE models pose considerable complexities primarily related to characteristics of the bio-material properties, the MBD technique with discrete rigid bodies offers the flexibility to create multi-segment models with relative ease and lower computational cost. In this study, a preliminary multibody dynamic model of a seated human body exposed to WBV along the vertical direction is formulated using MSC/ADAMS software. The model validity is demonstrated by comparing selected responses with the available measured data.

Methods

The seated human is represented by nine rigid body segments, including: head, neck, thoracic and lumbar torso, pelvis, hands and thighs, as shown in Fig. 1. The rigid bodies are coupled through different rotational and translational joints, some of which are force elements to allow vertical translations and sagittal–plane rotations of the segments. The measurements of transmission of vertical vibration through-the-body generally require subjects to voluntarily maintain a vertical head position to reduce head-accelerometer orientation errors. The head–neck–shoulder joint is thus considered to be rigid. The shoulders are assumed to be rigidly attached to the thoracic segment.

The torso is made up of three (upper, middle and lower) segments connected by visco-elastic revolute and translational joints to permit relative pitch and vertical motions. The forces and torques generated by the joints are derived assuming linear stiffness and damping properties, which were identified from published studies. The pelvis is connected to the rigid seat by similar elements representing the visco-elastic properties of the buttock tissues. The two thighs are rigidly connected to the pelvis, while the segment masses are chosen from the anthropometric data for the 50^{th} percentile male subject.

The initial model parameters for the joints were obtained from [2]. The model was analyzed to determine the force-motion relationship at the buttock-seat interface expressed in terms of apparent mass (AM) and through-the-body vibration transmission, expressed in terms of seat-to-head acceleration transmissibility (STHT), under a swept-sine vertical acceleration. Normal mode analysis was also performed to study the segment motions and resonant frequencies.

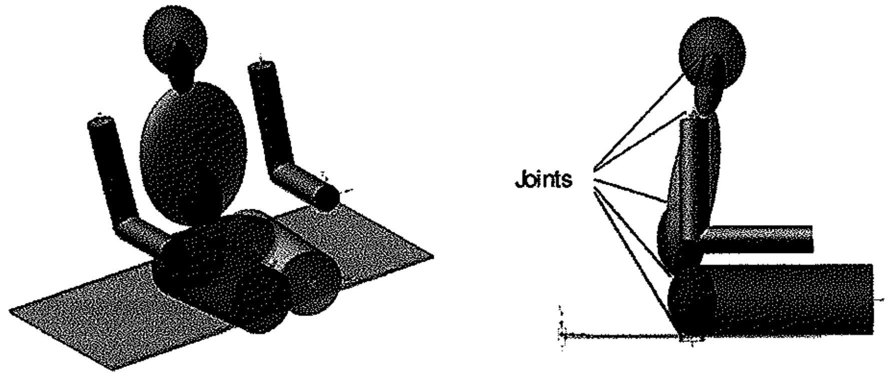

Fig. 1: A multi-body formalism of the seated body.

Results and Discussion

The model validity was initially examined by comparing the AM and STHT magnitude and phase responses with those reported in ISO 5982 [3] and Paddan and Griffin [4]. The results showed poor agreements between the model and reported responses, while the frequencies corresponding to the peak magnitudes were quite close. Normal mode analysis revealed two significant modes: upper-body pitch near 2 Hz, thoracic translation and pitch about the lumbar near 6.6 Hz. Both the AM and STHT responses showed peak magnitude near 4 Hz, while a relatively smaller magnitude peak was observed near 2 Hz. These frequencies agree well with those observed from the biodynamic responses under vertical and horizontal WBV, respectively. The discrepancies in the response magnitudes, however, suggested the need for verification and/or identification of suitable parameters for all the joints. An optimization-based parameter identification technique is thus applied with limit constraints around the reported values to enhance the validity of the model. The results suggest that the model parameters could be identified to match the AM and STHT responses, reasonably well. The feasibility of the resulting model in predicting the relative movements of segments and spine loads could then be explored.

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ASSESSMENTS AND REFINEMENTS OF AN ANTHROPODYNAMIC MANIKIN FOR SEATING DYNAMICS APPLICATIONS

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Introduction

The current laboratory methods for assessing the vibration attenuation performance of seats involve repetitive trials with a number of human occupants, and raise certain ethical concerns. Moreover, the measurements with human subjects yield considerable variability in the data. Alternatively, several anthropodynamic manikins have been developed for effective assessments of the coupled seat occupant system [1]. The effectiveness of a manikin in predicting the response of a coupled seat-occupant system lies in its ability to reproduce the biodynamic response of the seated human body in terms of force-motion relationship at the body-seat interface, such as apparent mass (APMS). A number of prototype manikins have thus been developed on the basis of biodynamic characteristics of vertical vibration-exposed seated occupants of different body masses in the vicinity of 5^{th}, 50^{th} and 95^{th} percentile male population. This study concerns with the analysis of a passive prototype manikin to enhance its ability to reproduce the idealized APMS response characteristics of the vibration-exposed seated human subjects defined in ISO-5982[2] for mean body masses of 55, 75 and 98 kg.

Methods

The APMS responses of a prototype anthropodynamic passive manikin were thoroughly characterized in the laboratory under different excitations and body mass configurations. The manikin was designed with sufficient flexibility to configure mechanical-equivalent models corresponding to seated body masses of 55, 75 and 98 kg, by adding/removing specified masses and springs (Fig. 1). The manikin, configured for a specific body mass, was positioned on a rigid seat without a backrest, which was fixed to the force platform of a whole-body vertical vibration simulator. The simulator was programmed to synthesize random vertical vibration with flat acceleration power spectrum in the 0.4-20 Hz frequency range with two different magnitudes: 1 and 2 m/s^2 overall rms acceleration. The total static and dynamic forces of the manikin to and the seat were measured using the force platform, while a single axis accelerometer was installed on the seat pan to measure acceleration due to vertical excitation. The measured data was appropriately corrected for the rigid seat inertia force, and the apparent mass

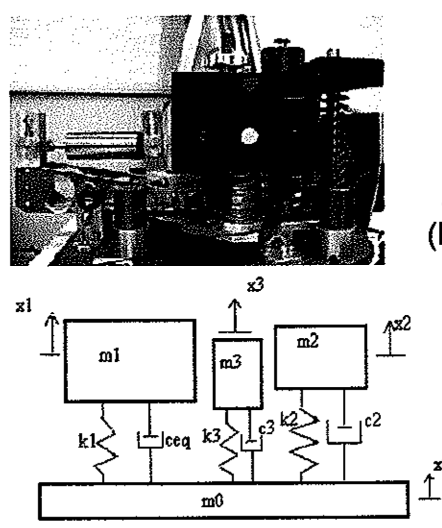


Fig. 1: A pictorial view and mathematical model of the manikin

System Evaluation Methods

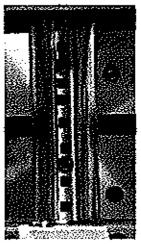


Figure 3: Vibration Distribution measurement

Several preliminary experiments have been performed to examine the characteristics of the system and its performance. A laser vibrometer (Polytec PI, H-300) was used to examine the distribution of sinusoidal acceleration on the handle vibrating at 2g in three directions, as shown in Figure 3a. The system was used to simulate 3-D sinusoidal vibration, a broadband random vibration from 7.5 Hz to 500 Hz, and a cutting saw vibration spectrum.

Evaluation Results

Figure 4 shows the distribution of the vibration on the handle. The maximum difference of the distribution along the handle longitudinal direction in the frequency range (<500 Hz) of concern was less than 9%.

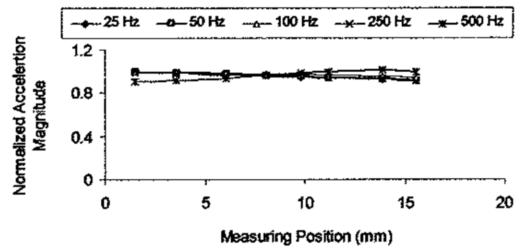
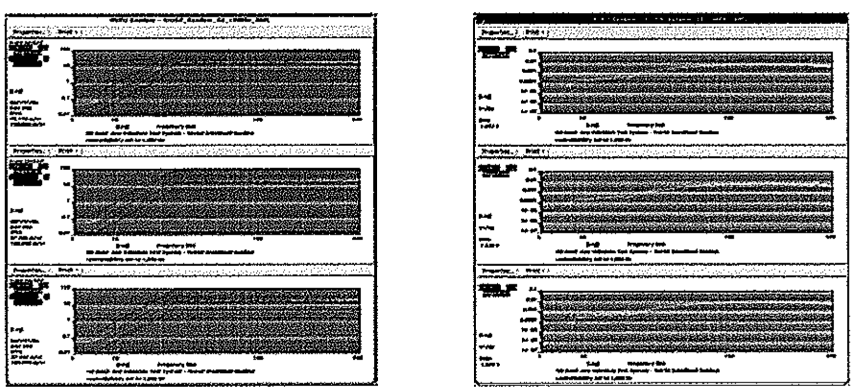


Figure 4: Vibration distribution on the handle

As an example, Figure 5 (a) and (b) display the Control and Drive plots demonstrating full performance. Overall noise levels due to the 10 g's RMS vibration on each axis exceeded 96 dBA in a 52 dBA ambient environment absent the vibration.



(a) Control signal (b) Drive signal

Figure 5: System performance

Conclusion

These preliminary results suggest that it is acceptable to use the 3-D test system to simulate the sinusoidal, broadband random, and time-history vibrations.

MULTI-AXIS HAND-ARM VIBRATION TESTING & SIMULATION AT THE NATIONAL INSTITUTE OF INDUSTRIAL HEALTH, KAWASAKI, JAPAN

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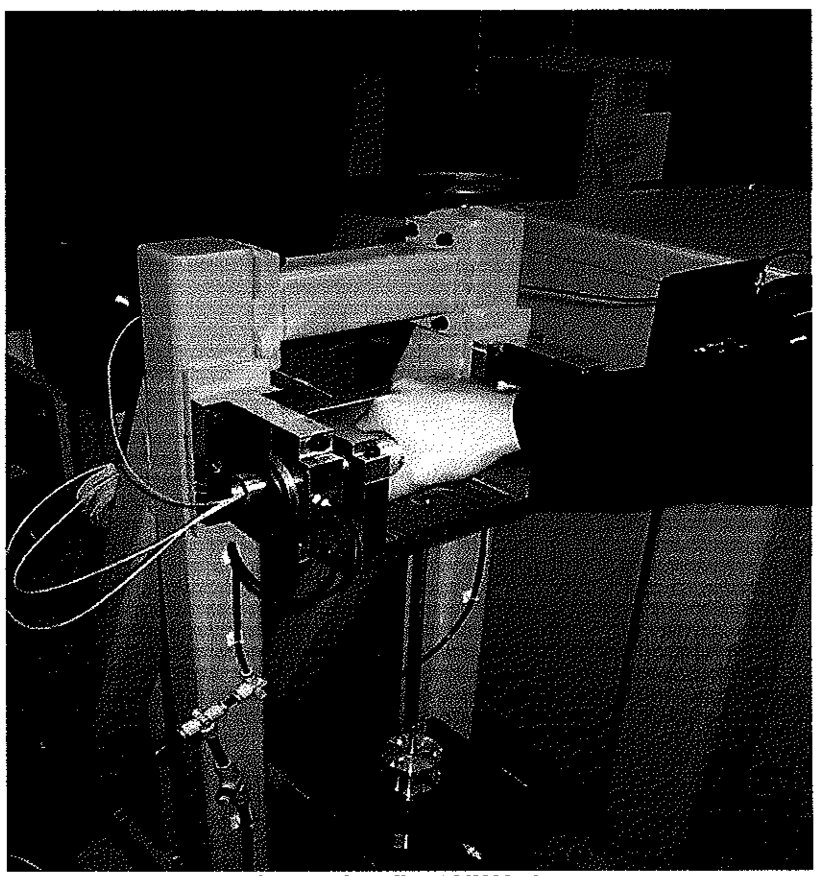
Introduction

Hand-Arm Vibration Syndrome (HAVS) was identified as early as 1918 in Bedford, Indiana in the U.S. Since then much research work has been done around the world in the areas of medical, epidemiological, engineering and legal aspects of HAVS. In Japan, much of the pioneering work in this field has been performed by Dr. Setsuo Maeda and his staff at the National Institute of Industrial Health (NIIH) in Kawasaki. Most recently, reports of work done by this group and by Dr. Ren Dong[1] of NIOSH in the U.S., as well as many other suppliers and Japanese practitioners were presented at the 13th Japan Group Meeting on Human Response to Vibration held in Osaka[2] during August 3-5, 2005.



Patient grasping test handle at NIIH, Japan

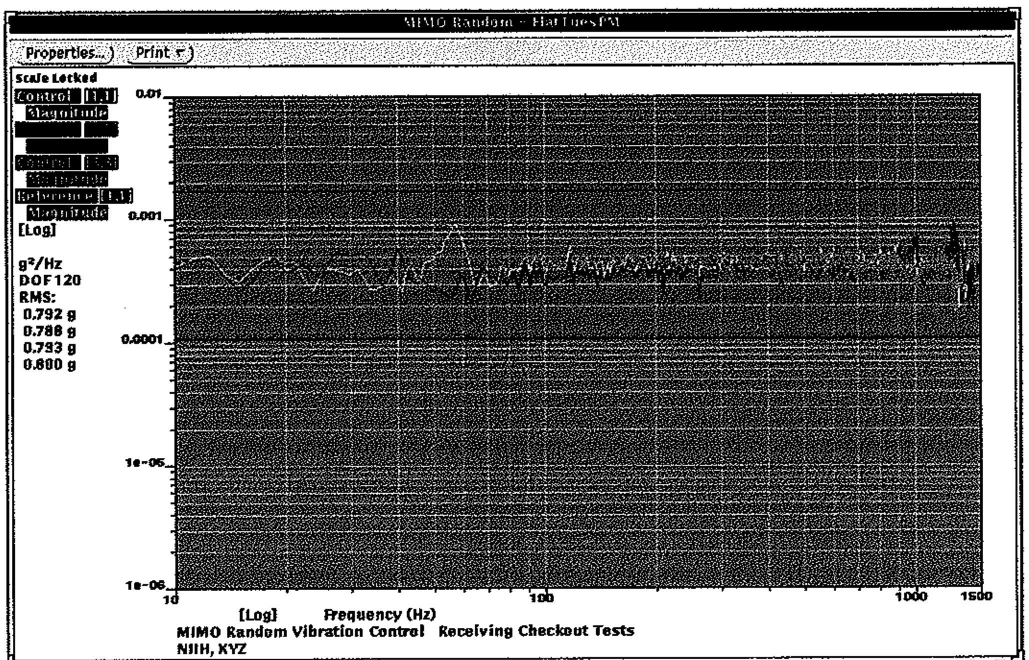
The laboratory at NIIH has been at the forefront of much of the testing technology and instrumentation verification involved in the latest HAVS research which is taking place. An example of this is the recently installed 3-axis vibration simulator in the NIIH laboratory. What follows is a brief description of this system and some results obtained to date.

Methods

Specific methods of measurement and analysis were under development as this abstract was prepared. The presentation may include actual patient response data if it is available at that time.

Results

Results of simultaneous X, Y, Z controlled excitation, like this example, are given.



X, Y, Z Responses controlled from 10 to 1,500 Hz

Discussion

Development is continuing on a modified special handle with embedded Force and Acceleration transducers to understand fully the patient HAVS responses.

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A PILOT STUDY OF THE TRANSMISSIBILITY OF THE RAT TAIL COMPARED TO THAT OF THE HUMAN FINGER

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Introduction

Continual occupational exposure to vibrating hand tools can damage the neural, vascular and other soft tissues of the fingers. Rat tail models have been developed to investigate the biological responses of the tissues to vibration.[1-2] However, the biodynamic response of the tail relative to that of the human fingers has not been characterized. The objective of this pilot study was to compare the transmissibilities of rat tails measured via a scanning laser vibrometer to those of human fingers gripping a handle.

Methods

In Part I of this experiment, four male Sprague Dawley rats (6 weeks old) were exposed to discrete 5g-rms sinusoids of 32, 63, 125, 160, 250, and 500 Hz. The rats were restrained in Broome-style restrainers with their tails constrained without compression to an exposure platform via elastic straps as shown in Figure 1. The platform was attached to a vertically vibrating shaker. The vibration was measured for the array of points shown in Figure 1 using a scanning laser vibrometer (Polytec) and the transmissibility calculated for each point on the tail relative to the reference points on the platform.

In Part II, three male human subjects were exposed at the frequencies specified in Part I - with the addition of 1000 Hz - at a magnitude at the ANSI <0.5-hr limit up to 63 Hz, after which the acceleration was held constant at 5g-rms. The subjects gripped an instrumented handle at 20 N as shown in Figure 2. The transmissibility was calculated relative to the reference points on the handle.

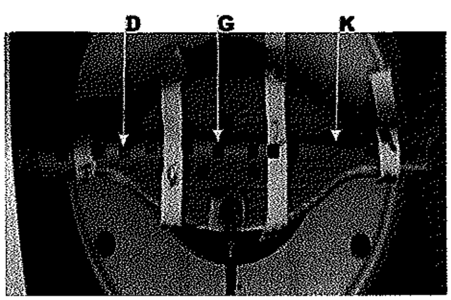

Fig. 1. Index points for tail. D is closest to the rat body.

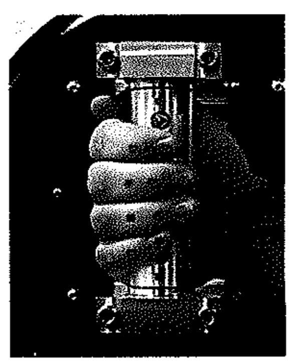

Fig. 2. Experimental set-up for Part II.

Results

Figure 3 shows the transmissibility calculated at the nails of the index, middle and ring fingers of the human subjects. Figure 4 shows a comparison of the transmissibilities of the three most active points on the rat tail with the mean response of all of the tips of the human fingers.

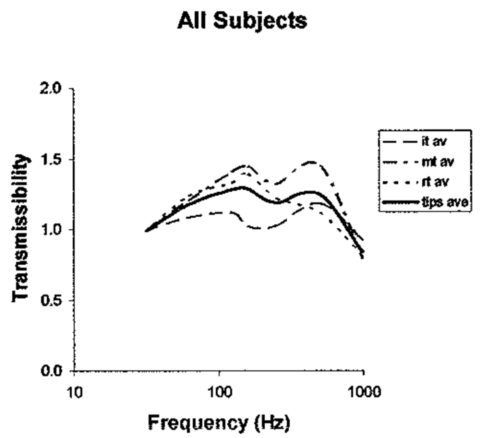

Fig. 3. Transmissibility at middle (mt), and index (it) finger nails.

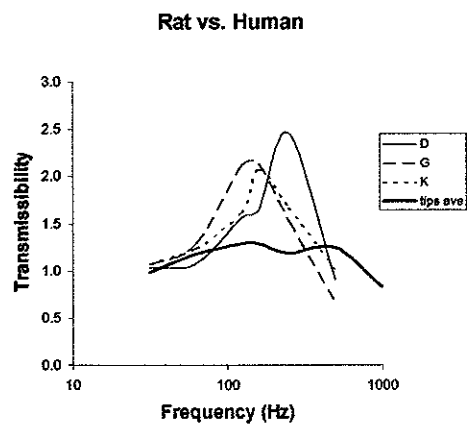

Fig. 4. Comparison of frequency ring (rt) responses of the tail model and the average for the finger nails.

Discussion

As shown in Figure 3, the finger nails tend to show similar frequency responses with comparable first resonances around 125-160 Hz and a second peak at 500 Hz, albeit with varying levels of amplification. The fingers are larger with more mass and damping, while the tail is also stiffer. The rat has considerably higher amplification at all of the most active points. Therefore the rat tail may offer an accelerated model for the investigation of the physiological response to vibration while having similar resonant frequencies to the finger tip.

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Podium Presentations

Session VIII: Vibration Reduction and Machine Testing

Chairs: Jack Wasserman and Alan Mayton

SEAT CUSHION AND POSTURE EFFECTS IN MILITARY PROPELLER AIRCRAFT VIBRATION ENVIRONMENTS

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Introduction

Annoyance, fatigue, and musculoskeletal pain have been reported during prolonged exposures to propulsion-generated vibration in military propeller aircraft[1]. The objective of this study was to determine the vibration mitigation properties of selected seat cushions and the effects of occupant seating posture during exposure to higher frequency multi-axis vibration associated with military propeller aircraft.

Methods

A Navy E-2C Hawkeye crew seat was mounted onto the Six Degree-of-Freedom Motion Simulator (SIXMODE). Six seat pan cushion configurations were tested during exposure to an E-2C vibration signal collected in the field[1]. Seat pan cushions 1 – 5 were used with the original E-2C seat back cushion. Cushion configuration 6 included seat pan cushion 5 with a prototype seat back cushion. Triaxial accelerometer pads were mounted onto the seat pan and seat back cushions to measure the vibration entering the human. Data were collected for seven subjects seated upright with their backs in contact with the seat (back-on) and not in contact with the seat (back-off). Spectral analysis techniques were used to analyze data at the two dominant frequencies associated with the propulsion system (propeller rotation frequency (PRF) ~18.5 Hz, and blade passage frequency (BPF) ~73.5 Hz). Overall accelerations were also calculated between 1 and 80 Hz. Vibration Total Values (VTVs) were calculated using the weighted seat pan and seat back (back-on only) accelerations and compared to the comfort reactions given in ISO 2631-1: 1997[2].

Results

In general, the highest accelerations observed at the seat pan occurred in the fore-and-aft (X) direction at both the PRF and the BPF for all cushions and both postures. The most pronounced effect was at the BPF in the X direction, where all configurations showed significantly lower seat pan accelerations than configuration 1 (original E-2C cushion) with the back-on posture. Configuration 5 was the exception with the back-off posture (Fig. 1A, Repeated Measures ANOVA, $P<0.05$). The most pronounced effect of posture occurred at the PRF in the X direction, where all cushion configurations showed significantly lower seat pan accelerations with the back-off posture (Fig. 1B).

All configurations except configuration 2 showed similar VTVs as compared to Configuration 1 (Fig. 2, $P<0.05$). Configuration 2 tended to show the lowest weighted acceleration levels. The overall VTVs (back-on only, Fig. 2B) showed significantly higher accelerations as compared to both the back-on and back-off seat pan point VTVs (Figs. 2A &

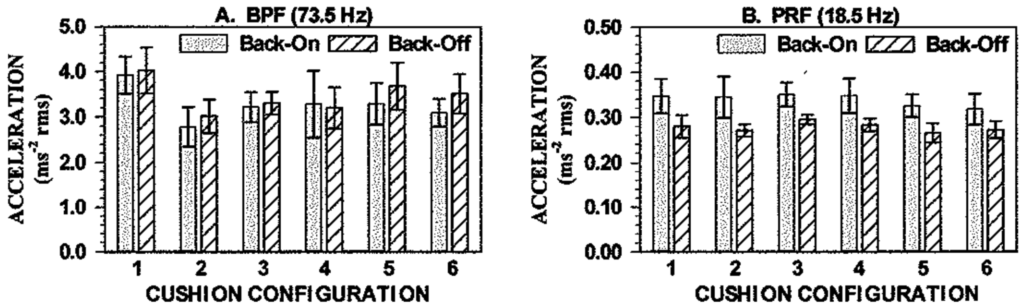

Figure 1 Mean Seat Pan X Accelerations +/- One Standard Deviation at the A. BPF and B. PRF

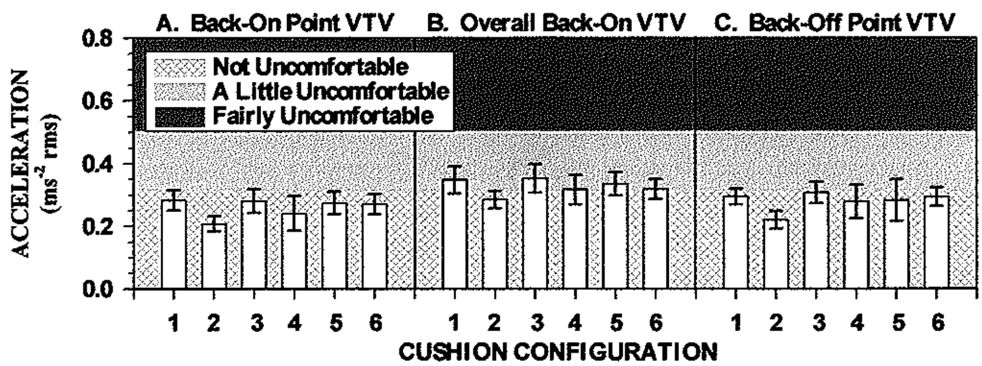

Figure 2 Mean VTVs +/- One Standard Deviation

2C) (Paired t-test, P<0.05). Configurations 3, 4, & 6 showed significantly higher back-off point VTVs (Fig. 2C) as compared to the back-on point VTVs (Fig. 2A). Figures 2B & 2C suggest that, in several instances, vibration would be considered at least "a little uncomfortable."

Discussion

The psychophysical effects reflected in the VTVs indicated that the occupants may only perceive a reduction in the vibration with Configuration 2, regardless of the unweighted results. It is noted that the ISO comfort reactions are based on public transport and may not reflect aircrew comfort perception during prolonged exposures. Posture, relative to sitting in contact with the seat back (back-on), does appear to have a significant effect on the vibration. Although not shown, the highest unweighted seat back vibration occurred in the vertical direction, while the highest weighted seat back vibration was estimated to be in the X direction (back-on). These results render it difficult to determine an appropriate strategy for reducing discomfort by mitigating higher frequency vibration through seat cushion design alone. Newer seat designs (active or semi-active vibration isolation systems) may improve seating comfort during prolonged vibration exposures.

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COMPARISON OF ANTI-VIBRATION INTERVENTIONS FOR USE WITH FASTENING TOOLS IN METAL

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Introduction

Tool manufacturers continue to incorporate new designs to the internal mechanism of tools in order to decrease the vibration that is delivered to the hand during operation. Modification of some tools to minimize tool vibration is not easily resolved through internal tool design. For this reason, vibration damping materials applied between the tool and the hand are a simple alternative. The damping materials may be applied to the area of the tool directly contacted by the operator or in a glove containing a vibration absorbing pad. These interventions are developed specifically to damp vibration but are not necessarily produced and tested under the same work conditions that a company may expose their workers. Therefore, it is important to test the value of the proposed interventions for the specific applications. This study evaluates the effectiveness of anti-vibration interventions currently in use at a local manufacturing company.

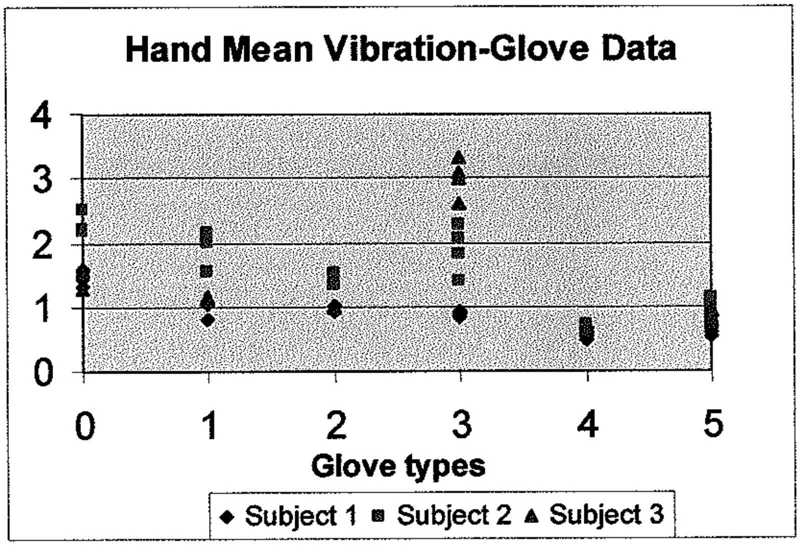
Methods

The design of this study evaluates the vibration energy produced at the tool handle and from the back of the operator's hand. Each operator performed a series of fastener installations in metal using several interventions and one series with no intervention as a control. Four of the interventions were gloves containing anti-vibration material and the fifth intervention was an anti-vibration material wrapped around the tool handle. The protocol for wrapping the tool handle was developed and is part of the equipment procedure at this manufacturing company. Test conditions mimicked production work conditions including similar materials, fasteners and technique for installation. Vibration values were collected using 3 tri-axial accelerometers with one firmly glued to the tool handle close the hand grip as recommended by ISO 5349. A second accelerometer was placed on the top of the pistol shaped tool. The third accelerometer was attached to the back of the hand close to the third knuckle using double sided tape.

Results

Preliminary results for 3 volunteers show a difference between the vibration values of the control condition (mean hand vibration on bare hand = 1.77 Gs) compared to all of the interventions ($p=.0001$ using Mixed Procedure, Tests of Fixed Effects).

The graph below shows individual trials for each subject for each condition. Glove 3 with the air bladder insert shows large variability between subjects (Range = 0.84-3.33 Gs). The other interventions show much less variability both within subjects and between subjects indicating consistent response with use of the intervention.



Glove Types
0 = bare hand
1 = mesh
2 = wrist support
3 = air bladder
4 = foam
5 = wrapped handle

Discussion

All interventions showed less vibration energy produced at the level of the hand compared to the control condition. Thus providing an interface between the operators hand and vibration source decreased the energy directed to the operator. Three of the gloves produced a beneficial response with minimal variation. Intervention glove 3 containing the air bladder provided less consistent beneficial effects due to the large variability in response. This device requires the operator to manually pump the air bladder to the desired level. The manufacturer recommends pumping the air bladder 50 repetitions prior to the initial use and a few additional pumps each day the glove is used. The amount of air delivered to the glove for this pilot was determined by the personal preference of the subjects and resulted in large variability in vibration output.

Intervention 5 consists of a Viscolas™ material wrapped over a tool handle, and held in place with shrink wrap. The manufacturing company developed this method to provide protection to the workers with a durable wrap that was cosmetically pleasing. The lowered vibration values for the Viscolas™ wrapped handle compared to the control indicates the method of wrapping the handle is protective to the operator.

Since both the gloves and the Viscolas™ wrap on the handle of the tool measured lower vibration values, work conditions and behaviors of the workers should be considered to determine the recommended intervention. Use of gloves to minimize vibration exposures requires the operator's consistent use of the glove during all tool use. Wrapping the handle of a tool to protect a worker from vibration exposures does not depend upon a worker's behavior for effectiveness. Assuming all areas of the tool encountered by the hand are covered with the Viscolas™ material, every time the worker grasps the tool, the hand is protected. Since three of the gloves in the study are fingerless, the anti-vibration material will not protect the exposed skin. Operators cannot manipulate small fasteners with full fingered gloves. Recommendations for anti-vibration materials for use in a work force should consider the work methods and behaviors of the operators. In determining a recommended intervention for a particular manufacturing process, it is important to test the real physical conditions as well as the typical behaviors of the workers.

VIBRATION CONTROL ON HAND-HELD INDUSTRIAL POWER TOOLS

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Product Ergonomics, Atlas Copco Tools & Assembly Systems, Stockholm, Sweden

Introduction

Work with hand-held power tools can be found in most industries all over the world. This type of work exposes the operators to different kind of loads like gripping-forces, feed-forces, exposure to vibration and noise, holding hot or cold surfaces and the exposure to dust. Designing a power tool with good ergonomics is a matter of finding the best compromise. As a simple example, increasing the mass is not acceptable because it will increase the forces needed to handle the tool. At the same time increased mass will in most cases reduce the vibrations.

Vibration disorders related to the use of hand-held power tools has been known and reported since long. It is therefore essential that low vibrating tools are developed and used. The new vibration regulations in Europe, based on the Physical Agents (Vibration) Directive, have put increased focus on the vibration control in industry.

Forces acting on the tool cause vibration

Tools for industrial use must be of very robust design to withstand the very hard use they are exposed to. Industrial tools are therefore normally designed with the main parts made of metal. From a vibration point of view this means that most tools can be regarded as rigid bodies, especially because the dominating frequency normally is equal to the rotational frequency of the tool spindle or the blow frequency for a percussive tool. These frequencies are with few exceptions below 200 Hz. Handles however can not always be regarded as rigidly connected to the tool. There are several examples of weak suspensions designed to reduce vibration transmitted to the hands of the operator. There are also examples of designs where the handles just happened to be non-rigidly connected and in some cases even in resonance within the frequency region of interest. Oscillating forces act on the tool and the result is vibration.

Design principals

In all cases forces are the source of vibration. This leads to the three basic principles to control vibration:

- **Control the magnitude of the vibrating forces.** Examples are the balancing unit on a grinder or the differential piston in a chipping hammer.
- **Make the tool less sensitive to the vibrating forces.** Examples can be when the mass of the guard on a grinder is rigidly connected to the tool to increase the inertia of the tool.
- **Isolate the vibrations in the tool from the grip surfaces.** Examples are vibration-dampening handles on grinders or pavement breakers, the air-spring behind the blow-mechanism in a riveting hammer or the mass spring system in a chipping hammer.

Control the magnitude of the vibrating forces

For rotating machinery the balance of the rotating parts is essential. The inserted tools that will be mounted on the tool spindle often give major contribution to the unbalance of the rotating parts. This is a problem because the tool manufacturer has no control over the inserted tools. The only thing that can be done is to design flanges and guides to fine tolerances as close as possible to the tolerance interval for the inserted tool.

Limiting the power of the tool will in most cases also reduce vibration but that is not a possible route because lower power leads to increased usage-time to get the job done and that would negatively affect the daily exposure.

Make the tool less sensitive to the vibrating forces

A tool will be less sensitive to oscillating forces when mass and or inertia is increased. To increase mass can be questioned from an ergonomic perspective. In some cases when a small increase in mass give a big increase in inertia it might still be a good solution. The tool can be regarded as a rigid body suspended in weak springs. Therefore it will move around its centre of rotation. The perpendicular distance between the forces acting and the centre of rotation will determine how the pattern of movement will be. By altering this distance the movement of the tool can be controlled.

Isolate the vibration in the tool body from the grip surfaces

To isolate the handles from the vibration in the tool body is the most common thing to do. Modern chain saws and breakers are examples where this principal have been successfully applied. The mass spring system must be designed to have the excitation frequency from the vibration well above the systems resonance. This requires a certain mass in the handles or the spring need to be very soft. A correlated problem is when mass is moved from the body of the tool to the handles. The reduced mass will make the tool-body more sensitive to the vibrating forces and the vibration amplitude in the body will increase.

Summary

An industrial powertool can in most cases be regarded as a rigid body. The handles are not always part of this rigid body.

- Forces acting on this rigid body are the source of vibration. The forces are either forces from the process or process independent e.g. unbalances in rotating parts.
- There are three basic principals for vibration control. Control the magnitude of the vibrating forces. Make the tool less sensitive to the forces. Isolate the vibration in the tool body from the grip surfaces.
- All three principals are used in vibration control on power tools either one by one or combined on the same tool.

VIBRATION EMISSION MEASUREMENT METHODS FOR GRINDERS

Magnus Persson
Atlas Copco Tools & Assembly Systems, Stockholm, Sweden

Introduction

ISO8662-4, "Hand-held portable power tools - Measurement of vibrations at the handle - Part 4: Grinders" is under revision. The new revision shall harmonize ISO 20643 "Mechanical vibration - Hand-held and hand-guided machinery - Principles for evaluation of vibration emission" which, among others, requires measurements in three directions and declared values related to the upper quartile of real-use vibration.
To get the most suitable test method, a round robin test was made for evaluation of the two test methods proposed by the ad-hoc group working with this standard revision.

Methods

Seven laboratories measured the vibration from four grinders of different sizes, with and without autobalancing units. The laboratories come from universities, health & safety laboratories and grinder manufacturers.

Two measurement methods are evaluated with respect to repeatability and reproducibility:

1. Grinding on a well-defined mild steel bar with depressed center wheels according to detailed test instructions. The test sequence starts and ends with 10 seconds of running the grinder in the air, when measuring the unbalance contribution to the vibration coming from the unbalance of the grinding wheel. Between these runs the average vibration during 60 seconds of grinding is measured. Three operators do five grinding tests per grinder.
2. Measurements using an aluminum unbalance disc similar to the one defined in ISO8662-4. Each operator runs the grinder four times, between each run the unbalance is moved 180 degrees to avoid variations caused by the play between the test wheel and the spindle. The averaging time is 10 seconds. Each grinder is tested by three operators.

Repeatability is the spread within a lab between operators and over short time period for one machine and reproducibility is the spread between laboratories and over longer time periods for one machine. Instrumentation and transducer location are chosen according to ISO8662-4 and circulated test instructions.

Results

Both the repeatability and reproducibility is poor for the real grinding test, see figure 1. The coefficient of variation for repeatability is approximately 40% higher for the grinding test and the coefficient of reproducibility is 60% higher for the grinding test than for the unbalance disc test.

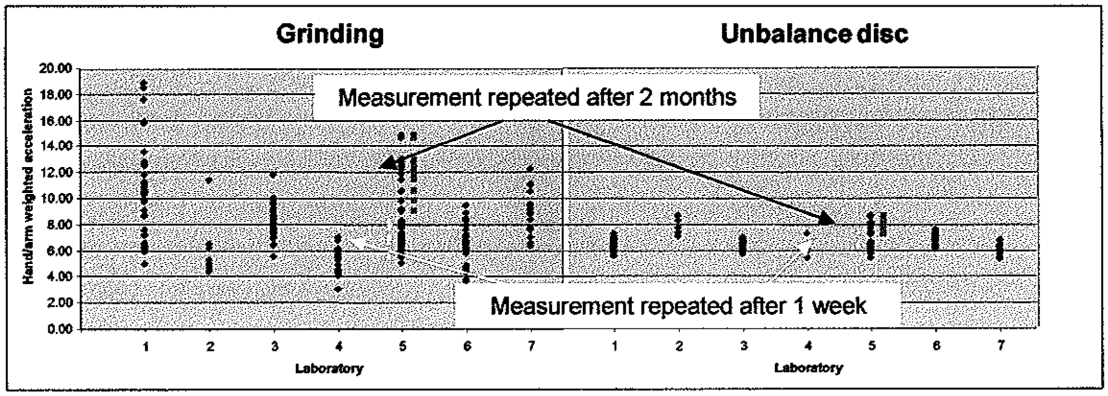

Figure 1. Example of result from grinding test and unbalance disc test. The grinding test shows a larger spread between test runs, operators, and laboratories and over time.

The unbalance disc test gives vibration values corresponding to the upper quartile of the real grinding test for grinders without autobalancing units. This is one requirement in the revised vibration measurement standard. Grinders with autobalancing unit gives lower values for the unbalance disc test, therefore they require additional grinding tests to fulfill this requirement.

Discussion

Unbalance disc test is proven to be the most accurate method for measuring vibrations from grinders, with one exception; grinders with autobalancing units. The result from this study also shows that it is extremely time consuming to get reliable field vibration measurements on grinders. The result is varying depending on many factors that are difficult to control; feed force, grinding wheel quality, work piece etc. The unbalance disc test gives values with good repeatability and reproducibility which well correspond to the upper quartile of the vast amount of grinding measurements made in this study. Thus, it is recommended to use the declared value according to ISO 8662-4 when assessing the vibration emission from grinders instead of doing field measurements. When using emission values from manufacturers, it is important to verify that the value is measured according to appropriate ISO-standard.

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COMPUTATIONAL SIMULATION OF A PNEUMATIC CHIPPING HAMMER

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Introduction

Occupational exposure to hand transmitted vibration (HTV) arises from the hand held powered tools extensively used in the mining and construction industry such as rock drills, chipping hammers, chain saws etc. Regular exposure to HTV is the major cause of a range of permanent injuries to human hands and arms which are commonly referred to as hand-arm vibration syndrome (HAVS). In addition to this, the percussive tools generate overall sound power levels in excess of 110dBA in most cases. Such a high sound power level greatly exceeds the maximum permissible exposure limit (PEL) of organizations such as National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA). Long term occupational exposure to this noise has been diagnosed as the main reason for permanent hearing loss in the operators. It is therefore important to develop an understanding of the mechanisms which lead to these high vibration and sound levels and in order to do this a detailed computational model of a pneumatic chipping hammer has been made.

This paper presents a nonlinear computational model of a pneumatic chipping hammer. In order to better understand the dynamics of the chipping hammer, the hammer was subdivided into components that are shown in figure 1 (a) (based on a chipping hammer manufactured by Atlas-Copco). The hammer mainly consisted of a center body, a moving piston and a chisel. Compressed air is used to drive the piston inside of a cylinder and on the downward stroke this piston impacts the chisel to create the hammer effect. The machine has one pneumatic valve and this valve regulates the air supply either to the upper chamber or to the lower chamber. The valve changes according to the relative pressures in the two chambers and the supply pressure. There are also twelve different exhaust ports at two positions along the cylinder labeled upper ports and lower ports. As the piston moves the ports can be closed or open (allowing exhaust).

Fundamentally, the computational model was made up of two different sub-models, a fluid model and a structural dynamic model as shown in Figure 3 (a) and (b) respectively. The first sub-model takes into consideration the fluid dynamics of the machine since the hammer is driven by compressed air. Equations for the mass flow rate though bleed orifices (assuming an isentropic process) [1] is used to determine the mass flow into and out of the upper and lower chambers. From this the pressures in the two chambers and consequently the forcing on the piston can be calculated. The second sub-model deals with modeling the structural

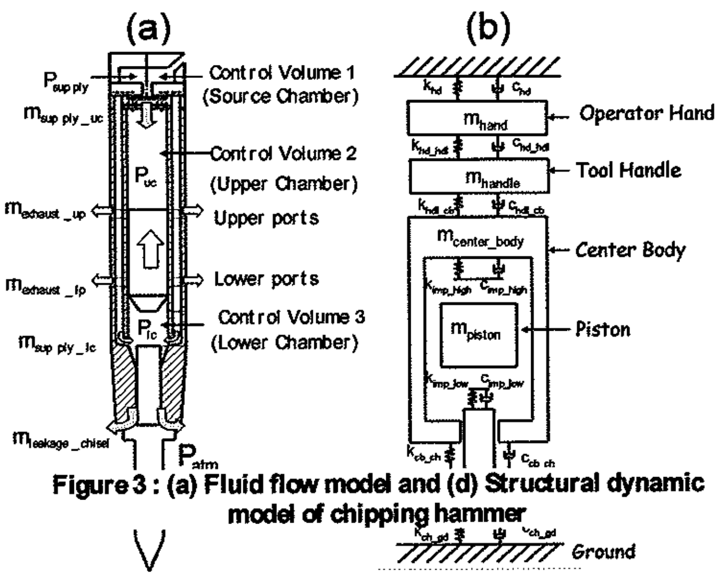

Figure 3 : (a) Fluid flow model and (d) Structural dynamic model of chipping hammer

components of the chipping hammer. The structural model consists of various lumped masses[2], each representing a specific component of the chipping hammer as well as the ground and operator's hand. The impact dynamics were also incorporated by connecting the piston and the chisel with a non-linear spring. The fluid flow and structural models were then coupled together using a time domain, state space formulation to compute the displacements of each component, the pressures in the chambers, the impact forces and the jet velocities from the exhaust ports. The computational model was then validated using experimental obtained vibration levels and exhaust velocities.

Results

Figure 4 (a) and (b) show the experimental and computational exhaust velocities from the upper and lower exhaust ports respectively. There is a very good match between the exhaust jet velocities measured during lab tests and the exhaust jet velocities calculated from the computational model. Also the tool impact frequency measured from lab tests is approximately 27 Hz which is very close to the tool impact frequency calculated from the computational model (32Hz). Keeping in mind the nonlinear nature of the fluid flow model, these can be considered as good results. However, further refinement of the fluid flow model will be continued in the near future. The structural dynamic response of the computational model will be discussed at the time of presentation.

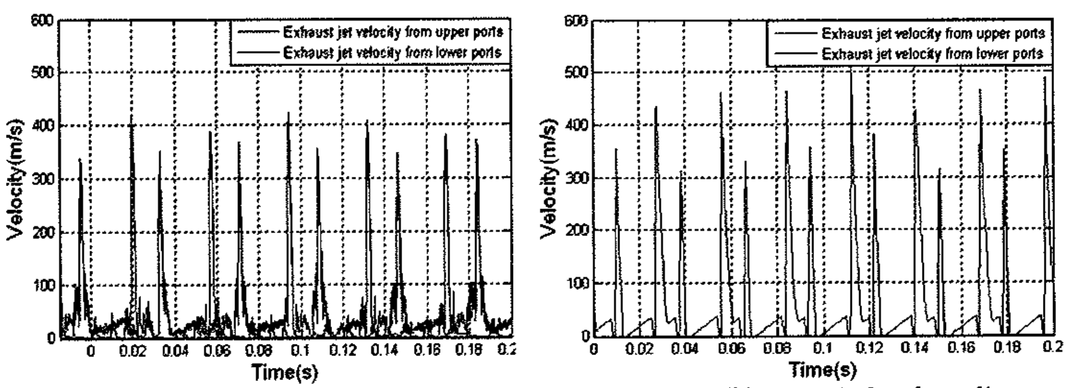

Figure 4 : Exhaust jet velocities (a) experimental results, (b) computational results

This model provides a unique opportunity to evaluate different vibration and noise control techniques and consequently to help determine the best possible control method. The model would avoid the need for extensive laboratory testing which is time consuming as well as expensive.

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DESIGN OF A TEST BENCH TO EVALUATE THE VIBRATION EMISSION VALUES OF JACKLEG ROCK DRILLS

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Introduction

Jackleg rock drills are widely used in the mining industry and are known to generate high levels of hand-arm vibration which contribute to the development of the hand-arm vibration syndrome for exposed miners.[1-3] To reduce the vibration levels, a prototype of an antivibration handle was developed as part of a previous study.[4] To provide some bench marking for this handle prototype and to follow the evolution of its performance over time, a test bench was developed to characterize the vibration emission values of jackleg drills under controlled operating conditions. As the current ISO 8662 series of standards could not apply directly to this type of tool, there was a need to design and validate a test bench to evaluate the vibration emission values of jackleg drills, while taking into account the conditions specific to the operation of this type of tool.

Methods

A test bench including an energy absorber, was developed for testing jackleg drills based on the ISO 8662-3 standard [5]. The energy absorber was bolted to a 3300 kg concrete block to ensure tool stability. A pictorial view of the device is given in Figure 1. For validation purposes, acceleration measurements at the handle of a conventional jackleg drill were taken simultaneously along the three axes (x_h, y_h and z_h) in an underground rock drilling operation as well as on the test bench. The handle accelerations were measured for three different jackleg angles (13°, 28° and 43°) determined with respect to the floor. Moreover, each measurement was repeated at least three times to asses the data repeatability.

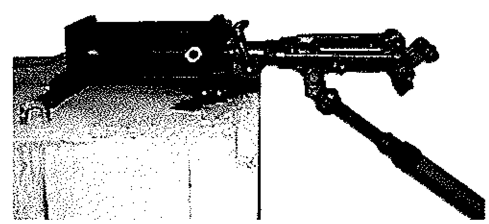

Figure 5. Jackleg drill (right) with the energy absorber (left)

Results

As a preliminary validation of the test bench, Figure 2 provides a comparison of the frequency weighted rms acceleration spectrum measured along the z_h-axis, for both underground drilling and operation on the test bench (28° jackleg angle in both cases). It is shown that the vibration measured on the handle of a jackleg drill operating on the test bench is representative of that recorded during typical rock drilling operations, despite the fact that some harmonics of the percussion frequencies are generated with a higher amplitude on the test bench. Table 1 provides a comparison of the overall frequency-weighted rms accelerations measured for all three jackleg angles. It is shown that the test bench provides comparable values of overall acceleration for all three axes, with much lower variation coefficients (COV) on the test bench, suggesting a higher measurement repeatability. In addition, it was verified that the measurements obtained on the test bench were reproducible, by ensuring that similar frequency-weighted rms accelerations could be obtained after completely reinstalling the jackleg drill on the test bench.

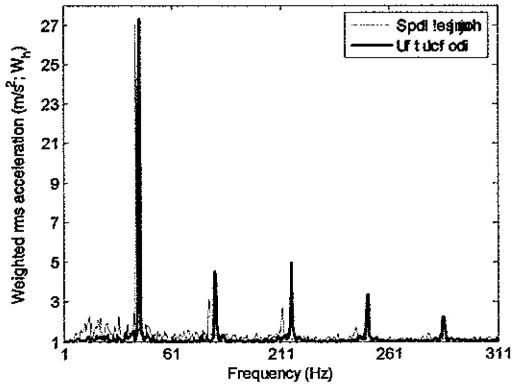

Figure 2. Comparison of vibration frequency spectrum measured on the test bench and while drilling (z_h percussion axis)

Table 1. Comparison of frequency weighted rms accelerations measured for three different jackleg angles on the test bench and while drilling.
m/s^2 (w_h)
COV (%)

		x axis	y axis	z axis	Total
13 deg	Bench	**10.66** 0.84	**5.33** 5.33	**20.72** 1.72	**23.90** 1.41
	Drilling	**12.80** 44.19	**6.18** 2.21	**24.30** 3.52	**28.41** 11.69
28 deg	Bench	**9.51** 1.98	**5.15** 2.03	**19.90** 0.79	**22.65** 0.73
	Drilling	**9.64** 8.96	**6.18** 29.70	**22.70** 13.13	**26.44** 13.33
43 deg	Bench	**11.46** 1.32	**5.52** 0.54	**18.74** 0.48	**22.65** 0.60
	Drilling	**8.78** 11.62	**4.92** 7.27	**19.73** 6.73	**22.16** 7.35

Discussion

The validation of a test bench to characterize the vibration emission values of jackleg rock drills has been presented. Preliminary results have shown that the test bench provides a good representation of the vibration measured during rock drilling operations, while providing a better repeatability of the acceleration values. Thus the test bench appears to be applicable to characterize the vibration emission values of jackleg drills.

Acknowledgements

The authors wish to acknowledge the financial support provided by SOREDEM .

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Podium Presentations

Session IX: Epidemiology, Standards Applications, and Prevention II

Chairs: David Wilder and Kristine Krajnak

RISK ASSESSMENT OF HAND-ARM VIBRATION BY ESTIMATE, TAKING THE EXAMPLE OF HAND-GUIDED STONE-WORKING MACHINES

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Introduction

Vibration measurements at the workplace are often complicated and expensive. The assessment of the risk in conformity with EC Directive 2002/44/EC "Vibration" (which lays down the minimum requirements of laws in Europe for occupational safety and health) can therefore be carried out on the basis of an estimate based on information from manufacturers as well as by measurement conforming to ISO 5349.

The characteristic values (emission values) determined by manufacturers in laboratory conditions may deviate from the exposure values measured at source at the workplace. Equally, deviations may arise as a result of the delay in the changeover of test methods from the single axis of measurement to the total vibration value for the three axes of measurement conforming to ISO 20643.

To prevent faulty estimates, the manufacturer's information has to be corrected by a tool-related factor in accordance with CEN/TR 15350. By taking the example of masonry and stone working machines, the empirically determined tool-related correction factor is checked and confirmed.

Methods

Vibration measurements were carried out in accordance with ISO 5349 in practical application conditions on 10 selected typical eccentric and orbital sanders, concrete and disc grinders as well as on wall chasers and stone saws.

Results

The total vibration value obtained for the investigated tools rangedfrom a_{hv} = 3.6 m/s² to a_{hv} = 11.6 m/s². When the values from the practical measurements are compared with the manufacturer's vibration values, the underestimation of the risk occurring in some cases can be largely compensated for by the tool-related factors conforming to CEN/TR 15350 (see Figure 1).

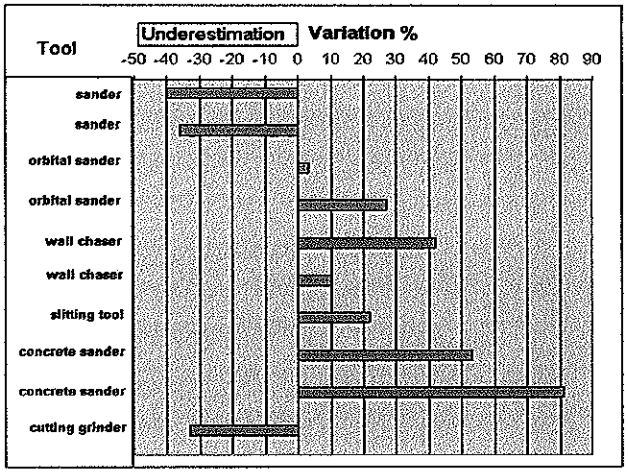

Figure 1.
Variation of the estimated vibration values from the values obtained in practice after correction.

Discussion

The risk assessment can be carried out on the basis of an estimate based on information from manufacturers. The procedure is presented with reference to examples. In three of the ten investigated cases, there was slight underestimation after correction. However, these variations lie within the accuracy range achievable with workplace measurements.

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WHOLE-BODY VIBRATION EXPOSURE AND DRIVER POSTURE EVALUATION DURING THE OPERATION OF LHD VEHICLES IN UNDERGROUND MINING

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Introduction

Load-haul dump vehicles (LHDs) are used to move waste rock and ore in underground mining operations. The LHD is designed for bi-directional operation and the driver sits sideways to the direction of travel. LHD operators have higher reports of low back pain and neck discomfort than other mobile equipment operators who do not sit sideways in the vehicle, but are exposed to whole-body vibration (WBV)[1].

Exposure to WBV is linked with reports of lower-back pain, neck problems and spinal degeneration[2,3]. Static sitting postures, sitting with the neck and back twisted, and sitting with the back in an unsupported posture are also linked with an increased risk of developing back pain[4]. The objective of this study was to determine typical vibration exposure levels and driving postures for LHD operators.

Methods

Whole-body vibration exposure was measured at the seat-pan, in accordance with the ISO 2631-1 standard[5], on seven LHD vehicles with a 10 yard bucket haulage capacity. Vibration data were recorded with a Biometrics™ DataLog II (P3X8) and stored on a 128 Mb Simpletech™ multimedia card. Comparisons were made to the ISO 2631-1 Health Guidance Caution Zone (HGCZ) in order to determine potential injury risk.

Operator posture was monitored with three digital video cameras which were secured inside each operator's cab to the top left corner, top right corner and back right corner. Reflective tape was placed on each driver's shoulders, head, and back in several locations and in several locations on the vehicle seat in order to aid in posture coding. Posture coding was performed with 3DMatch v4.50 multiple video view analysis feature. Vibration measurement and posture recording occurred simultaneously for 60 minutes while the LHD operator performed typical duties.

Results and Discussion

Results indicate LHD operators may be exposed to whole-body vibration levels putting them at risk for injury (Table 1). According to ISO 2631-1 the frequency weighted acceleration values corresponding to the lower and upper limits of the HGCZ (for an 8 hr exposure duration) are 0.45 and 0.90 m/s^2 respectively[5]. Six of the seven vehicles showed exposure levels within the HGCZ defined for 8 hours.

Preliminary video analysis indicated LHD operators were exposed to potentially harmful levels of WBV while adopting asymmetric postures (Table 2). For example, one LHD operator (Figure 1) worked with his neck twisted greater than 40 degrees for 93 % of a 60 minute work cycle. According to the Swedish National Work Injury Criteria, neck rotation should be less than 15 degrees if the motion is required for greater than 80% of the work time[6]. Results of this study highlight the need to further examine the contribution of non-neutral working postures and

WBV exposure in or above the ISO 2631-1 HGCZ given the development of higher than average levels of low back and neck injuries amongst LHD operators.

Table 1: Summary of frequency weighted acceleration (multiplying factor k for health evaluation applied) and the equivalent 8h frequency weighted acceleration (vibration cycle of 7 hours within an 8 hour work day) values for typical underground LHD operation. The axis associated with the dominant value is shown in bold.

Mine & Model	Duration (min.)	aw_x (m/s^2)	aw_y (m/s^2)	aw_z (m/s^2)	a_v (m/s^2)	a_8 (m/s^2)
1 -B	68	0.51	0.45	**0.69**	1.18	0.60
1 -A (1)	70	0.70	0.47	**0.81**	1.44	0.70
1 -A (2)	78	0.68	0.51	**1.01**	1.56	0.83
2 -F	124	**0.67**	0.45	0.63	1.30	0.41
2 -C	117	0.69	0.58	**1.12**	1.68	0.75
3 -C	66	0.65	0.56	**0.78**	1.43	0.69
3 -H	70	**0.61**	0.56	0.56	1.29	0.49

Table 2: Postures adopted along with the percentage of time spent in each posture during a 60 minute monitoring duration, for a typical LHD operator.

Posture Adopted	% time adopted
Neutral neck rotation (< 15 degrees of rotation)	3
Mild neck rotation (15 - 40 degrees of rotation)	4
Severe neck rotation (>40 degrees of rotation)	93
Neutral trunk rotation (< 15 degrees of rotation)	97
Mild trunk rotation (15 – 30 degrees of rotation)	3
Severe trunk rotation (> 30 degrees of rotation)	0
Neutral trunk flexion (< 15 degrees of flexion)	93
Mild trunk flexion (15-30 degrees of flexion)	7
Severe trunk flexion (>30 degrees of flexion)	0
Neutral trunk lateral bend (< 15 degrees of bend)	86
Moderate trunk lateral bend (15–30 degrees of bend)	14
Severe trunk lateral bend (> 30 degrees of bend)	0

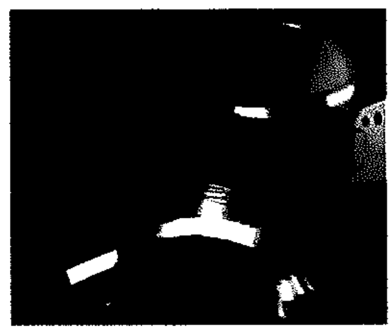

Figure1. Typical posture adopted by LHD drivers.

Acknowledgment

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MEASUREMENT AND EVALUATION OF VIBRATION EXPOSURE FOR LOCOMOTIVE CREW MEMBERS

Robert Larson, Christine Raasch, Janine Pierce
Exponent, Inc.

Introduction

The vibration and impact environment for crew members on locomotives has been investigated in a series of studies conducted by Exponent Failure Analysis Associates (Exponent) beginning in 1990. Locomotive cab vibration and impact levels were measured on a variety of locomotive models operating over many different track sections across the Union Pacific, Burlington Northern Santa Fe, CSX, Norfolk Southern, and CONRAIL systems. The comfort and health implications of exposure to the measured locomotive vibration levels were evaluated by comparison with the human vibration exposure boundaries given in the International Standards Organization (ISO) standard 2631-1:1997, the British Standard 6841:1987, European Union (EU) Directive 2002/44/EC, measurements made by Exponent on various commercial and recreational vehicles, and vibration exposure measurement data found in the literature.

Methods

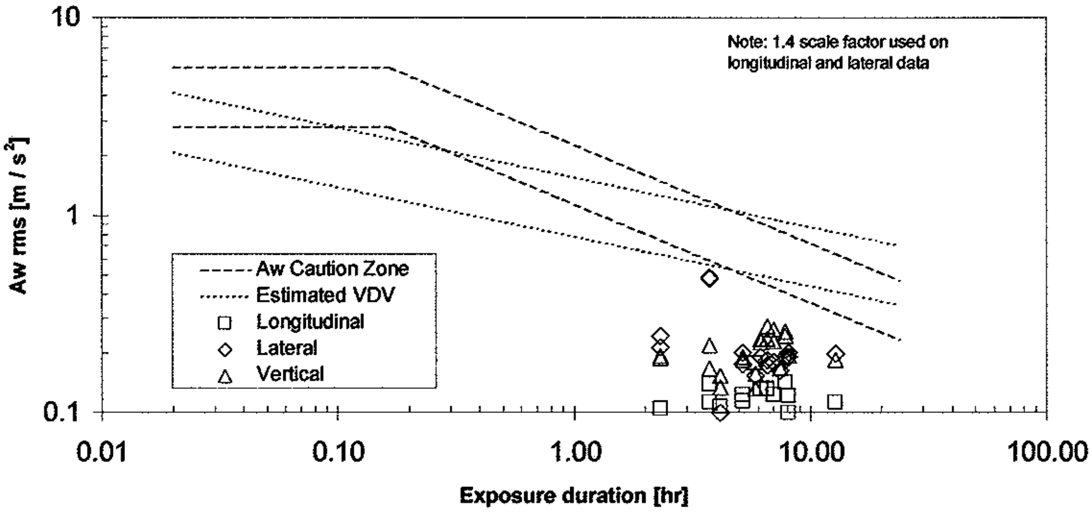
Initially, vibration levels experienced by locomotive crews were measured and recorded at incremental speeds covering the range of normal train operation. In 2003, a method of measuring the vibration exposure continuously by means of a digital recorder was developed, allowing the vibration level over the entire run or crew shift to be analyzed. For each seating location measured, acceleration was recorded on the seat surface beneath the ischial tuberosities (pelvis) of the seated crew member and on the cab floor directly under the seat. At each of the locations, triaxial accelerometers were used to measure the vibration along the longitudinal, lateral, and vertical axes. Since the vibration environment varies throughout the route, and locomotive vibration levels have been found to be primarily speed dependent, a speed sensor was used to continuously measure the speed of the train.

To evaluate the recorded vibrations levels, the data was divided into two-minute segments, which were each processed per the 1997 ISO standard for weighted RMS vibration levels and Vibration Dose Values (VDV). Additionally, PSDs and 1/3 Octave RMS values were calculated to determine the frequency content of the vibration. For each two-minute segment, the average speed of the locomotive was calculated to allow for correlation with the recorded vibration exposure values. The resulting exposure values for the entire run were calculated by combining the data from all of the two-minute segments.

Since introducing the continuous method of recording acceleration, 23 seating locations have been recorded on 11 locomotives traveling 11 different routes across various parts of the United States. One of the routes was a shift of 'yard work', traveling back and forth in a rail yard coupling train cars together.

Results

A guide to interpreting weighted acceleration values with respect to health is given in Annex B of the 1997 ISO standard. A health guidance caution zone is defined to indicate the level of vibration where a health risk could exist. The figure below shows the caution zone from the ISO standard as the area between the dashed lines. The dotted lines represents an alternative caution zone, also defined in the 1997 ISO standard, that is based on an estimated Vibration Dose Value (eVDV) and a health guidance caution zone range of 8.5 to 17 $m/s^{1.75}$. Also shown are the data points representing the exposure levels for all 23 measurements in all three directions. In all cases, the weighted rms accelerations measured were below both caution zones defined in ISO 2631.



To put the locomotive vibration exposure level in perspective, the results were compared to the levels measured on heavy trucks, light and medium duty trucks, a van and a motorcycle. The locomotive vibration levels were also compared to levels reported for various vehicles found in the literature. The vibration environment on locomotives was found to be comparable to commercial on-road vehicles and below many commercial off-road vehicles and recreational vehicles.

To evaluate the effect of transient vibration and shock, a VDV was calculated for all of the measurements. The VDVs calculated for locomotive crew members averaged 4.6 $m{\cdot}s^{-1.75}$, with the highest value at 6.1 $m{\cdot}s^{-1.75}$. These values are well below the action level of 15 $m{\cdot}s^{-1.75}$ defined in the British Standard (BS 6841:1987), the EU Directive 'action value' of 9.1 $m{\cdot}s^{-1.75}$, and the EU 'exposure limit' of 21 $m{\cdot}s^{-1.75}$.

Discussion

The vibration exposure experienced during locomotive operation was found to be consistently below the health guidance caution zones defined in the ISO whole body vibration exposure standard. The Vibration Dose Value measure of vibration exposure, which is an additional measure that is more sensitive to occasional shocks, was found to be less than the action levels of the British Standard and the EU Directive.

Environmental Effects on Truck Driver ISO 2631 Acceleration Exposure

Jack Wasserman, Logan Mullinix, Kelly Neal, Shekhar Khanal, Don Wasserman

Introduction

This paper presents current finding on truck driver average exposure to acceleration for several different manufacturer's cab-over trucks on a variety of roads in different countries. The predominant time, for this aspect of the study has been spent in the area around London, England and Warsaw, Poland.

The ECE directive 2002/44/EC has provided specific guidelines for vehicle operators 8 hour average acceleration exposure. The primary considerations have been on truck design including the air-ride driver's seat. The truck manufacturers have produced truck cabs that have some separate suspension from the truck frame. The truck seat manufacturers have been producing air-ride suspension seats for the cab. Both of these designs have had the objective of meeting the ECE directive and providing the vehicle drivers with some degrees of comfort.

This paper will provide some information on the ability of the vehicles to operate on a variety of roads and meet the objectives.

Method

The primary method for evaluation of the driver's exposure has been the use of a seat pad attached to the driver's seat. Although this sensor system provides the critical information for the driver, an understanding of the reasons for the values requires additional measurements.

The initial study in England used both driver and passenger seat pads, as shown in Figure 1, as well as triaxial accelerometers mounted on the base of the seat. The latest studies used significantly more transducers to better understand the relative rotations and translations on the truck frame, the cab, and the driver.

Figure 1 Triaxial Acceleration Seat Pad

The data was processed to produce the average accelerations for the X - axis, Y - axis, and Z – axis based on data for 360 seconds or longer. The time length is required by the ISO 2631 standard for reasonable accuracy.

Results

The data has shown road situations that have exceeded the 0.5 m/s^2 but not to exceed the 1.15 m/s^2 for extended periods of time. Comparisons between loaded and unloaded trucks and between different drivers have been done for certain situations. The major aspects related more to the road quality than the particular manufacturer for a vehicle or a seat. As can be seen in Figure 2, the driver's seat generally has lower values than the passenger's seat.

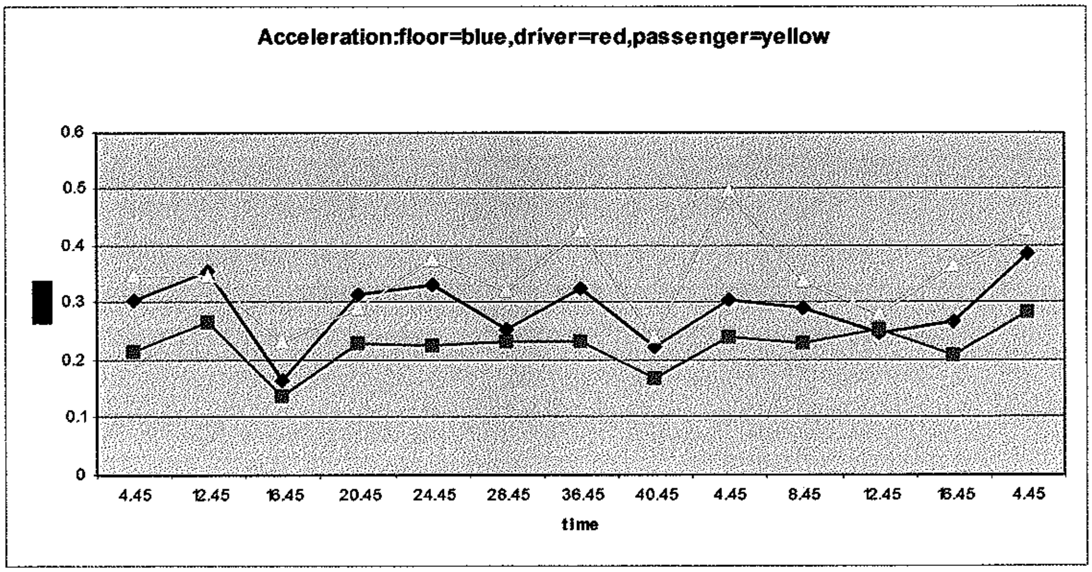


Figure 2 Comparison of Seating during time.

Conclusions

The initial results have shown that the dominant effects of the levels of acceleration expose have related to the quality of the roads and the truck speed. Continued testing is planned for the future to further understand the potential risks to the drivers and to allow a better process for assessment and design of truck seats.

EVALUATION OF THE CAPABILITY OF SEAT SUSPENSION TO REDUCE THE OPERATOR EXPOSURE TO VIBRATION IN TRACK TYPE TRACTORS.

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Tom Brodersen, Director - R and D, Sears Seating
Dave Marshall, R & D Manager, KAB Seating

Introduction

The European Union (EU) completed a new directive 2002/44/EC[1] called the Physical Agents Directive (PAD) that establishes action and limit values for hand-arm and whole body vibrations. The directive specifies that:

> " ...workers shall not be exposed above the exposure 'limit value'." [1]

and

> " ...once the exposure action values ... are exceeded, the employer shall establish and implement a programme of technical and/or organisational measures intended to reduce to a minimum exposure to mechanical vibration and the attendant risks..." [1]

The PAD limit value is effective for new machines starting July 6, 2007 and for used machines by at least July 6, 2010. These requirements apply to the users of machines, but machine manufacturers will be challenged to provide machines and information to help the users comply with the directive.

Caterpillar manufactures machines with the goal of enabling our customers to comply with all regulations dealing with health and safety. Caterpillar designs all of our machines to provide a safe, comfortable and productive work environment. This study was to determine if seat suspensions could provide a reduction in the vibration environment experienced by operators of Caterpillar mid sized (<50,000KG) Track Type Tractors

Methods

Seat manufacturers were asked to provide seat suspensions that provide improved isolation over and above current seat suspension. Each supplier was provided with ride profiles and was asked to demonstrate the vibration reduction on a shaker table. Two suppliers provided suspensions that were compared with the current seat suspension in a field study. Three full factorial experiments were conducted. The first experiment was to evaluate overall suspension performance for four operations. The second experiment was to determine the benefit of the adjustable vertical damper at three different levels and the third experiment was to determine the effect of the fore/aft and side/side isolators. Six operators were used for the study. Acceleration was measured at the seat base and at the operator seat pad. Both the transfer function and the ISO 2631 RMS ride values were used to determine the seat suspension's effectiveness of isolating the operator from vibration. A structured questionnaire was used to determine the operators' subjective assessment of the seat suspensions.

Results

There was significant operator-to-operator variability in the vertical direction (>35%), however there was little variability in the fore/aft and side/side direction based on seat base acceleration. There was significant variation in the vertical vibration levels for all four operations; slot dozing, ripping, cross v-ditch, and roading. Roading showed much lower fore/aft and side/side vibration levels then the other operations. Slot dozing showed lower side/side vibration levels than other operations but was similar to roading. The fore/aft and side/side levels appear to be a function of the ground profile.

The seat suspensions demonstrated reductions in the ISO Ride values for the vertical direction in the shake table test however they did not show any significant reduction during the field operations. The exception was during the roading operations where the advance seat suspensions showed measurable reductions. The damper settings again showed significant differences during the shake test but had little or no effect during the field test. The fore/aft isolator did not provide a statistically significant reduction in the ISO ride values however the Side/Side isolator did provide a 20% reduction.

The seat suspensions did provide an improvement in the operator subjective evaluation of the machine vibration environment. In the vertical directions, the operators felt the advanced suspension provide a slight improvement. The fore/aft isolator provided a significant improvement in the vibration environment. This occurred despite the fact that the isolators provided no statistically significant improvement in the ISO ride values. The side/side isolator did provide a slight improvement in the operator perception of the vibration environment.

Discussion

Seat suspensions tested will not provide a significant reduction in the ISO RMS ride values for the current generation of construction machines however they do provide a significant improvement in the operator subjective opinion of the machine vibration environment. This may imply that the methodology used in the European Union (EU) directive 2002/44/EC may not be appropriate for evaluating operator comfort in construction machines. The basis of the ISO weighting curves are human response testing in a seated position without foot pedals, seat backs, arm rests and control contact. The operator seated position in construction machines may change how the human responds to vibration and perceives vibration. Further work is required to understand the effect of foot pedals, back rests, arm rest and control contact on the operator perception of the vibration environment.

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ISO 3411 Earth-moving machinery – Human physical dimensions and minimum operator space envelope. International Organisation for Standardisation, Geneva.

MUSCULOSKELETAL SYMPTOMS AMONG OPERATORS OF HEAVY MOBILE EQUIPMENT

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The purpose of this study was to assess the adequacy of the cab design and to determine the percentage of musculoskeletal symptoms among operators of mobile equipment used in mining and construction. A questionnaire was designed to assess demographics, work information, job history, and musculoskeletal symptoms in operators of heavy mobile equipment. Information concerning equipment included design of the seat/chair, levers, pedals, bothersome vibration, quality of ingress/egress from the equipment, proper preventative maintenance and repairs, and age of the equipment. The body regions that were evaluated included the neck, middle/upper back, low-back, shoulder/upper-arm, elbow/forearm, wrist/hand, hip, knee, and ankle/foot. Five hundred and eighty six operators completed the questionnaire. The results indicate that these workers are at risk for developing musculoskeletal disorders, and the need to quantify risk factors (i.e., whole-body vibration and static sitting postures).

Introduction

Kittusamy and Buchholz[1] estimated that there are currently 540,000 operators of heavy mobile equipment, who are generally referred to as operating engineers, in the United States. Their estimate also shows that ninety percent of the operating engineers are involved in performing excavating and paving work, whereas the remaining 10% are crane operators and all of these operating engineers are exposed to whole body vibration. Two important risk factors for musculoskeletal disorders among operators of heavy earth-moving equipment are static sitting and whole body vibration,[2,3] where long term exposure to these risk factors have been associated with low back pain, disc degeneration, sciatic pain, and muscle fatigue.[4]

Methods

A work and health questionnaire was designed to assess demographics, work information, job history and musculoskeletal symptoms in operators of heavy mobile equipment. Self-administered work and health questionnaires were distributed to operating engineers by the International Union of Operating Engineers training centers in several states within the United States of America. The operators who attended their regularly scheduled training classes, from December 2001 to May 2005, at the training centers were requested to complete the questionnaire during their training session. The participation was voluntary, but participation was highly encouraged by the training officers. All of the participants were briefed about the purpose of the study and they signed an informed consent form.

Results

Five hundred and eighty six operators out 598 (98%) completed the questionnaire from 6 different local unions in 8 different states. A majority of the participants were male (91%). A majority of the operators (72%) were journey level. The ages of the operators ranged from 18 to 68 years. The majority of the operators (>65%) indicated that the cab (i.e., seat/chair, levers and pedals) was adequately designed for their job. Some of the operators reported that they were not bothered by vibration and that the quality of egress from the equipment was good. Most of the operators (>80%) indicated that proper maintenance and repairs were performed on their equipment. The classification of equipment as being old or new was almost identical.

The prevalence of musculoskeletal symptoms in the total population was 58.5%. Three body regions that received the highest total percent of symptoms categorized as somewhat severe or higher, included the knee, shoulder/upper-arm, and the low back.

Summary

The current study is in agreement with the prevalence of musculoskeletal symptoms in various body regions as reported by Zimmerman et al.[5] Also, similar results were observed in a pilot study of operators of heavy construction equipment that further reiterate the findings in the current study[6] .

Construction workers are often afflicted with musculoskeletal symptoms that compromise their health and well-being. However, there have been few formal studies of the nature and potentially preventable causes of these symptoms. The results from this study indicate that the operators are at risk for developing musculoskeletal disorders, the need to quantify risk factors (i.e., whole-body vibration and static sitting postures), and develop engineering controls to reduce the exposure levels.

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Poster Presentations

HEAD-TRUNK MOTION INCREASE WITH ARM-REST CONTROLS

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Introduction

Heavy equipment manufacturers have made a long-term commitment to minimize operator vibration exposure for comfort, performance, and health reasons. Domestic and international guidelines/standards and EC laws dictate exposure limits based on measurement of vibration at the interface between the seat and the operator's buttocks using seat-pad accelerometry.[1-4] This is historically based on the assumption that the only major source of vibration is transmitted through the seat pan. However, vibration may also be imparted to the head and neck via the steering wheel and/or arm-rest controls and a relatively rigid upper body.[5] Unfortunately, little is known regarding the influence of arm position on head and neck motion. The purpose of this study was to investigate relative head and trunk motions during riding simulations of large construction equipment, using three different arm control options.

Methods

Five typical heavy equipment ride files were "played back" through a man-rated Servo Test 6-degree-of-freedom vibration system. An 8-camera Vicon motion capture system operating at 200 frames per second, recorded the motion of reflective surface markers on 5th, 50th, and 95th percentile right-handed male subjects, using 3 seat and control configurations (steering wheel (SW), floor mounted armrest controls (FM), seat-mounted armrest controls (SM)). Two trials were performed for each ride and seat control combination (each trial: 60 sec of 6-dof and 60 sec of vertical vibration). The relative motions (change in distances) from the marker over the xiphoid process (caudal end of sternum) to markers over each shoulder, each mid-clavicle, the presternal notch, and to each of four markers on a tight band around the head were calculated (12,001 frames, 6-dof motion only). As a rigid body control, distances between markers on the head band were also monitored. The standard deviation (SD) of the 12,001 distances between pairs of markers was normalized by the mean (L) of the associated distances producing: SD/L which was used as a measure of motion. Error assessments were also performed by analyzing the motion between relatively fixed markers (on the headband). A repeated measures analysis of variance was used to evaluate the results. While five ride files were used, only one ride file containing significant lateral acceleration components was analyzed for comparing the effects of two armrest controls versus use of a steering wheel for this part of our study.

Results

Values of SD/L between the points on the relatively rigid head band were consistently small and similar to each other for all conditions with one exception due to treatment (SM v SW, $p=0.0145$). SD/L between the markers over the xiphoid process and the presternal notch, another region that should be relatively rigid, were also similar to each other for all conditions. Use of floor-mounted, arm rest controls versus a steering wheel produced a significant increase in the value of SD/L between the xiphoid process and: the right shoulder marker (92%, $p=0.0316$), the right mid-clavicle marker (47%, $p=0.0478$), and the right-front marker on the head band (28%, $p=0.0182$). Use of floor-mounted, arm rest controls versus seat-mounted, arm rest controls produced a significant increase in the value of SD/L between the xiphoid process and the right-back marker on the head band (14%, p=0.0467).

Discussion

During a pilot study to assess the efficacy of a motion capture system in whole-body vibration studies, the authors observed a large increase in head-trunk relative motion due to the use of armrest controls, raising a concern about an increased likelihood of injuries. With the use of a steering wheel, the trunk and arms can behave as active dampers, attenuating horizontal motions and maintaining a stable platform for the head-neck system (an inverted pendulum). Armrest controls more rigidly couple the shoulders, via the upper arms, to a vibration source and bypass the damping provided by the entire arm, potentially increasing the risk of motion-related musculoskeletal problems in the neck and upper trunk. While armrests may reduce arm and shoulder fatigue and reduce the effect of the vibrating trunk mass on the lower back, they may do so at the expense of increased motion at the neck and shoulders. The vibration community needs to consider the effect of and attenuation of vibration from sources other than the seat pan. The authors urge the standards and law making communities to consider vibration sources in addition to those at the operator's seat pan.

Acknowledgements

This study was funded by Caterpillar, Inc. of Peoria, IL and was conducted at Sears Manufacturing of Davenport, IA with the help of Mike Drinkall and Jason Boldt. Dean Macken of the Engineering Design and Prototyping Center at the College of Engineering at The University of Iowa helped a great deal with design and setup of specialized equipment. Brad Parker, of the Center for Computer-Aided Design at The University of Iowa provided vital help with computer hardware and software. The study was conducted through the Center for Computer-Aided Design (directed by Karim Abdel-Malek at The University of Iowa), where one of its goals is to optimize the Digital Human.

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ARM AND SHOULDER MUSCLE ACTIVITY ARE GREATER WITH STEERING WHEEL VS. SEAT MOUNTED CONTROLS

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Introduction

Chronic whole-body vibration exposure, as expected in large construction and mining vehicles, has been associated with neck and back pain and injury.[1] While work has been done towards gaining a better understanding of the relationship between vibration and shock and muscle activity of the back musculature[2], relatively little information regarding the activity of neck, shoulder and upper arm muscles is known. Today's equipment designs must conform to domestic and international standards, however these standards do not specifically address the vibration exposure in the head and upper quarter. Further it is not well known how the control configuration within a vehicle (e.g. steering wheel versus arm controls) influences muscle voluntary and reflex activity levels. Greater muscle activity may lead to greater muscle fatigue – which in turn may be associated with greater risk of injury.[2] Thus, muscle contractions needed to maintain static postures as well as those resulting reflexively should be considered during an analysis of seating position. Unfortunately, little is known regarding the influence of arm position on head and neck muscle function. The purpose of this study was to investigate the relative muscle activities of 5 neck, shoulder, and upper arm muscles during riding simulations of large construction equipment, using three different arm control options.

Methods

Five typical heavy equipment ride files were "played back" through a man-rated Servo Test 6-degree of freedom (dof) vibration system. Each ride was repeated using 3 seat and control configurations (steering wheel (SW), floor mounted arm-rest controls (FM), seat mounted arm-rest controls (SM)). Two trials were performed for each ride and seat control combination (each trial: 60 sec of 6-dof and 60 sec of vertical vibration). Five channels of surface electromyography (EMG) of the right-side cervical erector spinae muscles (neck extensors), sternocleidomastoid (neck flexor), upper trapezius (shoulder elevator), biceps brachii (elbow flexor) and triceps brachii (elbow extensor) muscles were collected throughout each ride (~ 2min) using pre-amplified (10x), 1 cm silver bar electrodes, with 1 cm fixed inter-electrode distances (Delsys, Inc). Further analog amplification was set at 10k (1k for one subject), and sampled at 1000Hz using a 12-bit DAQ card and Labview 7.1 software (National Instruments). A total of 7 right-handed male subjects were tested, but only 5 had complete EMG data sets to analyze for this sub-study. EMG was analyzed using root mean square (RMS, in mV) of 20 ms moving windows, and then averaged across the entire trial for a measure of mean total muscle activity (voluntary and reflexive). The muscle activity to maintain the static posture was estimated as the mean RMS EMG over a 1 sec interval just prior to and/or after completion of the ride. Repeated Measures ANOVAs were used to test for with-in subject differences using $\alpha = 0.05$.

Results

The upper trapezius and triceps brachii muscles were significantly more active (mean EMG muscle activity) while using the steering wheel controls than for either the floor mounted or seat mounted arm rest controls. Whereas, the floor mounted arm controls tended to produce greater activity in the biceps brachii. Overall, the seat mounted controls resulted in the lowest mean EMG levels across all five muscles. No significant differences were observed in the neck flexor (sternocleidomastoid) or the neck extensor (erector spinae) muscles across control configurations.

Discussion

This pilot study suggests that muscle activity is indeed influenced by arm control postures. In our companion study on relative neck and shoulder motion, we indicate greater relative motion with the armrest control configurations. Interestingly, in this study we observed greater static and dynamic muscle activity with the steering wheel configuration. The arms may behave as active dampers particularly when the control configuration is not mounted to the seat (SW or FM), potentially attenuating head and neck motions. However, it is not entirely clear as to whether the greater relative motion or the potential for greater muscle fatigue over time may be the most problematic for equipment operators. Certainly the risk of injury may depend on the type of injury considered, e.g. overuse muscle injury versus repetitive motion joint pathology. There may be trade-offs between the potential for reduced fatigue associated with arm-rest controls, which is supported by our observations of decreased mean muscle activity, and the potential for greater apparent muscle and joint stiffness associated with tonic muscle activity – and thereby reduced motions. These preliminary results would suggest that the vibration community needs to consider the effect of and attenuation of vibration in the upper quarter considering the influence of postural muscle activity with different arm control configurations on the transmissibility of vibration into the head and neck.

Acknowledgements

This study was funded by Caterpillar, Inc. of Peoria, IL and was conducted at Sears Manufacturing of Davenport, IA with the help of Mike Drinkall and Jason Boldt. At the University of Iowa, Dean Macken of the Engineering Design and Prototyping Center in the College of Engineering assisted with design and setup of specialized equipment, and Brad Parker, of the Center for Computer-Aided Design (CCAD) provided vital help with computer hardware and software. The study was conducted through CCAD (directed by Karim Abdel-Malek) where one of its goals is to optimize the Digital Human.

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EVALUATION OF POWERED WHEELCHAIRS WITH SUSPENSION AND EXPOSURE TO WHOLE-BODY VIBRATION

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Introduction

Although wheelchair users are regularly subjected to whole-body vibrations little research has been conducted to assess these vibrations or attempt to reduce them [2,3,5]. Most of the wheelchair and whole-body vibration research done to this point has been conducted on manual wheelchairs. Van Sickle et al showed that manual wheelchair propulsion over a simulated road course produces vibration loads that exceed the ISO 2631-1 standards for the fatigue-decreased proficiency boundary at the seat of the wheelchair as well as the head of the user [6]. In a study by Boninger et al [1], 66% of wheelchair users reported neck pain since acquiring their wheelchair. One of the key reasons believed to be the cause of pain, was the exposure to whole-body vibration. Kwarciak et al [4] and Wolf et al [7] performed similar studies using two methods of analysis to evaluate vibrations on suspension and non-suspension wheelchairs while descending curbs of varying heights. Both studies revealed no significant difference in the abilities of the wheelchairs to reduce the amounts of vibrations transferred to the wheelchair user. Although the efforts of wheelchair companies to reduce the amounts of whole-body vibration transmitted to wheelchair users through the addition of suspension systems is encouraging, the technology is not yet ideal. Additionally, the research to date has focused on manual wheelchairs exclusively, while little attention has been shown to powered wheelchairs.

Methods

This study includes the use of two suspension electric powered wheelchairs: The Quickie S-626 and the Invacare 3G Torque SP Storm Series. Each subject tested all of the configurations of the suspension wheelchairs. These included the Invacare with suspension, the Quickie with suspension set to three settings (most stiff, least stiff, and 50% stiffness), and both wheelchairs with solid inserts to act as non-suspension wheelchairs. Sixteen able bodied subjects have been recruited for this study so far. In each of the configurations of the wheelchairs, the subjects traversed an Activities of Daily Living (ADL) course. Vibrations were collected from a tri-axial accelerometer attached to a seat plate beneath the cushion during driving over the activities course. A mixed model ANOVA was used to determine if there were differences between suspensions based on Vibration Dose Value (VDV).

Results

Statistical analyses of the VDV data revealed significant differences between the six different suspensions over each of the obstacles in the activities of daily living course. Post-hoc analyses revealed that for each of the obstacles, significant differences existed between the Invacare suspension and the Invacare solid insert. For the Quickie power wheelchair the solid insert setting was not significantly different from the most-stiff setting for each of the obstacles except the smooth surface. The solid insert setting was significantly different than the lowest and mid stiffness settings for all of the obstacles except the smooth surface and the deck surface.

Table 1 – Average and total VDV values ($m/s^{1.75}$) for each suspension setting

	Invacare Insert	Invacare Suspension	Quickie Insert	Quickie Least Stiff	Quickie Mid-Stiff	Quickie Most Stiff
Deck	0.23	0.26	0.25	0.23	0.23	0.25
Door	1.07	0.72	0.81	0.56	0.51	0.77
Curb	2.45	1.56	2.87	1.41	2.06	2.78
Dimple	0.69	0.61	0.69	0.59	0.58	0.68
Smooth	0.14	0.11	0.14	0.12	0.12	0.15
Carpet	1.00	0.83	1.16	0.71	0.70	1.02
Total VDV	**2.55**	**1.65**	**2.91**	**1.55**	**2.10**	**2.87**

Discussion

Although most of the suspension systems are capable of reducing the amounts of vibration transmitted to the users, the exception being the Quickie S-626 with the most-stiff suspension setting (this setting was not significantly different from the solid insert setting for all obstacles except the smooth surface), the results of the vibration dose values seem to indicate that they may not reduce them enough to reduce probability of injury in powered wheelchair users. When examining the total VDV over the entire activities of daily living course, in relation to the Health Guidance Caution Zone (HGCZ), there is not significant time allowed before WBVs are considered dangerous.

The information on the transmissions of vibrations from different suspension systems can lead to improvement in their design and function allowing powered wheelchairs to adequately reduce the amount of whole-body vibrations experienced by their users. Future research should investigate vibrations experienced by wheelchair users in real environments over extended periods of time.

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ESTABLISHMENT OF AN EXPERIMENTAL SYSTEM FOR MEASRING BIODYNAMIC RESPONSE OF HAND-ARM

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Introduction

This paper addresses establishment of an experimental system for measuring biodynamic response (BR) of hand-arm system at the NIIH in Japan. BR measurement system at the NIIH is nearly equivalent to NIOSH installed system. The feasibility of the system is examined through the apparent mass (AM) measurement of the empty handle and a set of calibration masses.

Apparatus

The grip force was measured by using the handle shown in Fig. 1. The handle has two force sensors (KISTLER, 9212) and one accelerometer (PCB, 356A12). A low-pass filter with 5 Hz cut-off frequency was used to the grip force from measured force signal. Figure 2 shows BR measurement system in this study. The push or pull force at the handle was measured by using the force plate (KISTLER, 9286AA). The grip force and the push / pull force were displayed on a monitor. The shaker (IMV, VE-100S) is used to vibrate the hand-arm system along the forearm axis (Z_h direction) (ISO 10068, 1998; ISO 5349-1, 2001). In most situations force actions for operating tools are expressed by grip, push, pull and combined these actions. These actions can be simulated in the test system. AM was obtained by performing H1 estimator in the PULSE™ system (B&K, 3109) and it is denoted at the one-third octave band center frequencies.

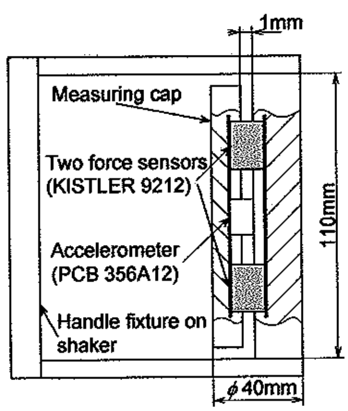

Fig. 1 Instrumented handle of the system

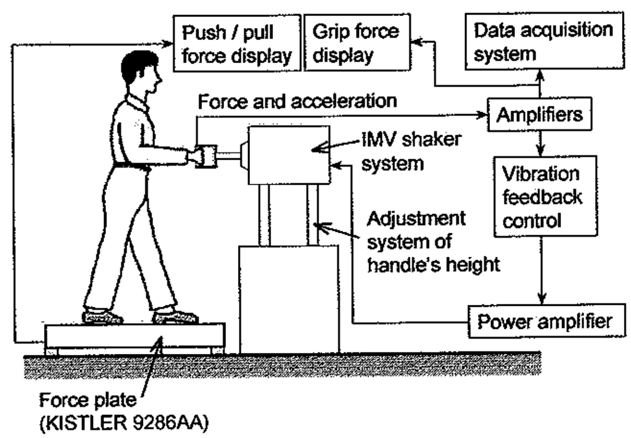

Fig. 2 Measurement system at the NIIH

Methods

In order to investigate the reliability of the system, AM measurement of the handle was performed. It is assumed that the handle is rigid in the upper limit of adoptive frequency range in this study. This assumption is validated in AM measurement of the empty handle. A pseudo-random vibration in the frequency range of 10 to 1,250 Hz was used and its amplitude is 1.0 $(m/s^2)^2/Hz$ with a flat power spectral density (PSD) in the experiment.

Measured AM includes the mass effect of the measuring cap in a subject experiment. Compensated apparent mass $AM_c(\omega)$ is obtained by Eq. (1) [1-2].

$$AM_c(\omega) = AM_{total}(\omega) - AM_{cap}(\omega) \quad (1)$$

where $AM_{total}(\omega)$ is measured response with the mass of the measuring cap and BR of a subject, $AM_{cap}(\omega)$ is the response of measuring cap in an empty handle test. In this study it is assumed that $AM_{total}(\omega)$ is the response with attached small piece of metal to the measuring cap by adhesive tape. Eight pieces (1, 2, 3, 4, 5, 10, 15 and 20g) of metal were used in the experiment.

Results and Discussions

The measured AM of the empty handle differences between measured and true values are less than 3%. Since resonant frequency is higher enough frequency range of measurement (12.5 – Hz), the assumptions seem to hold in the frequency range of measurement. The calibrations of the measuring cap's mass shown in Fig. 3. The measured pieces of generally agree with the true mass value. measured mass values of over 10g are than the true mass value in the high frequency range (>600Hz).

AM the than 1,000 are mass The bigger

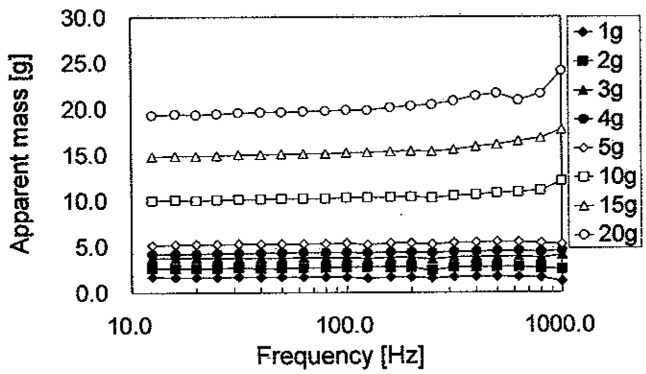

Fig. 3 Mass compensation results

The amplification of the response seems increases with the increase in the metal mass. This is likely because each piece of metal is resiliently attached to the measuring cap by adhesive tape and the metal and tape form a local 1D system. The resonant frequency of the system reduces with the increase in the mass value. This further supports the validity of the measurement system and the mass cancellation method.

Conclusions

Throughout the course of this study, several conclusions are obtained as follows:

(1) A BR experimental system for measuring biodynamic response of hand-arm system and vibration exposure tests was established in NIIH.

(2) The instrumented handle of the system was validated through the AM measurement.

(3) The mass of the measuring cap in the AM measurement was well compensated by the mass cancellation method, which confirms its validity.

Acknowledgements

The authors acknowledge the assistance of staff at NIOSH, Dr. Dong, R. G. and Mr. Welcome, D. E. Their help is greatly appreciated.

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Training Simulators Extend Laboratory Testing Techniques for WBV Analysis

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Shekar Khanal
Gretchen Hinton
Don Wasserman

Introduction

Human testing has always been a needed way to provide information on the effects of vehicle vibration, however, the manner of testing has not reflected the real situations of driver's hands on a steering wheel and a seat with back support and driving tasks. The typical system have used a standard sinusoidal excitation rather than the typical types of road – truck excitations

The new truck driver training simulators provide the combination of road roughness, speed effects, cab environment and individual tasks. The system has a full six axis simulation potential. The simulators have the protection of the individual by a combination of two ways for the individual to stop the motion as well as an operator with visual capability who can stop the testing. The closed simulator, shown in Figure 1, has the potential for providing motion during the operation.

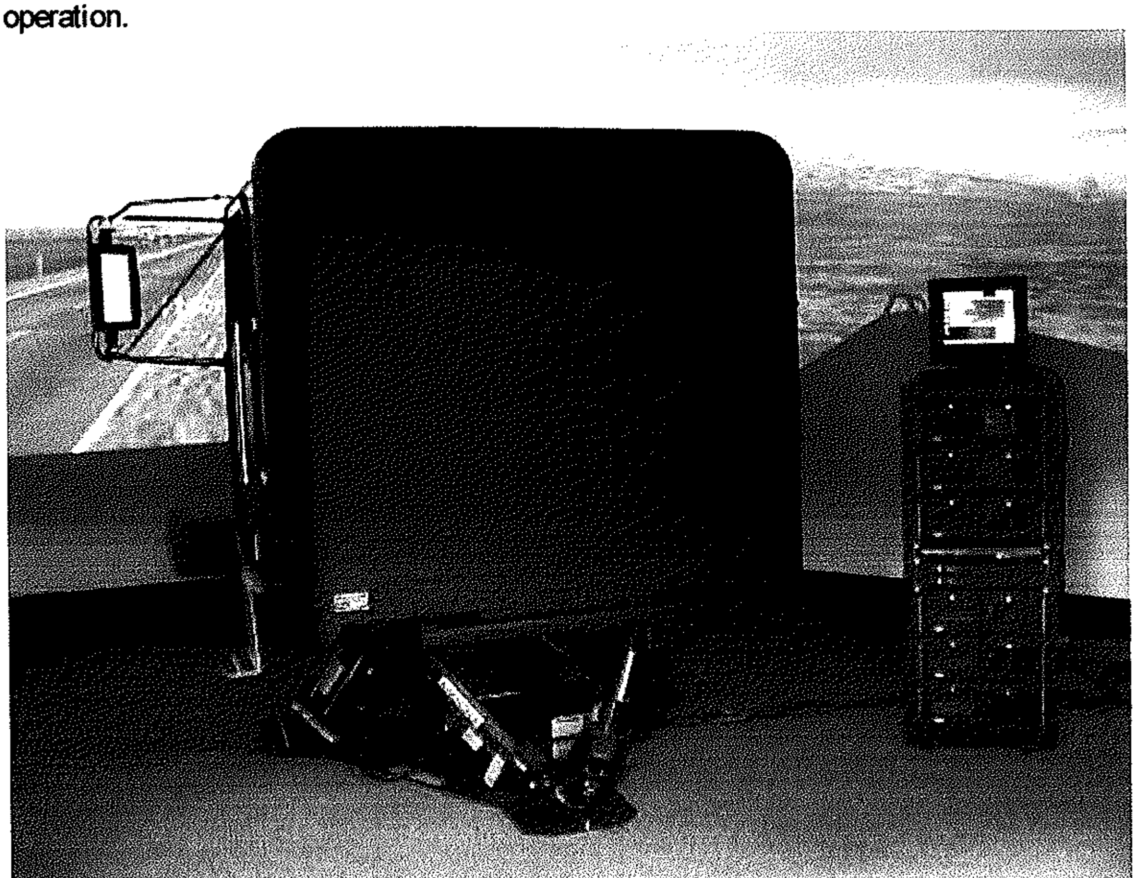

Figure 1 Mark III Truck Simulator

Plan Objectives

The current project is to evaluate the levels and distribution available from a standard truck driver training simulator. The simulator has a combination of regular routs and "rough" routs.

The system will be operated with a combination of triaxial seat pads and floor accelerometers for comparison to the date collected from the trucks in Europe

Results

Comparisons of the truck testing data will be provided as part of the planning for future research activity. Initial testing has been done on the vibration exposure for the operator of the simulator when the roads are "rough". The actual rms weighted value for vertical acceleration was 0.254 m/s^2. The 1/3 Octave spectrum shown in Figure 2 is from driver's seat in England. This seat showed significant loading in the 4 Hz. band. The simulator does have some loading in this area, but it is much lower.

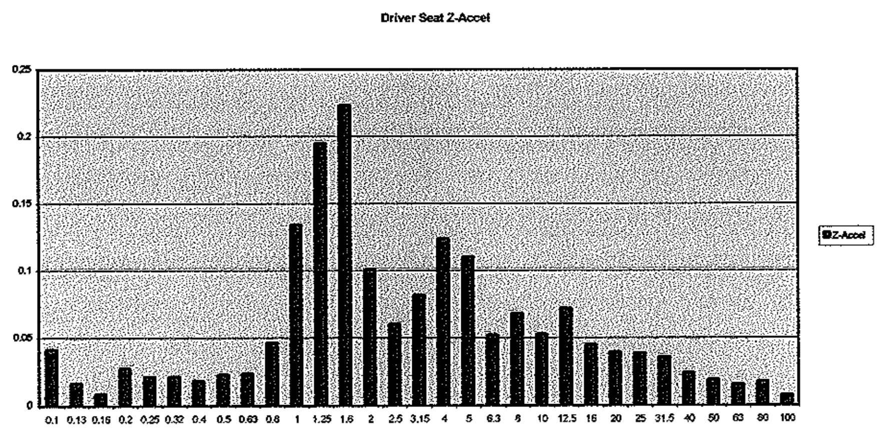

Figure 2 Driver's Seat 1/3 Octave Z –Axis Acceleration

For testing purposes, the values in the 4 – 8 Hz region may need to be increased to the normal band level.

INSTRUMENTED HANDLES FOR STUDYING HAND-TRANSMITTED VIBRATION EXPOSURE

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Introduction

Instrumented handles or dynamometers are widely used to measure hand forces and/or the biodynamic response of hand-arm system. To study hand-transmitted vibration exposure, six generations of instrument handles were constructed or initially developed by researchers in ECTB/HELD/NIOSH. This presentation provided a summary of these handles. Their basic characteristics, limitations, and usefulness are described, which may help their appropriate applications and further improvements.

Six Designs of Instrumented Handles

Handle 1: The conceptual design is recommended in ISO 10819 (1996)[1] for glove test. The grip force is measured by detecting bending strains on a measuring beam in the handle. A special handle fixture was designed to connect the handle to a shaker. Except the screws, the handle and fixture were made from aluminum.

Handle 2: The design is based on the principle of shear strain measurement.[2-3] Both grip and push forces can be measured simultaneously using this handle. This handle was directly designed for a simulated vibrating tool.

Handle 3: This design is basically composed of a handle base, a measuring cap, and two charge-based sensors (Kistler 9212) sandwiched between the base and cap. The handle was also made from aluminum. The fixture for Handle 1 was also used with this handle. This generation of handle has three different handle diameters (30, 40, and 50mm).[4]

Handle 4: This design is an improvement from Handle 3. The handle fixture was totally redesigned and it was much stiffer than the previous one. The aluminum measuring cap was replaced with a magnesium cap.

Handle 5: The basic structure of this handle is the same as that for Handle 3. However, the piezoelectric sensors were replaced with two strain gage based sensors (Interface SML-50).

Handle 6: This handle includes two measuring caps, four piezoelectric sensors, and a handle centre base. The handle fixture was the same as that with Handle 4.

Methods for Handle Examinations

The static and dynamic characterizations were performed using the methods reported by Dong et al.[5-6]

Results and Discussion

Handle 1: The static force measurement depended on the hand grip location on the handle. Its natural frequency was less than 200 Hz.[5,6] Because the transmissibility of gloves may not vary significantly with the applied grip force, this handle may be acceptable for glove test. However, the force measurements with this handle may not be reliable.

Handle 2: The static force measured with this handle was insensitive to the hand acting location. However, when the handle was vibrating, the force signals could be totally distorted. For this reason, it was not used for vibration studies.

Handles 3 and 4: The static force measurements with these handles were independent of the hand grip location.[6] The resonant frequency of the early version was about 1,450 Hz and the latest was about 1,900 Hz. These handles have been extensively used for both static and biodynamic measurement up to 1,000 Hz.[4,6] The experimental data measured with the handle have been used to develop biodynamic models. A sample model, together with its parameters, is shown in Fig. 1. The modelling results agree excellently with the experimental data, as shown in Fig. 2. The natural frequencies (29 Hz and 208 Hz), the damping ratios (0.29 and 0.73), and the potential static deformations of the hand-arm system in the possible hand force range are also very reasonable. Without the reliable and accurate experimental data, it is impossible to establish such a model.

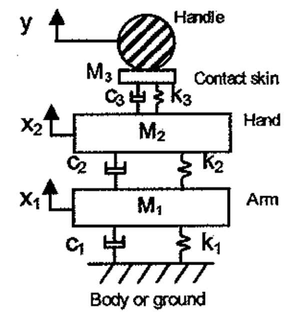

Fig. 1: A 3-DOF model (M_1=1.2320 kg; M_2=0.1774 kg; M_3=0.0338 kg; k_1 = 1.5 kN/m; k_2 = 48.5 kN/m; k_3=252.8 kN/m; c_1=54 N-s/m; c_2=104 N-s/m; c_3=231 N-s/m.)

Handle 5: Piezoelectric force sensor can have a significant zero-drift problem. The handle equipped with such a sensor may not be suitable for a long duration force measurement. The handle equipped with strain gauge sensors has no such a problem. However, because the sensor is not as stiff as the charge-based sensor, the handle resonance was at about 900 Hz. It has been used for studying hand force recall.[7]

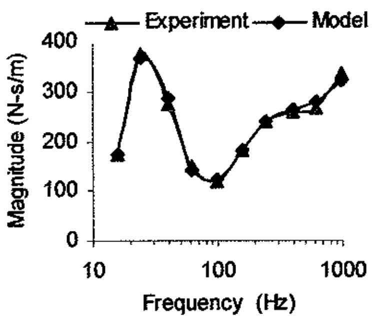

Fig. 2: Comparison of modeling and experimental impedance data (50 N grip-only) (r = 0.993).

Handle 6: Except for Handles 2 and 6, the other handles cannot simultaneously measure both grip and push forces. The push force is usually measured using a force plate in the experiment. The dynamic responses distributed on the fingers and palm can only be measured separately using Handles 3-5. Handle 6 was developed to overcome the deficiencies. Its natural frequency was about 1,450 Hz.

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A NOVEL THEORY: ELLIPSE OF GRIP FORCE

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Introduction

Hand forces are important factors for risk assessment of hand-arm vibration syndrome (HAVS).[1] Grip force is one of the most important force components in the operation of powered hand tools. A considerable number of studies on grip force have been reported. It is well known that the grip force applied on a cylindrical handle is not uniformly distributed on each axis across the center of the handle cross-section.[2] Therefore, maximum and minimum orientations of grip force exist around the handle. Such orientations have not been clearly identified. In a recently proposed international standard (ISO/CD 15230, 2005),[3] it is stated that "the direction of the main gripping force is generally parallel to the z-axis defined in ISO 8727." [4] This assertion is questionable, and further examinations are required. The objective of this study was to establish a fundamental theory on the distribution of the grip force around cylindrical handles.

Methods

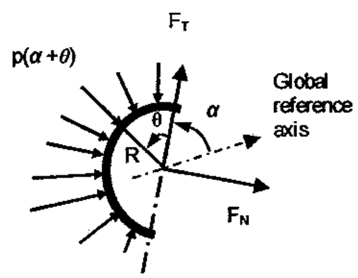

Fig. 1 Grip force definition

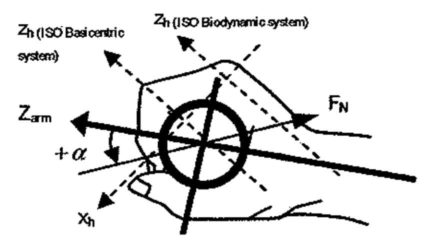

Fig. 2: Hand coordinate systems (z_h & x_h: ISO system.[1,4] Z_{arm}: forearm z-axis. F_N: grip normal force at α deg.

As shown in Fig. 1, the grip force is defined as a vector composed of normal and shear components (F_N & F_T) in this study. Fig. 2 shows the hand coordinate system defined in this study, together with the ISO systems.[1,4] Based on this novel grip force definition, we derived four fundamental properties and a theorem. More significantly, we formulated a novel hypothesis: similar to Mohr's circle of stress, the normal and shear components can be represented approximately using an ellipse on the plane of the two force coordinates, as shown in Fig. 3. The maximum and minimum grip normal forces are termed as the first principal grip force (F_1) and the second principal grip normal force (F_2), respectively. Their corresponding orientations are termed as the first principal grip angle (α_1) and the second principal grip angle (α_2).

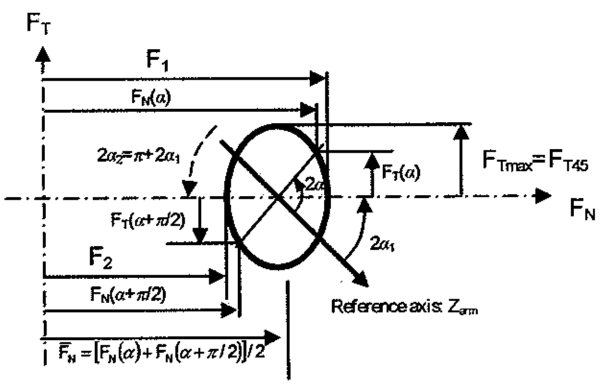

Fig. 3: A novel hypothesis: ellipse of grip force.

A series of experiments were conducted to test this hypothesis. Twelve subjects participated in the experiment. Three cylindrical handles (30, 40, and 48 mm) were used. Each of them was equipped with a flexible contact pressure sensor (TekScan, Model #5101-100). Fig. 4 shows the measurement setup and hand grip posture. Each subject was required to align the hand mark (on Z_{arm} axis) with the handle mark and to apply the maximum and medium (50%) grip forces on the handle.

Fig. 4: Test setup & hand posture

Results and Discussion

Fig. 5 shows an example of the experimental results. Table 1 provides comparisons of the elliptical model predictions and the test data. The results strongly support the hypothesis. This study also found that the maximum grip pressure around the handle is distributed in the finger contact area. On the 40 mm handle, the first principal force is more than 40% of the second principal force (t-test: $p < 0.001$). The maximum force is located in the finger contact orientation at approximately 27° from the Z_{arm}-axis that is about 29° from the hand z_h-axis defined in ISO 5349-1 or ISO 8727. It is significantly greater than that on the Z_{arm}-axis (t-test: $p < 0.001$). The maximum force on the 30 mm handle moves further from the Z_{arm}-axis, and that on the 48 mm handle moves closer to this axis. Therefore, even if the z_h-axis in the basicentric system defined in ISO 8727 could align with the Z_{arm}-axis in the operations of some tools, the above-mentioned statement in ISO/DIS 15230 (2005) is generally invalid. The proposed theory can be used to improve the standard and to develop a more effective method for grip force measurement.

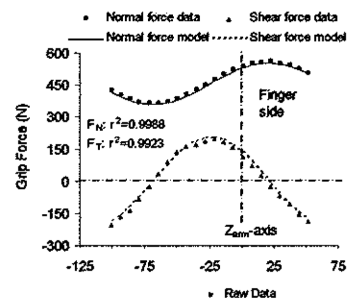

Fig. 5: Data comparisons

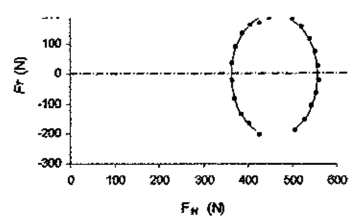

Table 1: Modelling and test data for 40 mm handle

Ellipse Parameters	$\alpha_1 - \alpha_2$ (deg.)	F_{T45}/F_{Tmax}	$(F_1-F_2)/F_{Tmax}$	r^2-value for F_N fitting	r^2-value for F_T fitting
Mean	89.4	0.9741	0.9313	0.9937	0.9642
SD	5.8	0.0286	0.0767	0.0082	0.0425
Theory	90.0	1.0000		1.0000	1.0000

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CHEST TRANSMISSIBILITY CHARACTERISTICS DURING EXPOSURE TO SINGLE- AND COMBINED-AXIS VIBRATION

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Introduction

Ground, air, and water vehicles can expose humans to substantial multi-axis vibration. Multiple input/multiple output relationships or models exist for estimating frequency response functions of linear systems[1, 2]. These relationships have been applied by some investigators to evaluate the effects of occupied seat vibration[3, 4]. Using a multiple input/single output model, this study investigated the effects of single- and combined-axis vibration in the fore-and-aft (X), lateral (Y), and vertical (Z) directions on vibration transmission to the human chest. Frequency response functions (transmissibilities) were estimated and compared for the back-on and back-off postures.

Methods

A rigid seat with seat back was mounted onto the Six Degree-of-Freedom Motion Simulator (SIXMODE). A flat acceleration vibration signal was generated between 2 and 40 Hz at 1.0 ms^{-2} rms in the single and combined X, Y, Z, XY, XZ, YZ, and XYZ axes. The signals were shifted in time so that the combined inputs were not fully correlated. Lightweight triaxial accelerometers were used to measure accelerations at the seat base (input) and at the bony manubrium of the chest (output). The maximum of nine frequency response functions ($H(\omega)$) or transmissibilities were estimated from the auto- and cross-spectra. The system transfer matrix for the XYZ inputs and chest Z output is

$$\begin{bmatrix} H_{xZ} \\ H_{yZ} \\ H_{zZ} \end{bmatrix} = \begin{bmatrix} P_{xx} & P_{xy} & P_{xz} \\ P_{yx} & P_{yy} & P_{yz} \\ P_{zx} & P_{zy} & P_{zz} \end{bmatrix}^{-1} \begin{bmatrix} P_{xZ} \\ P_{yZ} \\ P_{zZ} \end{bmatrix} \quad (1)$$

where P_{xZ}, P_{yZ}, and P_{zZ} are the cross-spectra between the three inputs at the seat base and the Z output at the chest, respectively, and P_{xx}, $P_{xy,\ldots zz}$ are the auto- and cross-spectra between the input signals (ω not shown in Eq. 1). Equation 1 can be similarly written for the chest X and Y outputs. Matlab® was used to estimate the auto- and cross-spectral densities for calculating the transmissibilities, ordinary coherences (for single inputs), partial coherences, and multiple coherences.

Results

Figure 1 illustrates the major chest transmissibilities observed for the two postures. Vertical vibration showed a consistent influence on the chest X response (Chest X/Z), most likely causing chest pitch. Some chest Z responses were observed with X-axis inputs, but the results were variable and difficult to interpret. In general, other factors besides the known inputs did not affect the transmissibilities shown in Figure 1 (Repeated Measures ANOVA, $P<0.05$). This was

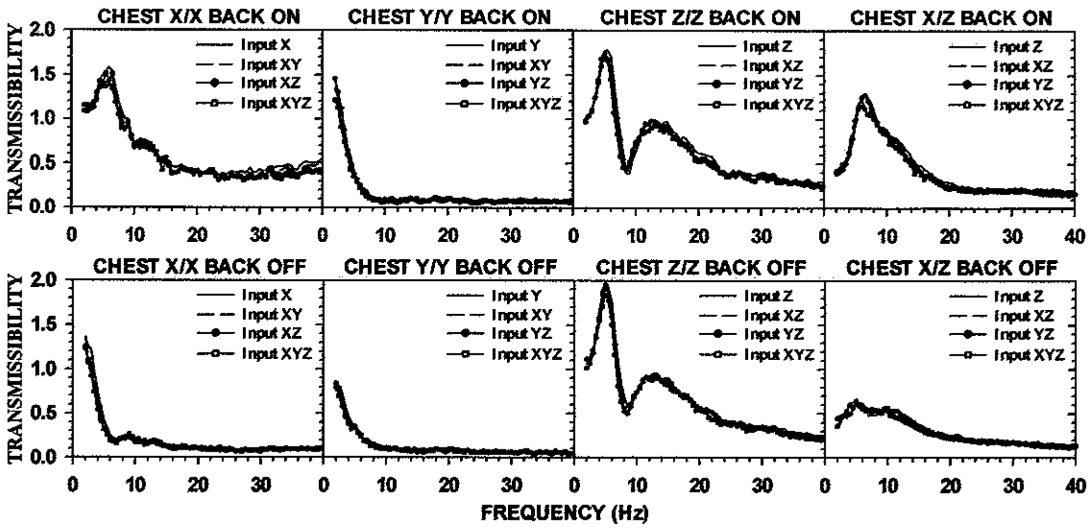

Figure 1 Mean Chest Transmissibilities from Nine Subjects (4 Females, 5 Males)

reflected by the relatively high partial coherences, particularly associated with the primary peak responses (majority PCoh>0.85). More variable coherences were noted among the subjects for Chest X/Z for the XZ and XYZ inputs, the lowest mean value being 0.75±0.14. Regardless of the input, the back-off posture showed the elimination of the 4-6 Hz peak in Chest X/X, the significant reduction in the peak frequency for Chest X/Z, and the significant reductions in the Chest Y/Y and Chest X/Z transmissibilities (Fig. 1, Paired t-test, $P<0.05$).

Discussion

Lower partial coherences would suggest that the chest responses were not fully accounted for by a linear relationship to the known inputs. This could occur due to chest pitch, which was expected to some extent with both the X and Z inputs. Except for a few cases, the partial coherences were relatively high. The seating posture was found to have a significant effect on the chest multi-axis biodynamics. Specifically, coupling with the seat back promoted the influence of vertical vibration on the chest X response, causing higher upper torso motion in the X direction at a peak coincident with whole-body resonance (~4-6 Hz, as observed in Chest Z/Z). When contact with the seat back was removed, these effects were reduced and the peak chest X motions appeared dampened at higher frequencies. The chest X motion with the back off appeared to be more influenced by lower frequency vibration associated with relatively higher seat displacement (~2 Hz).

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A FIELD STUDY: MEASUREMENT AND EVALUATION OF WHOLE BODY VIBRATION FOR MH-60S PILOTS

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Naval Medical Center San Diego
Debra Yniguez, COMHSCWINGPAC

Introduction

Pilots of the MH-60S helicopter are exposed to continuous whole body vibration (WBV). Pilot fatigue is a growing operational concern due to the increased frequency of extended durations of missions (6-8+hours) in support of Operations Iraqi Freedom and Enduring Freedom. Endurance aspects of the currently used rotary wing seating systems were not optimized for the longer missions and wide range of pilot anthropometric measurements, which is now typical of naval aviation. The current seating systems were designed primarily to meet crashworthiness requirements, not for the wide range of pilot anthropometry or to mitigate WBV. Albeit, an issue, pilot fatigue and reduced mission effectiveness are also critical concerns.

Current Hazard Reports indicated that pain in pilots' legs and backs begin two to four hours into the flight and increase with time. Mission readiness also decreases with an increase in flight duration due to the constant distraction of pilots shifting in their seats while trying to get comfortable. Froom, et al [2] reported a dose-response relationship between the length of military helicopter flights and back discomfort. He also concluded that this pain is typically dull, over the lower back, and its prevalence and intensity are dependent on the total flight hours of exposure.

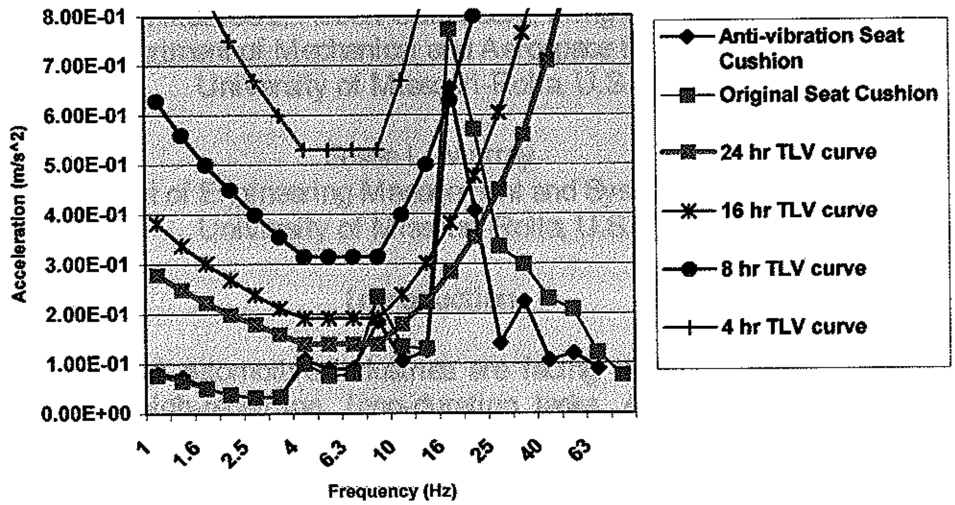
Methods

This study evaluated WBV produced in the pilot seating systems onboard the MH-60S. The purpose of the study was to test and compare the effectiveness of two different seat cushions, the current seat cushion versus an anti-vibration seat cushion. Both seat cushions were measured for acceleration levels averaged over five-minute intervals using a triaxial seat pad accelerometer. The recordings were completed for a 3-hour straight and level flight. A frequency analysis from 0-80 hertz (Hz) was conducted on all acceleration measurements to determine the dominant axis and frequency of the pilots' vibration exposure. The results were then compared to the applicable Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH) [1] and the International Organization for Standardization (ISO) 2631.1 [3] to determine the MH-60S pilots' permissible exposure time for both seat cushions.

Results

The results of the study showed that for both seat cushions the vibration levels of the z-axis at 16 Hz had the shortest allowable exposure duration, according to the ACGIH TLVs. In the z-axis at 16 Hz, the MH-60S's current seat cushion's acceleration levels indicated an exposure time limit of approximately 6 hours, while the anti-vibration seat cushion's acceleration levels pierced the 8-hour exposure time limit curve. This is shown in the graph below.

Z-axis Acceleration Levels Compared to ACGIH TLVs



When compared to the ISO standard, the acceleration levels are 0.86 m/s^2 and 0.73 m/s^2 for the current and anti-vibration seat cushions, respectively.

Discussion

While the anti-vibration seat cushion's acceleration levels were slightly lower than the current seat cushion's levels, the helicopter pilots are still overexposed to WBV. Since the average flight during a deployment or mission could last up to 8 hours, the current exposure places the pilots at an unacceptable risk of injury, lack of mission readiness, and possible equipment damage. In the future, helicopters will be outfitted with auxiliary fuel tanks, enabling even longer flights.

Additional research should be conducted to include a larger sample size, evaluate specific flight profiles other than straight and level flights, and perform transmissibility studies aboard the MH-60S targeting specific portions of the human body. Additionally, extensive follow-up epidemiological studies should be performed for Navy helicopter pilots to evaluate the incidence rates of back injury and their relationship to whole body vibration exposure.

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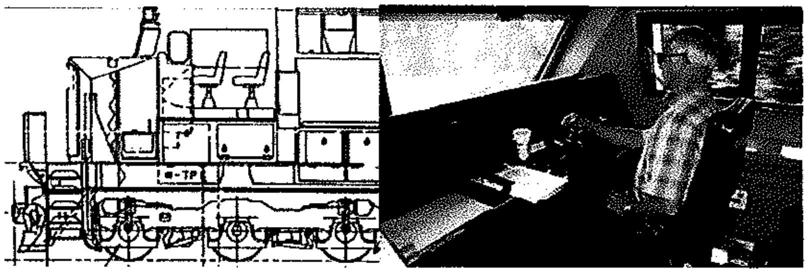

The results of the vibration and shock measurement of the basic x, y, z-axis ($a_{w\ rms}$) and vector sum (a_v) ranges were 0.07- 0.19, 0.13-0.4, 0.14-0.5 and 0.27 – 0.65, respectively. The ranges of the "shock" indicators MTVV/a_w and VDV/($a_w \cdot T^{1/4}$) were (x,y,z): 3.2-7.6, 2.9- 9.4, 3.3-10 and 1.44-2.3, 1.37-1.71, 1.44-1.94 and exceeded in a number of cases the critical values given by ISO 2631 (1). The daily equivalent static compression dose S_{ed} range was 0.11 to 0.79, mean 0.32 and the R-factor range was 0.12 to 0.92, mean 34, suggesting possible conflicting shock exposure risk information.

Discussion

Different shock indicator values were computed based on both ISO standards. Although, the new ISO 2631-5 method for evaluation of vibration containing multiple shocks suggests in our calculations possibly a low exposure risk other data and experience suggest an underestimation error relying solely on this indicator. We propose considering a combined sum score, in an overall risk assessment, that includes ergonomic co-factors such as awkward body posture, cab and seat design, and other environmental factors.

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CLINICAL ASSESSMENT AND CHARACTERISTICS OF MEN AND WOMEN EXPOSED TO HIGH LEVEL OF HAND-ARM VIBRATION

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Introduction

While the neurological and vascular aspects of Hand-Arm Vibration Syndrome (HAVS) has been generally accepted as a medical condition, the medical criteria and the clinical findings used to establish the diagnosis has been more difficult to bring to consensus. The criteria was first quantified by the Taylor-Palmear scale.[1] This criteria was subsequently modified in 1986 at the 1st Stockholm Workshop[2,3] to included more acceptance for the neurological effects that characterized the predominate findings in some workers. The relationship between hand-arm vibration and Carpal Tunnel Syndrome was defined in NIOSH 97-141[4].

While the aforementioned documents have defined the clinical entities associated with hand-arm vibration exposure, agreement on the clinical findings and test to confirm the diagnosis has be been more difficult to bring to consensus. Clinicians assessing HAVS has relied on a number of varied neurological and vascular tests. The neurological testing has focused on assessing damage to the sensory capability of the fingers for the neurological component including tests to measuring ability to sense vibration, cold or other end point finger sensor functions. However, the vascular testing has been traditionally focused on the ability to either measure vascular function or to reproduce the vascular blanching that occurs in HAVS with cold water provocation. Recent assessment of this testing in the United Kingdom Coal Miner's study has questioned the value of this testing especially in reviews by McGeoch.[5] In an attempt to provide some type of definitive testing to substantiate vascular damage from hand-arm vibration exposure, angiography is an alternative or adjunct to cold water provocation testing.

The standards that have been established to predict the level, type and incidence of HAVS have been based on clinical studies and reports that have essentially been all male populations. However, the recent entry of women into more vibration intensive jobs has brought about the exposure of some women to high levels of vibration previously only previously experienced by men. However, there have been only few studies that look at HAVS in women[6]. Although exposed the same vibration levels, it has not been clear that the latency and type of pathology of HAVS in women will be the same as for men.

The purpose of this study is to look at recent case studies of men and women exposed to jobs with high levels of hand-arm vibration with extensive clinical testing for both the neurological and vascular components of HAVS as well as other associated upper extremity conditions such as Carpal Tunnel Syndrome.

Methods

Clinical cases referred for evaluation with neurological testing including, vibrometry, Simmes-Weinstein mono filaments, 2 point discrimination, Purdue peg board testing and nerve conduction testing. Vascular testing included Allen's testing, Doppler studies of both upper extremities, cold water provocation testing and angiograph. Additional laboratory blood work and clinical examination was done to rule out alternative disease conditions that could confound results such as diabetes, collagen-vascular disease, etc.[6]

Results

Although the study was too small for statistical significance, review of the cases show that when exposed to the same high levels of hand arm vibration, women develop HAVS symptoms sooner than might be expected and early onset of Carpal Tunnel Syndrome.. In contrast men take longer to develop the same symptoms and are more likely to develop other finding such as tendonitis before they develop the constellation of symptoms and findings found in women.

Comparison of the vascular testing techniques indicates that the angiography can be helpful in confirming the vascular damage from hand-arm vibration exposure in both men and women. Furthermore, angiography may help localize areas of damage from specific exposure. The study proved to be too small to compare the effectiveness the various vascular testing techniques but suggest that further study is warranted.

Discussion

The study shows that there is a suggestion that present standards for the latency of HAVS and other vibration related disorders may be different for women then for men. Also review of clinical cases shows that angiography is useful tool in confirming and defining the level of vascular pathology in case of significant HAVS. Further enlarged studies to confirm both of these findings are recommended.

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ACUTE EFFECTS OF VIBRATION ON THE RAT-TAIL ARTERY

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Introduction

Acute vibration causes vasoconstriction in naïve human subjects[1]. Vibration-induced decrease in skin perfusion has also been reported in the rat-tail vibration model [2]. After vibration exposure, rat-tail arteries demonstrate vacuoles in smooth muscle cells, similar to that caused by pharmacological vasoconstrictors[3]. This study addressed the effects of different frequencies, durations and patterns of vibration on lumen size and vacuole formation using the rat-tail vibration model in male Sprague-Dawley rats (~300 g).

Methods

The different groups were: 4-hr continuous vibration at 30, 60, 120 and 800 Hz; continuous exposure durations of 5 min, 1 hr and 4 hr at 60 Hz; and 4-hr cumulative exposure of 60 Hz delivered intermittently in cycles of 10 min on and 5 min off. Acceleration was set at 49 m/s^2 r.m.s. for all frequencies. Unanesthetized rats were restrained in cages on a nonvibrating platform with their tails placed on a vibrating stage driven by a B&K motor (4809). The sham control animals were also placed in the vibration apparatus but not vibrated. Room temperature was controlled at 25 ± 1°C. Ventral arteries from proximal tail segments 7 were immersion fixed in aldehydes, embedded in epon-araldite and sectioned (0.5 µm) for morphological analysis. Vascular lumen sizes were measured as the percent ratio of the lumen perimeter to internal elastic membrane length using Image J software (NIH). The number of vacuoles in the smooth muscle layer of each artery section was counted.

Results

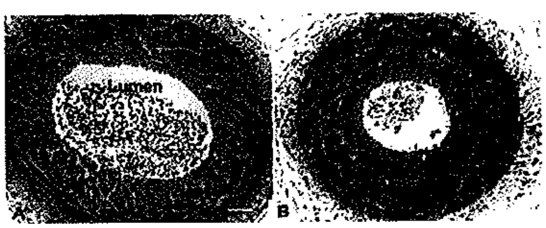
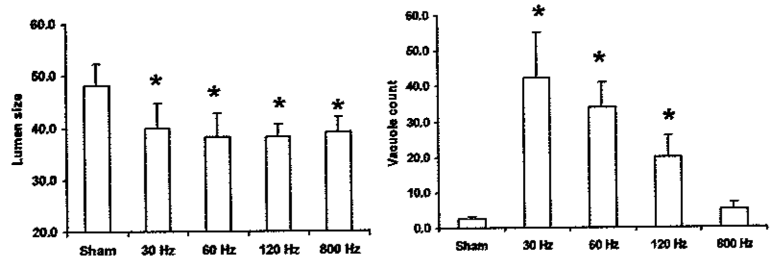


Fig 1: Semithin sections of arteries. A. Sham control. B. 4-hr vibration 60 Hz. In vibrated arteries, the lumen decreases in size, and smooth muscle cells (SMC) exhibit vacuoles (arrow). Bar equals 40 µm for each panel.

Fig 2: Bar graphs of lumen size and vacuole count when vibrated for 4 hrs at 30, 60, 120 and 800 Hz. * significantly different from sham, p<0.05.



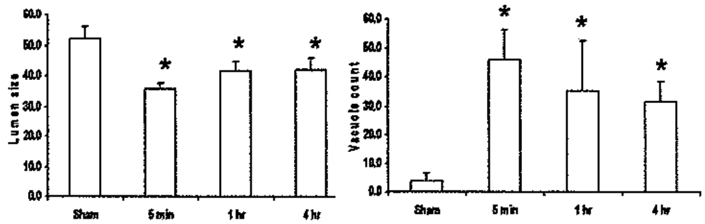


Fig 3: Bar graphs of lumen size and vacuole count when vibrated for 5 min, 1 hr and 4 hrs at 60 Hz. * significantly different from sham, $p<0.05$.

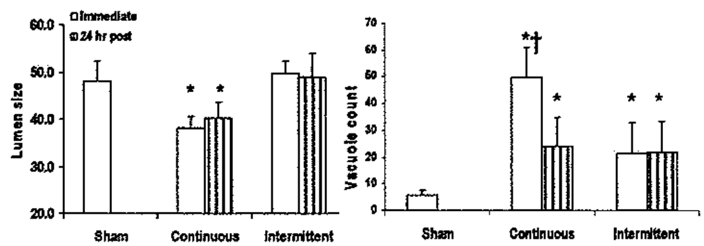


Fig 4: Bar graphs of lumen size and vacuole count when vibrated continuously or intermittently for 4 hrs at 60 Hz and examined immediately or 24 hr after exposure. * significantly different from sham, † significantly different from other vibrated groups, $p<0.05$.

Discussion

1. Vasoconstriction is induced by vibration at 30, 60, 120 and 800 Hz.
2. Vibration exposure of 60 Hz for 5 min is sufficient to cause vasoconstriction and generate smooth muscle cell vacuoles.
3. The decrease in lumen size persists at least 24 hrs after cessation of 60 Hz continuous vibration.
4. Both patterns of vibration, continuous and intermittent, cause the formation of smooth muscle cell vacuoles.

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EFFECTS OF REPEATED VIBRATION EXPOSURES IN MUSCLE TISSUE

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Introduction

Workers exposed to vibrating hand tools are at risk of developing symptoms such as cold-induced vasospasms, loss of tactile sensitivity, and loss of grip strength in the fingers and hands. These symptoms are known collectively as vibration white finger (VWF) or hand-arm vibration syndrome (HAVS). Symptoms of VWF or HAVS are in part due to repeated and prolonged peripheral vasoconstriction[1, 2]. The reduction in blood flow that occurs with vasoconstriction can result in oxygen deprivation (hypoxia) in soft tissues, such as nerves and muscle, and lead to functional and structural changes in these tissues. The present study examined muscle tissue to determine if vibration-induced changes in transcript levels and protein concentrations result in enhanced vasoconstriction and hypoxia. Manual dexterity was also assessed intermittently to determine if vibration-induced changes in cellular factors are accompanied by performance deficits.

Methods

An animal model was developed to study the biological and functional changes that occur in response to repeated segmental vibration exposures. In this model, the right paw of intact rats was exposed to a platform vibrated at a frequency 250 Hz and amplitude of 49 m/s^2 to simulate the vibration characteristics of hand-held grinders. Three groups of 8 rats each were studied: a vibration-exposed group, an exposure-control group, and a cage-control group. Exposure sessions, with or without vibration, were conducted 4 hr/day, 5 days/week for 5 weeks.

Manual dexterity was assessed intermittently during the 5-week exposure period with the Montoya stair-case test[3], which quantifies the rat's ability to reach for, grasp, and retrieve small food pellets placed below the rat on different levels or steps. Following the 5-week exposure period, the flexor muscles of the right forelimb were collected for analysis of gene expression, protein concentrations, and immunohistochemistry.

Results

Vibration-exposure resulted in an approximate 2-fold increase in the expression of α2C and α1D receptor transcripts in flexor muscles (Figure 1). These receptors mediate norepinephrine-induced vasoconstriction in smaller arteries. Vibration-exposure also resulted in an approximate 2-fold increase in hypoxia-induced factor-1α (HIF-1α), a transcription factor that is expressed in response to tissue hypoxia. Western analyses demonstrated that restraint caused a decrease in α1-receptor protein concentrations in the flexor, but vibration-exposure prevented the restraint-induced reduction (Figure 2). Immunohistochemistry performed on flexor muscles (not shown) demonstrated that α1 receptors are primarily located in arteries; maintained levels of these receptors could contribute to prolonged vasoconstriction following repeated vibration exposure. The staircase test showed some performance improvement, or a training effect, in manual dexterity for the control groups but not the vibration-exposed group (Figure 3).

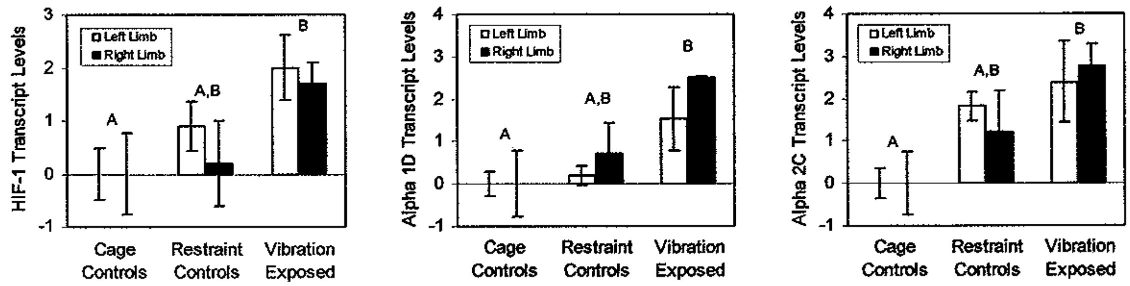

Figure 1. Relative gene transcript levels, expressed as mean fold change (±SE) in critical threshold from cage controls, for α2c, α1a/d, and HIF-1α in the left and right (exposed) limbs. Right limb is not significantly different from left; with right and left combined, A is significantly different from B.

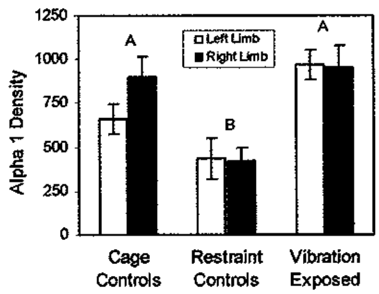

Figure 2. Mean relative optical density (±SE) of α1 proteins in the right flexor muscles as determined by western blot analysis.

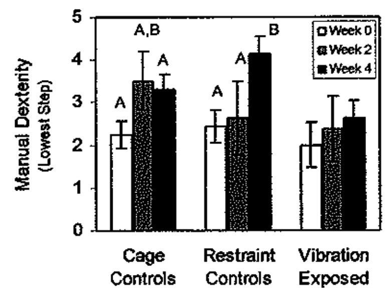

Figure 3. Staircase test of manual dexterity in the right limb (mean±SE; higher = better dexterity).

Results are consistent with the notion that vibration causes increased vasoconstriction in the vasculature, and subsequent damage or loss of function may be associated with hypoxia. Similar changes in transcript levels in both right and left limbs in the vibration-exposed group are consistent with reports of vibration-induced sympathetic vasoconstriction responses in contralateral (nonexposed) limbs[4]. Results also support the hypothesis that vibration-induced disturbances in motor control, manual dexterity, or loss of strength might be linked to hypoxia. A better understanding of these mechanisms can lead to the identification of early indicators of injury and improved methods for diagnosis and treatment of VWF or HAVS.

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VIBRATION EXPOSURE REDUCES NITRIC OXIDE CONCENTRATIONS IN THE VENTRAL ARTERY OF THE RAT TAIL

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Introduction

Vibration transmitted to the upper limb by the chronic use of hand tools can result in cold-induced vasospasms finger blanching and cyanosis, similar to that seen with Raynaud's phenomenon (4). These vasospasms, commonly referred to as vibration white finger (VWF), are in part the result of an increased sensitivity of peripheral arteries to the vasoconstricting effects of norepinephrine (e.g., (1-3)). However, alterations in vasodilating factors could also contribute to vasospasms. The goal of these studies was to determine if exposure to a single bout of vibration alters concentrations of the vasodilator, nitric oxide (NO), in a rat tail model of vibration. To determine if vibration exposure alters NO, we exposed animals to a single bout of vibration and measured concentrations of the synthetic enzymes, nitric oxide synthetase (NOS)-1 and NOS-3 in the ventral tail artery. We also directly assessed arterial concentrations of NO using a nitrate/nitrite assay.

Methods

General apparatus. Animals were placed in Broome-style restrainers, and their tail was secured to a vibrating or stable platform. Rats were exposed to a single 4 h bout of tail vibration (125 Hz, acceleration of 49 m/sec^2 r.m.s.) or restraint control. Animals were euthanized with an overdose of pentobarbital (100 mg/kg) and the ventral tail artery was dissected and frozen.

Experiment 1: Male Sprague Dawley rats (6 weeks old, n = 32) were used for all exposures. All animals were maintained in AAALAC accredited facilities, and all procedures were approved by the NIOSH Animal Care and Use Committee, and were in compliance with the CDC Regulations for the Care and Use of Laboratory Animals. Animals were euthanized 1 or 24 h after the completion of the exposure. Western analyses were performed on total proteins (80 μg/lane) isolated from the C16-18 artery segments. Band densities were detected by chemiluminescence and quantified using Scion Image, and analyzed using 2-way ANOVAs.

Experiment 2. Nitrate/nitrite concentrations.. Male Sprague Dawley rats (n = 24, 6 weeks of age) were maintained and exposed as described above. All animals were euthanized 24 h after the exposure and the ventral artery was collected. Nitrate/nitrite concentrations were measured in ventral artery tissue homogenates using the nitrate/nitrite colormetric Assay Kit (Caymen).

Results

Analyses of band densities revealed that there was an effect of time ($F(1, 17) = 6.03$, $p < 0.03$) on NOS-1 protein in arteries exposed to vibration, with NOS levels being lower in arteries collected 24 h after the exposure than arteries collected 1 h after the exposure. Although NOS-1 proteins concentrations were slightly lower in control arteries collected 24 h after an exposure than arteries collected 1 h after exposure, post-hoc contrasts indicated they were not significantly different than 1 h controls. In contrast, NOS-1 band densities from arteries collected 24 h after the exposure were lower than those collected 1 h after the exposure ($p < 0.01$; Figure 1). NOS-3

ACUTE VIBRATION INDUCES OXIDATIVE STRESS AND CHANGES IN TRANSCRIPTION IN SOFT TISSUE OF RAT TAILS

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Introduction

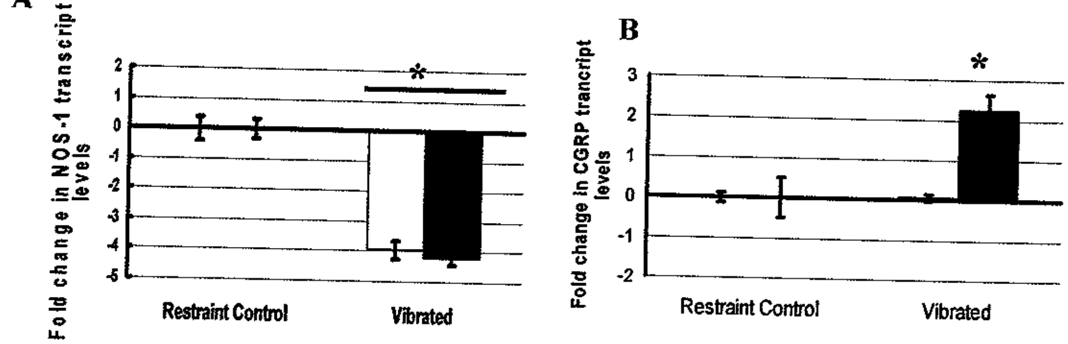
Repeated exposure to hand-arm vibration through the use of vibrating hand tools can result in the development of the disorder known as hand-arm vibration syndrome (HAVS; (1,3)). One of the hallmark symptoms of HAVS is cold-induced peripheral vasospasms that result in finger blanching (4). Although the vascular and neural pathology associated with vasospasms has been described, little is known about cellular mechanisms leading to this damage (4). To understand how vibration may alter vascular and neural physiology and anatomy, rats were exposed to a single bout of tail vibration and the molecular responses of neural and vascular tissues were measured to determine if there are immediate or sustained affects of vibration that may underlie longer term changes in physiology.

Methods

Experiment 1. Male Sprague Dawley rats (n = 32, 6 weeks of age) were housed in AAALAC accredited facilities. All procedures were approved by the NIOSH Animal Care and Use Committee and were in compliance with the CDC guidelines for care and use of laboratory animals. Vibration exposures were performed by restraining rats in Broome-style restrainers, and securing their tails to a vibration platform using 6 mm wide straps that were placed over the tail every 3 cm. Restraint control rats were treated in the same manner, except that the tail platform was mounted on isolation blocks and not on a shaker. The vibration exposure was 125 Hz, 49 m/s^2, for 4 h. Rats were euthanized with an overdose of pentobarbital (100 mg/kg) 1 h or 24 hours after the exposure. RTqPCR was used to measure transcript levels for endothelin 1 (ET-1), the 3 forms of nitric oxide synthetase (NOS) NOS-1, NOS-2, NOS-3 and norepinephrine receptor subtypes 1D, 2A, 2C, in artery tissue, and to measure calcitonin gene-related peptide (CGRP) and nitric oxide synthase-1 (NOS-1) in ventral nerves. Data were analyzed using 2-way ANOVAs.

Experiment 2. Male Sprague Dawley rats (n =24, 6 weeks of age) were maintained as described above. Animals were exposed to a single bout of restraint or vibration. Another group of animals served as cage controls. All animals were euthanized 24 h after the exposure, and tail arteries were isolated and frozen. Reactive oxygen species ROS) were measured using electron spin resonance spectroscopy (ESR). Arteries were homogenized over ice in 1 ml of PBS with protease inhibitor cocktail, using a tissue tearer (Biospecs Products Inc. Racine, WI USA). The sample was split into two 0.5 ml samples. One set had PBS and the spin label hydroxyl-TEMPO [0.1 mM] added while the other set had hydroxyl-TEMPO [1.0 mM] plus the specific hydroxyl radical scavenger, dimethylthiourea (DMTU), added to confirm the presence of the hydroxyl radical. Samples were vortexed and then placed in a flat cell for ESR analysis. The ESR spectrometer settings were: receiver gain, 6.32×10^2; time constant, 0.02 s; modulation amplitude, 1.0 G; scan time, 20 sec; magnetic field, 3490 ± 100 G (2). Data were analyzed using 1-way ANOVAs.

Results



Figures 1A-B. Fold changes in NOS-1(A) and CGRP (B) in the ventral tail arteries rats exposed to a single bout of vibration or restraint. The data are expressed as fold changes in transcript levels (mean ± sem) from the time matched controls. White bars represent transcript levels from tissue collected 1 h after the exposure and black bar represent transcript levels from tissue collected 24 h after the exposure (* different from time matched restraint control, $p < 0.05$). Exposure to vibration resulted in a reduction in NOS-1 transcript levels (main effect of exposure $F(1, 26) = 6.67$, $P < 0.02$) and an increase in CGRP transcript levels in nerve tissue collected 24 h after the exposure ($p < 0.05$).

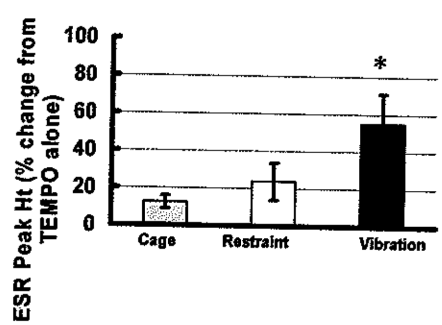


Figure 2. ROS measured using ESR. Acute vibration exposure resulted in an increase in hydroxyl radicals. The data to the left represent the ESR peak height when both TEMPO and DMTU were added to homogenates from the tail artery. The data are presented as the percent increase in peak height between TEMPO + DMTU and TEMPO alone. (mean ± sem; $p < 0.05$, different from cage and restraint controls; $F(1, 20) = 8.68$, $p < 0.002$).

Discussion

- Nitric oxide (NO) is a potent vasodilator produced by nerves and arteries. Vibration-induced reductions in the neural form of NOS, NOS-1, may result in reductions in NO synthesis and contribute to a prolonged noradrenergic-induced vasoconstriction.
- Increases in oxidative stress can result in a reduction in NOS activity. Acute exposure to vibration increase ROS in the arteries. This increase in ROS in arteries (and potentially nerves) may result in a reduction in NOS activity and NO production.
- The increase in CGRP transcript levels, which are not seen until 24 h after the exposure, may act to relieve the vibration induced vasoconstriction.

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VISUALIZATION OF MULTI-DIGIT MANIPULATION MECHANICS

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Introduction

Manipulation of hand-held objects in 3D space is a complex task. Understanding how individual digits interact with a hand-held object provides helpful information for hand tool designers, researchers, clinicians, and occupational therapists. At the object-digit interface, the contact mechanics can be represented by three force and three torque components. Six-component force/torque transducers can register all the three forces and three torques at the digit-object interface, and therefore are advantageous in the study of manipulation mechanics. The large number of force and torque signals from multiple force/torque transducers are difficult to interpret and therefore making experimental research of manipulation a challenging task. The purpose of this study was to develop a 3D visualization tool for the investigation of the contact mechanics at the object-digit interfaces during manipulation tasks.

Methods

A 3D stick-figure hand model was created based on digitized 23 anatomical landmarks of the hand. Five miniature 6-component force/torque transducers (4 × Nano17 for the fingers, 1 × Mini40 for the thumb, ATI Industrial Automation, NC) were used to record force and torque data at the tips of individual digits. Thirty channels of force/torque signals from the transducers were collected by a 16-bit analogue-digital converter (PCI-6031, National Instrument, Austin, TX) installed in a computer. The transducers were mounted on a custom-made rectangular aluminum handle for object manipulation. Coordinate frames were established at each transducer, on the handle, and at the base of the MicroScribe digitizer. To visualize the force vectors at the digit-tips, the coordinates of the hand landmarks in the MicroScribe coordinate frame and the force vectors in local transducer coordinate frames were transformed to a common coordinate frame defined on the handle. One healthy right-handed, male subject participated in the experimental study. During the tests, the participant sat in a chair by a testing table. The forearm was strapped to an arm holder in neutral rotation position. The instrumented handle was fixed on the testing table by a C-clamp through an adapting plate. With the hand of the subject gripped on the instrumental handle, the landmarks of the instrumented handle and the transducers, as well as the anatomical landmarks of the hand were digitized using the MicroScribe digitizer for the purpose of coordinate frame establishment and transformation as described above. The subject performed three different maximum isometric voluntary contraction tasks: (1) grasping, (2) rotating in pronation, and (3) lifting.

Results

The 3D hand model and representative force vector clusters in a single trial of grasping, rotating, and lifting tasks are shown in Figure 1. Each cluster was formed by displaying all the 3D force vectors during the period of "stabilized" maximum effort in a trial. The magnitude and orientation of the force vectors of individual digits were strongly dependent on the task. Compared to the grasping and lifting tasks where forces were more evenly distributed among 4 fingers, forces in the rotating tasks were more concentrated on the two radial fingers, which was an advantageous strategy to produce pronation torque. In the grasping tasks, there was a trend that the force vectors of the four fingers converged. During the rotating tasks, there was a trend that the lower was the finger, the greater the projection angle, and the force vectors of the thumb pointed towards the ulnar aspect (-24.7 degrees). Therefore, the force vectors of individual digits tended to form a force couple to generate pronation torque. During the lifting tasks, the force vectors of all digits pointed upwards to generate maximal resultant uplifting force.

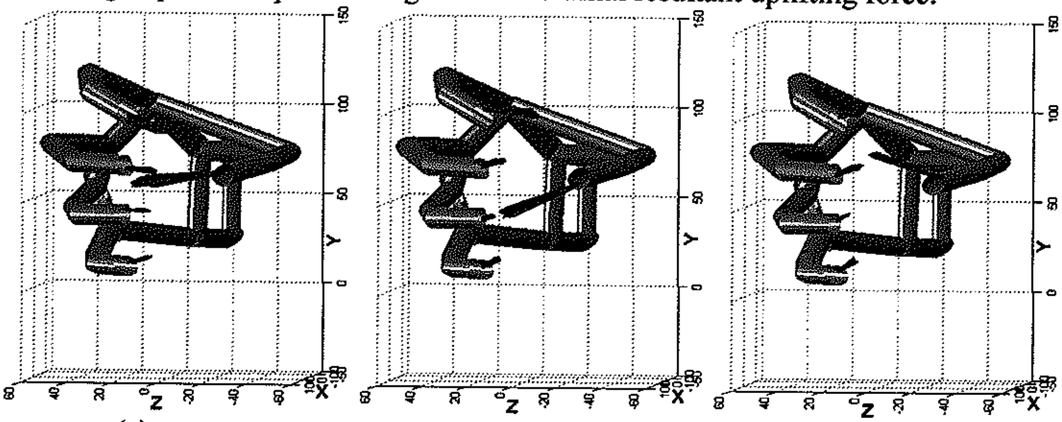

Figure 1. Three-dimensional hand model and representative force vector clusters at the digit-tips in tasks of (a) grasping, (b) rotating in pronation, and (c) lifting. Note that the magnitudes of all the force clusters within a task were equally scaled to achieve a reasonable visualization effects.

Discussion

The employment of 6-component force/torque transducers enabled us to construct 3D force vectors at the digit-object interfaces. Our preliminary results showed that during 5-digit manipulation, the human subject tended to maximize task efficiency by utilizing different force coordination strategies for different tasks. Complex force vector coordination patterns during manipulation tasks could be directly perceived through visualization. The 3D visualization tool developed in the current study could provide expedient and intuitive understanding of the mechanical interaction at the object-digit interfaces and the coordination among multiple digits. It could potentially be an effective tool for the understanding of human hand control and ergonomic designs that involve the usage of multiple digits. Further development of the current visualization tool will focus on incorporating kinematic data synchronized with force/torque measurement so that a relationship of the dynamic hand motion and manipulation mechanics could be established. The integration of force/torque data and kinematic data not only provides a dynamic visualization of grasping mechanics, but also allows for more advanced biomechanical studies such as the calculation of joint torques and muscle/tendon forces.

USE OF TUNGSTEN TO REDUCE VIBRATION EXPOSURE IN AIRCRAFT MANUFACTURING

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Introduction

Riveting operations in aircraft manufacturing involves the use of power tools for manually drilling holes for the rivets, power drills for the setting of the holes for the rivets, as well as rivet guns to drive and set the rivets. To close the rivet, the rivet is driven against a metallic bar commonly called a "bucking bar". The bucking bars are typically held firmly to increase the quality of the riveting, as well as keep the bucking bar from "dancing" against the metal piece being riveted. Thus, employees in aircraft manufacturing involved in riveting are exposed to hand-arm vibration from several sources, and epidemiological evidence suggests that vibration-related musculoskeletal disorders are associated with long term exposure to riveting tasks in the aircraft manufacturing of aircraft.[1,2] Recently, tungsten technology has been introduced into aircraft manufacturing for bucking bars, which are heavier than traditional steel bucking bars of the same size. Rivet guns with tungsten pistons instead of steel pistons have also recently been introduced with the objective of reducing vibration exposure to the riveter. The objective of this study was to assess vibration characteristics of steel and tungsten bucking bars and rivet guns to identify the combination that simultaneously reduced the combined exposure to both the "riveter" and "bucker".

Methods

Vibration (10g tri-axial accelerometer, Biometrics S2-10G-MF Series 2) was measured from eight experienced employees using seven different rivet guns on size 6 rivets, with the same person bucking for all subjects. Vibration was also measured on two different bucking bars for these same eight subjects, with the same person driving the rivets using the various rivet guns. The rivet guns consisted of three E4 steel piston guns with different RPMs (Guns A-E4, B-E4, C-E4), an E4 vibration dampened rivet gun (Gun D-E4D), an E3 steel piston rivet gun (Gun E-E3) and an E3 and E4 tungsten piston rivet guns (Guns F-E3T and G-E4T). The bucking bars were made of 90% tungsten (1694g) and cold-rolled steel (843g), and were the same shape and size. A two-way repeated measures analysis of variance was performed on the vibration (mean frequency weighted resultant acceleration) on both the rivet gun side and the bucking bar side, and mean rankings were used to assess the vibration simultaneously for the rivet gun and bucking bars to investigate which combinations provided the lowest vibration exposure.

Results

Frequency weighted resultant acceleration was significantly lower on the E3 tungsten (F-E3T) rivet gun than the E4 steel piston (B-E4) and the E4 tungsten piston (G-E4T) rivet guns (Figure 1). When measuring vibration on the bucking bar, the E4 (A-E4) steel piston rivet gun resulted in lower vibration on the bucking bars than the E4 tungsten piston (G-E4T) and E4 vibration dampened (D-E4D) rivet guns (Figure 2). Additionally, use of tungsten bucking bars resulted in a 35% decrease in resultant frequency weighted acceleration than when using steel bucking bars.

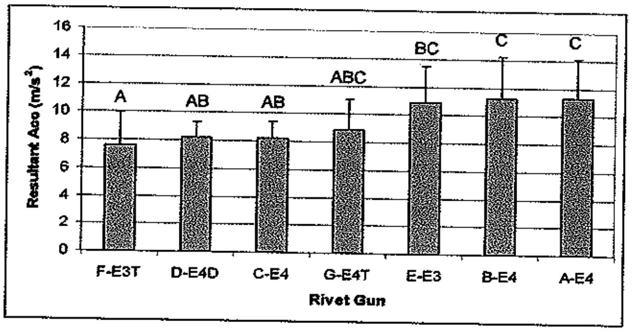

Figure 1. Resultant vibration measured on the rivet gun

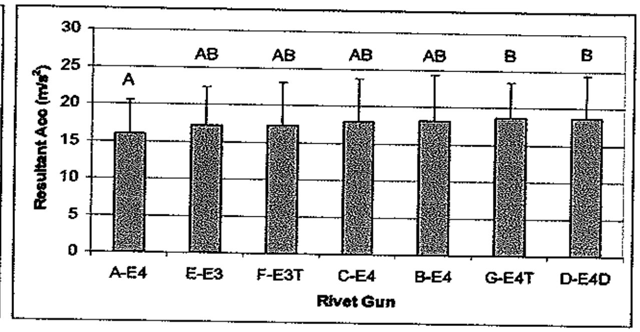

Figure 2. Resultant vibration measured on the bucking bar as a function of rivet gun used.

Discussion

Differences in vibration magnitudes were observed, however, the differences depended on whether the vibration was measured from the rivet gun or on the bucking bar. The vibration measured on the rivet guns indicated that the E3 (F-E3T) and E4 (G-E4T) tungsten piston rivet guns resulted in lower magnitudes, whereas E4 steel piston guns (B-E4 and A-E4) had higher magnitudes. Using tungsten bucking bars substantially decreased the vibration to the "buckers" compared to using steel bucking bars. However, the rivet guns that produced the lowest vibration to the riveter (dampened: D-E4D; tungsten: G-E4T) resulted in the highest vibration experienced on the bucking bar (Figure 3). Using the rankings on vibration levels for the tungsten bucking bar and different rivet guns to assess vibration exposure to the "riveters" and "buckers" simultaneously, using the E3 tungsten piston rivet gun (F-E3T) appears to reduce the vibration levels when considering both the riveting side and bucking bar side simultaneously when driving size 6 rivets. In conclusion, use of tungsten technology has the potential to reduce vibration exposure to riveters and buckers in certain riveting tasks.

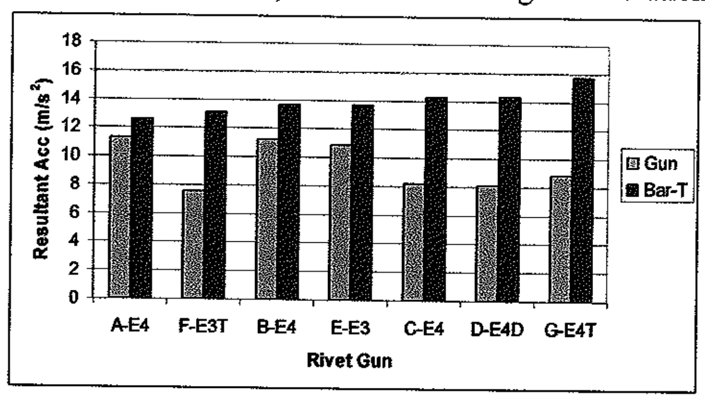

Figure 3. Resultant vibration measured on the rivet gun and the tungsten bucking bar.

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HANDLE DESIGN FOR OPTIMAL HAND FUNCTION

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Tubular Handles can negatively affect the contents of the carpal tunnel. Years of injuries from grasping handles for tools and machines can cause carpal tunnel syndrome, tendonitis and wrist joint injuries. The can cause inability to use a hand and resulted in the longer absences from work than injuries from falls, accidents or fires.[1]

Cylindrical, tubular and rectangular handles are rolled flat structures. They place the hand on a rolled flat surface where the ends of the middle and ring fingers overlap the index and small fingers. They are pulled along a series of lines that contact the end joint of the index finger, the middle bones of the middle and ring fingers and the end bone of the small finger. Cylinders are pulled diagonally in the hand toward the carpal tunnel (CT) area. Gripping in this manner tenses asymmetric muscle groups in the forearm.

Handles could work better if they do not place pressure on the CT and conform to the natural function or neutral hand position where the hand rests or dangles at the side of the body, the finger tips form a diagonal, the palm and fingers form a cup, the thumb rests between the index and middle fingers and the wrist is mildly extended. However, handles designed for the neutral position are pulled by diagonally oriented fingers into the valley between the thenar and hypothenar muscles where they can compress the median nerve and tendons exiting the CT.

Seven principles for handles that do not place pressure on the carpal tunnel and employ optimal hand position are presented. First, handles should align the ends of the fingers parallel to the horizontal crease and not diagonally. Second, handles should extend from the cupped fingers to meet the muscles at the base of the thumb on the radial side of the hand and extend further on the other or ulnar side to meet a portion of the small muscles. Third, handles should have a recess on the proximal side to prevent contacting or placing pressure on the carpal tunnel. Fourth, handle design should be based on hand measurements in a position of function. Fifth, handles should come in sizes. Sixth, handles should be placed on tools to maintain the wrist and elbow in neutral position. The seventh is handles should support the maximum area of the hand and absorb, but not direct, vibration to the carpal tunnel. These principles led to prototypes and patents for handles for gripping, pinching and squeezing[2,3,4].

The poster will illustrate and explain the principles Bonsil handles. Research, with existing tools, is needed to substantiate claims made for the Bonsil handle.

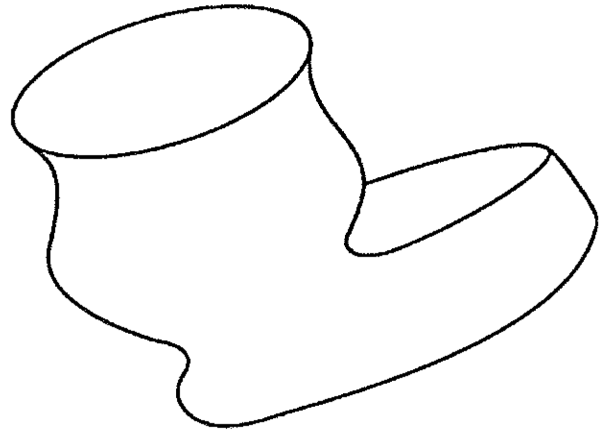

Figure 1

Figure 1 illustrates a large Bonsil handle. The upper section of handles for hammers will have a smaller radius than large power tools. Handles that support the upper body, such as crutches, canes and bicycles will have longer front to back lengths and shorter side to side lengths. The ulnar section extends further for supportive handles than for handles gripped like hammers.

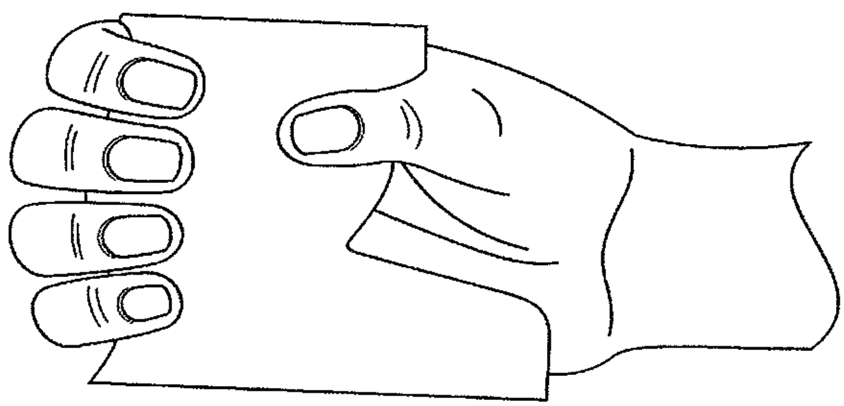

Figure 2

Figure 2 illustrates a hand wrapped around the Bonsil handle. Note, aligning the fingers preserves the cups formed by the fingers and palm. The thumb opposes the space between the index and middle fingers for strongest potential grip. The ulnar extension balances radial and ulnar grip. The CT area is not touched.

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VIBRATION TIME AND REST TIME DURING SINUSOIDAL VIBRATION EXPERIMENTS: DO THESE FACTORS AFFECT COMFORT RATINGS?

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Introduction

Industrial exposure to whole-body vibration is associated with injury and discomfort. Certain industries, notably mining, construction, and forestry, involve complex 6 degrees of freedom vibration. Laboratory-based studies of vibration are essential for controlled and systematic evaluation of the human responses to vibration[2]. The purpose of this pilot study was to evaluate whether the duration of the vibration exposure, and rest between vibrations, significantly influence the subjective ratings of comfort during laboratory-based studies of vibration.

Methods

Subjects: The cumulative vibration dose was calculated, and was below the health guidance caution zone recommended by International standards[3]. The experimental procedures were approved by the University of Guelph Research Ethics Board. Ten adult subjects participated in this pilot experiment. All subjects completed the entire experimental paradigm; no subjects complained of pain during or after the experiment.

Experimental Design: The experiment consisted of four blocks of vibration exposures; either 15 or 20 seconds of vibration (1 df:Z axis, 3 df:XY plane, 3df:YZ plane, or 6 df) alternating with either 5 or 10 seconds rest. The order of presentation of the four blocks was randomized. Each of the blocks was composed of 37 individual sinusoidal vibration exposures in randomized sequence. This abstract focused on ten identical trials, (6.3 Hz vertical vibration, 0.55 m/s^2 RMS) interspersed within each block, in order to assess whether the subjects' comfort ratings systematically varied between the 15 or 20 vibration exposures, the 5 or 10 second rest between vibrations, or within each block. The experiment involved 43 minutes of vibration within the 62 minute experiment.

Vibration Apparatus: A commercial parallel robotic platform was used to apply the specific vibration exposures (R2000, Parallel Robotics Systems Corporation, Hampton, New Hampshire). The subjects sat on a passenger seat from a 1992 Honda Accord that was rigidly mounted to the robotic platform (Figure 1). This robotic system performed the specific vibration exposures operating under closed-loop displacement control. A custom-written Matlab program automated the testing sequence.

Comfort Measures: Subjective feelings of comfort were verbally reported following each vibration exposure (during the rest period). The comfort scale was modelled after a previously published 9 point continuous comfort scale[1] which provided the greatest reliability and discrimination between different vibration intensities among 14 scales, but was modified to enable verbal reports (0 = "zero discomfort" & 8 = "max. discomfort").

Statistical Analysis: The raw comfort scale values for the ten identical vibration trials in each of the four blocks were analyzed using a three-way ANOVA.

Results

Figure 2 illustrates each of the subjects' comfort ratings for the ten repeated trials, collapsed across blocks of vibration duration. Statistical analysis did not observe significant interactions or main effects.

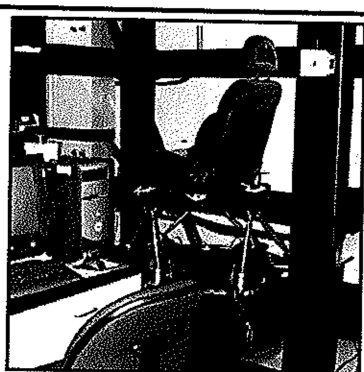

Figure 1. Photograph showing the seat mounted to the robot.

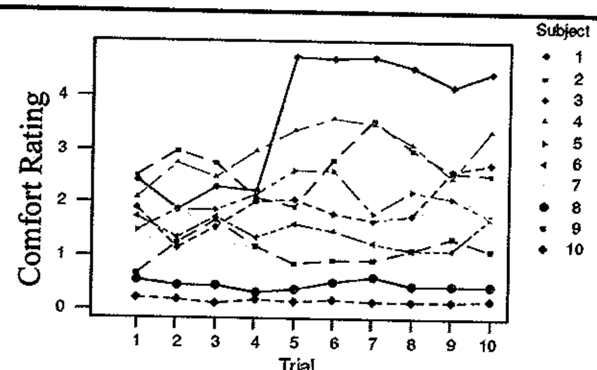

Figure 2. Comfort ratings for each of the subjects for the ten repeated trials.

Discussion

We did not observe statistically significant differences in comfort between the 15 or 20 second vibration exposures, or the 5 vs10 second rest durations. In addition, the comfort ratings did not vary systematically within the blocks of vibration. It appears that the one hour experiment duration did not result in systematic changes in reported comfort. This information is helpful for designing future laboratory-based vibration experiments.

Acknowledgements: Support provided by the Workplace Safety and Insurance Board of Ontario. The authors are grateful to the subjects for their participation.

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Index of Authors

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Industrial Health 2010, 48, 725–742 **Original Article**

Examination of the Frequency-weighting Curve for Accelerations Measured on the Seat and at the Surface Supporting the Feet during Horizontal Whole-body Vibrations in x- and y-Directions

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Abstract: In a laboratory experiment, six male subjects were exposed to sinusoidal (0.8, 1.6, 3.15, 6.3 and 12.5 Hz) or random octave band-width white noise (mid-frequencies identical to those of the sinusoidal vibrations) whole-body vibration in x- or y-directions, at six levels of magnitude (0.4, 0.8 and 1.6 m/s^2 r.m.s. non- and frequency-weighted) with two repetitions. In order to examine time effects, additional reference stimuli were used. Each subject was exposed to these 304 exposure conditions with a duration of about one minute on four different days (76 exposures per day). The subject's sensations of vibration intensity and vibration comfort were obtained by cross modality matching (length of a line). The subjects sat with an upright posture on a hard seat without backrest, hands on the thighs. The derived equivalent sensation contours suggest an underestimation of the sensation varying in extent from 2 dB to 8 dB at 1.6, 3.15, 6.3 and 12.5 Hz in comparison with the reference frequency 0.8 Hz for both types and directions of signals by the current evaluation methods according to ISO 2631-1 with the most pronounced effects revealed at the frequencies 3.15 and 6.3 Hz and at lower intensities (overall vibration total value a_{wv} around 0.48 m/s^2 to 0.8 m/s^2 at the reference frequency 0.8 Hz).

Key words: Whole-body vibrations, Laboratory experiment, Frequency weighting, Subjective judgement

Introduction

The recently published report of the European Agency for Safety and Health at Work discovered a need for joint scientific efforts to clarify the prerequisite for an adequate risk assessment in the case of whole-body vibration (WBV). The implementation of the EC-directive 2002/44/EC[1] intensified the discussion of the correctness of frequency-weighting curves and limit values for WBV. The evaluation methods concerning health risks, comfort and performance due to WBV, described in ISO 2631-1[2] and used in application of the EU directive, are currently under critical discussion[3].

ISO 2631 was first published in 1974 and later republished with new editorials and few corrections. An editorial combination of ISO 2631 (1978) and ISO 2631 AM 1 (1982b) resulted in ISO 2631-1 (1985). The version ISO 2631-1 (1997) replaced the earlier edition from 1985. The current frequency weightings in ISO 2631-1 (1997) were derived from meta-analyses of laboratory studies from the seventies of the last century. Frequency weightings obtained from equivalent discomfort contours are used for estimating the health risk as well, assuming an increase of risk with increasing vibration discomfort and pain, although this hypothesis has not been validated. However, the method is well established in practice. With an absence of information to the contrary, there seems to be no alternative method for health risk assessment.

Numerous experimental studies dealt with the effect of the frequency on discomfort caused by whole-body vibration[4–10]. Inconsistencies in the obtained equivalent comfort contours might partially be explained by the dissimilar experimental methods (method of judging, sitting posture, seat, point of excitation etc.), but some divergences may have arisen from the different magnitudes of vibration that have been investigated.

Even in very early studies, significant major effects of acceleration and frequency and their interactions on discomfort or comfort ratings were obtained (Dempsey[11], Oborne[12]). These studies were limited to sinusoidal vertical vibration. Further investigations additionally included horizontal and roll, pitch and yaw vibrations. Parsons[13] did not discover differences in levels described as "uncomfortable" between vibrations in the fore-and-aft and lateral axes. However, levels in these axes were found to be different from those obtained in the z-axis. In contrast to ISO 2631-1, mean discomfort caused by vertical acceleration showed only a small effect of frequency. Griffin[7] concluded that the shapes of equivalent comfort contours need not normally depend on vibration level,

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possibly influenced by the choice of reference signal for magnitude estimation.

Griefahn and Bröde[6] used an intensity matching method. Applying the weighting of ISO 2631-1 they reported an underestimation of discomfort caused by sinusoidal horizontal WBV in y-direction in comparison with z-axis WBV for frequencies above 1.6 Hz. Maeda and Mansfield[8] reported a divergence of predicted and measured subjective ratings when ISO 2631-1 frequency weighting was used. Morioka[14] obtained significant interactions between vibration magnitude (0.02 to 1.25 m/s^2), frequency (2-315 Hz) and axis (x-, y- and z-axis) and concluded that probably no single linear frequency weighting can provide accurate predictions of discomfort caused by a wide range of magnitudes.

In different studies, various terms were used for judging the sensation caused by vibration. Griffin[15], Wyllie[16], Morioka[14] and Jang[17] asked the subjects to judge the "vibration discomfort". In ISO 2631-1, 1991, the phrase "effect of vibration on the comfort" is used. Jönsson[18] requested the subjects to rate the vibration on a scale from "uncomfortable" to "comfortable". In Europe, the use of these terms is linked with linguistic and semantic difficulties. For example, the word "discomfort" does not exist in German. The authors of the present study decided to ask for judgements of "vibration comfort" and additionally for the "vibration intensity" assuming that this phrase is less uncertain at least for German speaking subjects. Presumably, because of the same reasons, Griefahn[6] determined the "equal comfort contours" by asking the German speaking subjects to alter a vibration signal until they judged it to be equal in "magnitude" to a reference signal.

The theory of cross-modality matching used in the present study is based on investigations carried out by Stevens[19]. The authors found, that the association between the magnitude of the physical stimulus Φ and the sensation Ψ can be described by a power function.

(1) $\Psi = \Phi^m$

The power function can be logarithmised in order to get a linear association between lg Ψ and lg Φ:

(2) $\lg\Psi = m \times \lg\Phi$

The factor m is the so called "Stevens' exponent". Stevens determined these exponents for different types of stimuli. The subjects were asked to assign a number to a stimulus representing its sensation. This judging method is called "magnitude estimation". As a result of these experiments, the exponent can be assumed to be only dependent on the type of stimulus and nearly constant, provided the task is identical for all subjects and conditions when external influences on the judgements are absent or constant.

In contrast, cross-modality matching is based on the subjects' ability to judge their sensation according to the sensation caused by another stimulus. For example, the subjects could be requested to adjust the length of a line (response modality) according to a sensation caused by a simultaneous vibration (stimulus). This equilibrium of stimuli (exposed stimulus and scalable stimulus adjustable by the subject e.g. the brightness of an area, length of a line, force of a hand grip) can be influenced by other conditions (additional stimuli).

This procedure can be mathematically described as follows:

(3) $\Psi_1 = \Phi_1^{m1}$

power function of the stimulus which has to be judged (e.g. vibration)

(4) $\Psi_2 = \Phi_2^{m2}$

power function of the response modality (e.g. length of a line)

Provided that the sensation concerning stimulus and response modality are equalised with respect to the question which has to be answered (e.g. intensity or discomfort or annoyance):

(5) $\Psi_1 = \Psi_2$, therefore follows

(6) $\Phi_1^{m1} = \Phi_2^{m2}$

Logarithmised in order to get linear associations:

(7) $m_1 \times \lg \Phi_1 = m_2 \times \lg \Phi_2$ and finally

(8) $\lg \Phi_2 = m_1 / m_2 \times \lg \Phi_1$

In the present study, the vibration stimuli were judged by adjusting the length of a line presented on a screen simultaneously with the vibrations, in accordance with the sensations. The Stevens' exponent is m_2=1 for a length of a line[19]. Therefore, the determined exponents could be directly compared with those obtained by magnitude estimation in previous studies[9, 14, 20].

Exposure to whole-body vibration shall be assessed on the basis of frequency-weighted accelerations and multiplying factors in accordance with ISO 2631-1. For the evaluation of the effect of vibration on comfort, the weighted root mean square acceleration shall be determined for each axis of translational vibration at the surface which supports the person. For seated persons and horizontal seat surface vibration, the frequency weighting W_d should be applied with the multiplying factor k=1. The point vibration total value a_v shall than be calculated by a root-sum-of-squares summation. Alternatively, where the comfort is affected by vibrations at more than one point an overall vibration total value a_{ov} can be determined from the root-sum-of-squares of the point vibration total values. In this case, vibration at the feet is recommended to be assessed using the frequency weighting W_k and the multiplying factor k=0.25.

The study aimed to examine the effects of sinusoidal and random whole-body vibration in x- and y-axis on the perceived intensity and comfort. The equivalent intensity and comfort contours predicted on the basis of the overall vibration total value a_{ov} at different vibration magnitudes were compared to the current evaluation methods according to ISO 2631-1.

Subjects and Methods

Subjects and posture

In a laboratory experiment, six male subjects were exposed to whole-body vibrations of different magnitudes, frequencies and types of vibration signal. In order to determine the optimal sample size, information about the variance of the dependent variables is necessary. The authors have already performed similar investigations using cross-modality matching for the subjective judgements, but the vibration signals and seats were not comparable with those in the current study. However, the authors understood from their previous experience[21, 26] that six subjects should be sufficient for discovering significant differences in the mean values of intensity or comfort judgements due to different vibration magnitude levels. There were no available data obtained by the authors concerning the effects of different frequencies, directions and types of vibration signals, using the same method in previous studies. Data analyses of the present study discovered that the number of subjects was sufficient for observing the expected differences due to vibration magnitude and frequency, but the current paper does not focus on this topic. A publication on this issue is in preparation.

The subjects were selected from a then available 36-person subgroup of a larger dataset consisting of 100 subjects with fixed subject numbers (the numbers did not change after the selection). Therefore, a subject with number 37 appears in Fig. 1. In order to guarantee the subjects' suitability and to equalize the physical prerequisites, the results of medical and anthropometric examinations including a list of contraindications were used. The ages varied from 24 to 46 yr (mean value 31 yr), the heights from 177.7 cm to 188.5 cm (mean value 183.9 cm), the body masses from 72 kg to 94.3 kg (mean value 84.5 kg) and the body mass indices from 20.7 to 27.8 (mean value 25.0). The individual values are shown in Fig. 1. Previous studies indicated that a similar understanding of semantic nuances is favourable for the comparability of subjective judgements. Therefore, subjects with comparable educational level were chosen. Moreover, comprehensive experience in driving might influence the subjective judgements (Seidel *et al.*[29]). For that reason, professional drivers were excluded. It could be of interest to investigate differences in subgroups of different professions, but a study design of that kind would be very time-consuming and expensive.

The subjects sat with an upright posture on a hard seat without backrest, with hands on the thighs.

The Ethics Committee of the Berlin General Medical Council approved the experiments. Informed consent was obtained from all subjects.

Vibration exposure and measurements

The experiment was conducted with a six-degree-of-freedom (DOF) servo-hydraulic simulator with a control system by FCS Control Systems B.V. (The Netherlands) in the vibration laboratory of the Federal Institute for Occupational Safety and Health, Berlin, Germany, considering the guidelines for human experiments with WBV (ISO 13090-1, 1998). Drive files were generated and optimised to realize the desired accelerations. The translational accelerations were measured on the platform and on the seat in three axes (accelerometer Type Endevco 7290A-10) with a sampling frequency of 1 kHz.

The subjects were exposed to sinusoidal (five frequencies 0.8, 1.6, 3.15, 6.3 and 12.5 Hz) or random octave band-width white noise (mid-frequencies identical with those of sinusoidal vibration) whole-body vibration in x- or y-directions, at six levels of magnitude (0.41, 0.82 and 1.65 m/s^2 desired overall vibration total value non-weighted $a_{des,ov(n.w.)}$ (n.w. - M1, M2 and M3) and frequency weighted $a_{des,ov}$ (w. - M4, M5 and M6)) with two repetitions. Table 1 shows the desired – not the measured - accelerations in the main axes. Magnitudes M4, M5 and M6 with desired overall vibration total values $a_{des,ov}$ weighted according to ISO 2631-1, were chosen to be numerically equal to the modified non-weighted desired overall vibration total values $a_{des,ov(n.w.)}$ M1-M3 (grey lines in Table 1).

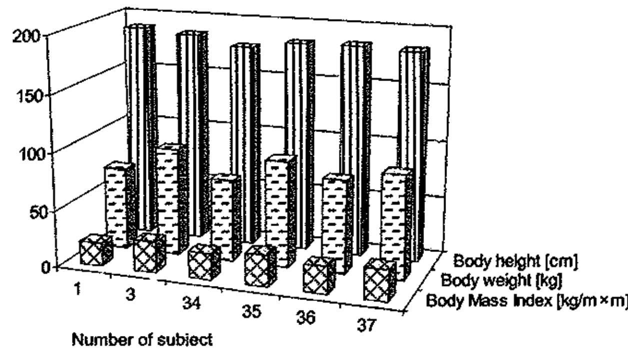

Fig. 1. Body Mass Index, weight and height of the six selected volunteers.

Table 1. Levels of the root mean square (r.m.s.) values of the desired non-weighted acceleration in the axes of excitation on the seat and at the feet $a_{des,ex,seat,feet}$ and calculated desired overall vibration total values $a_{des,ov}$, weighted according to ISO 2631-1 (Eq. (9)) and modified without frequency weighting $a_{des,ov(n.w.)}$ (Eq. (10)), sinusoidal (F) or random octave band-width white noise (B) in m/s^{-2} with magnitudes M).

	Frequency [Hz]	0.8	1.6	3.15	6.3	12.5
Magnitude [m/s^2]		F1/ B1	F2/ B2	F3/ B3	F4/ B4	F5/ B5
M1	$a_{des,ex,seat,feet}$	0.40	0.40	0.40	0.40	0.40
	$a_{des,ov(n.w.)}$	0.41	0.41	0.41	0.41	0.41
	$a_{des,ov}$	0.40	0.39	0.27	0.17	0.11
M2	$a_{des,ex,seat,feet}$	0.80	0.80	0.80	0.80	0.80
	$a_{des,ov(n.w.)}$	0.82	0.82	0.82	0.82	0.82
	$a_{des,ov}$	0.80	0.78	0.54	0.33	0.22
M3	$a_{des,ex,seat,feet}$	1.60	1.60	1.60	1.60	1.60
	$a_{des,ov(n.w.)}$	1.65	1.65	1.65	1.65	1.65
	$a_{des,ov}$	1.60	1.56	1.08	0.67	0.44
M4	$a_{des,ex,seat,feet}$	0.41	0.42	0.61	0.99	1.47
	$a_{des,ov(n.w.)}$	0.42	0.43	0.63	1.02	1.52
	$a_{des,ov}$	0.41	0.41	0.41	0.41	0.41
M5	$a_{des,ex,seat,feet}$	0.82	0.84	1.22	1.97	2.96
	$a_{des,ov(n.w.)}$	0.85	0.87	1.26	2.03	3.05
	$a_{des,ov}$	0.82	0.82	0.82	0.82	0.82
M6	$a_{des,ex,seat,feet}$	1.65	1.69	2.46	3.95	5.96
	$a_{des,ov(n.w.)}$	1.70	1.74	2.54	4.07	6.14
	$a_{des,ov}$	1.65	1.65	1.65	1.65	1.65

The idea behind this study design was to perform the investigation twice, with both non-weighted and weighted values. Assuming that the frequency-weighting curves recommended in ISO 2631-1 correctly reflect the sensations, the shape of the frequency-weighting curves derived from the sensations due to the non-weighted magnitude levels M1 to M3 should coincidence with the current weighting curves. The equivalent sensation contours and frequency-weighting curves derived from

Table 2. Experimental design

Day of experiment	Direction of exposure	Repetition	Reference stimuli
1	Y	1	M2F3X and Z
2	Y	2	M2B3X and Z
3	X	1	M2B3Y and Z
4	X	2	M2F3Y and Z

X, Y and Z=axes of excitation, M=magnitude, F=sinusoidal vibration, B=random octave band-width white noise.

Table 3. Exposure conditions used for subject 1 at experimental day number one

Trial 1	Trial 2	Trial 3	Trial 4
M2F3X	**M2F3X**	**M2F3X**	**M2F3X**
M2F3Z	**M2F3Z**	**M2F3Z**	**M2F3Z**
M6F1Y	M4F2Y	M4B5Y	M5B3Y
M6B1Y	M2F1Y	M2F3Y	M6B4Y
M5B1Y	M4B2Y	M4F5Y	M6F3Y
M1F2Y	M1B1Y	M2B3Y	M6F4Y
M5F1Y	M5F2Y	M3B5Y	M6B3Y
M1B2Y	M1F1Y	M3F3Y	M5B4Y
M4B1Y	M5B2Y	M3F5Y	M1F4Y
M2F2Y	M6B5Y	M3B3Y	M5F4Y
M4F1Y	M6F2Y	M2B5Y	M1B4Y
M2B2Y	M6F5Y	M4F3Y	M4B4Y
M3B1Y	M6B2Y	M2F5Y	M2F4Y
M3F2Y	M5B5Y	M4B3Y	M4F4Y
M3F1Y	M1F3Y	M1B5Y	M2B4Y
M3B2Y	M5F5Y	M5F3Y	M3B4Y
M2B1Y	M1B3Y	M1F5Y	M3F4Y
M2F3X	**M2F3X**	**M2F3X**	**M2F3X**
M2F3Z	**M2F3Z**	**M2F3Z**	**M2F3Z**

bold letters – reference stimuli.

the weighted magnitude levels M4 to M6 should be horizontal lines.

In Table 1, the desired overall vibration total values were calculated in accordance with equation (9) and equation (10), assuming the accelerations in the cross axes were zero.

To examine the time effects, 16 additional reference stimuli were used per day. Every subject was exposed to these 304 exposure conditions on four different days, 76 single exposures per day, randomized and divided into 4 trials of 19 single exposures (Table 2 and Table 3). Each single exposure had a duration of about one minute (Fig. 2). There were short pauses between the single exposures. Therefore, one trial lasted approximately 25–30 min. The subjects were asked to walk or stand during the 10 min pause between the trials. Altogether, it took roughly two hours to two and a half hours to realize the 76 single exposures per day. Day 2 and day 4 were complete repetitions of day 1 and day 3, respectively, but the exposure conditions were presented in a different order. No sequence of exposure conditions was used twice. The experimental design was described in more detail in Kreisel *et al*[28].

(9)

$$a_{des,ov(n.w.)} = \sqrt{a^2_{des,ex,seat} + 0.25^2 \times a^2_{des,ex,feet}}$$ modified

with

$a_{des,ex,seat}$ = desired non-weighted acceleration (r.m.s.) on the seat in the axis of excitation and

$a_{des,ex,feet}$ = desired non-weighted acceleration (r.m.s.) at the feet (platform) in the axis of excitation

(10)

$$a_{des,ov} = \sqrt{a^2_{des,Wd,ex,seat} + 0.25^2 \times a^2_{des,Wk,ex,feet}}$$

according to ISO 2631-1

with

$a_{des,Wd,ex,seat}$ = desired weighted acceleration (r.m.s.) on the seat in the axis of excitation and

$a_{des,Wk,ex,feet}$ = desired weighted acceleration (r.m.s.) at the feet (platform) in the axis of excitation

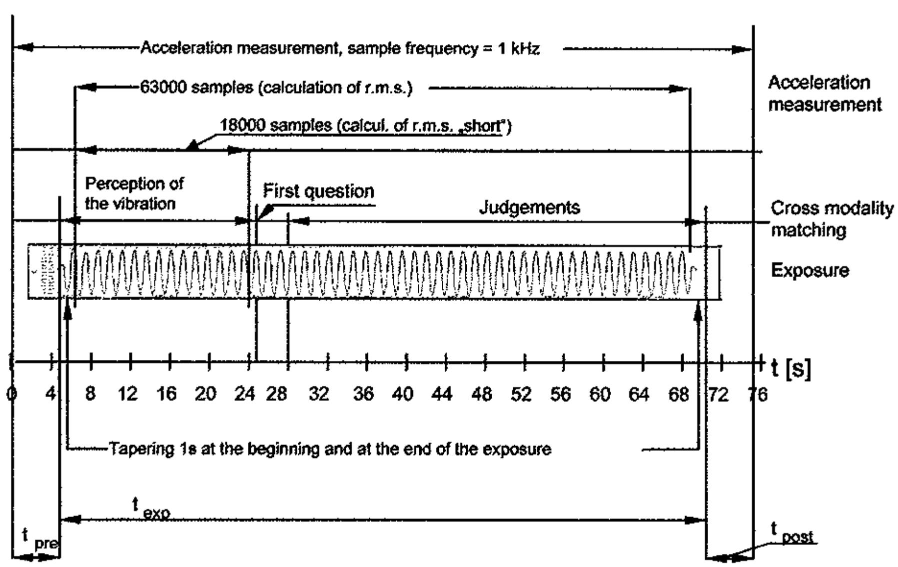

Fig. 2. Measurement of acceleration and subjective judgements during one single exposure.

and assumption: accelerations in the cross axes equal zero in both equations

The combination of the frequency-weighting curves W_d and W_k and the multiplying factors k=1 (seat) and k=0.25 (feet) is defined as $W_d \wedge W_k$ in this paper for convenience, using the Boolean operator for conjunction (^). It is valid for the calculation of the desired overall vibration total value in this experiment. Supposing identical exposure on the seat and the platform due to the mechanical stiffness between seat and platform and assuming that the accelerations in the cross axes were zero, equation (11) was derived from equation (10).

(11)

$$a_{ov} = a_{ex} \times \sqrt{1.0^2 \times W_d^2 + 0.25^2 \times W_k^2} = a_{ex} \times (W_d \wedge W_k)$$

with

W_d and W_k = weighting factors according to ISO 2631-1, Table 3 and

a_{ex} = non-weighted acceleration (r.m.s.) on the seat and at the feet (platform) in the axis of excitation

The sensations of vibration intensity and vibration comfort were obtained by cross-modality matching (length of a line). The subjects responded by adjusting the length of a line presented on a screen in front of them. They were instructed to adjust the length of the line in accordance with their sensations, i.e., the stronger the sensation the longer the line had to be. The subjects used a mouse which was fixed on the vibration simulator to be easily gripped with their right hand (Fig. 3). The cross-modality matching included answers on the following questions:

How intensive do you perceive the vibration to be?

How comfortable do you perceive the vibration to be?

Day 1 started with a training session with at least 10 different representative exposures to allow the subjects to reach a similar level of experience. No subject expressed having been restricted due to the maximum length of the presented line (1,481 mm) on a screen at a distance of 2,600 mm from the subject's eyes, neither during the training session nor during the main study. At the beginning of each experimental day, the subjects had to read a written instruction (Appendix B). The insructions were repeated by the operator at certain time points during the trials.

Data analyses

Data were examined with the statistical program SPSS 15.0.1. The order of successive steps in the data analyses is illustrated in Fig. 4.

The overall vibration total values calculated from the measured accelerations $a_{ov(n.w.)}$ and a_{ov} (Eq. (12) and Eq. (13)) differed from the desired overall vibration total values $a_{des,ov(n.w.)}$ and $a_{des,ov}$ according to Table 1 in about 10% of the cases by 1 dB or more. Therefore, these excitations and the corresponding responses (length of lines) were treated as missing values when differences of mean values between the responses caused by different exposure levels or time points had to be examined (*t*-Tests and Variance Analyses). The excitations in the higher frequencies were most frequently concerned. The cross-axis vibration reached a maximum of 31.7% (y-axis during excitation in x-axis) and 26.6% (x-axis during excitation in y-axis) for sinusoidal excitation at 12.5 Hz, calculated on the basis of the mean values of the r.m.s. of the measured accelerations in main and cross axes. Information about the background vibration is given in Appendix A.

(12)

$$a_{ov(n.w.)} = (a_{x,seat}^2 + a_{y,seat}^2 + a_{z,seat}^2 + 0.25^2 \times a_{x,feet}^2 + 0.25^2 \times a_{y,feet}^2 + 0.4^2 \times a_{z,feet}^2)^{1/2}$$

modified

with

$a_{x,seat}$, $a_{y,seat}$, $a_{z,seat}$ = measured non-weighted acceleration (r.m.s.) on the seat in the x-, y- and z-axis and

$a_{x,feet}$, $a_{y,feet}$, $a_{z,feet}$ = measured non-weighted acceleration (r.m.s.) at the feet (platform) in the x-, y- and z-axis

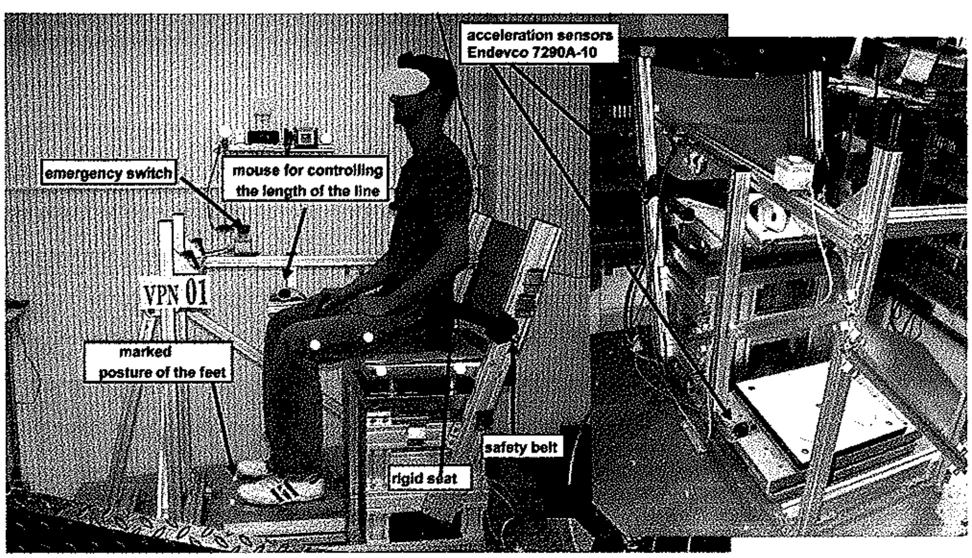

Fig. 3. Subject sitting on the rigid seat and location of the acceleration sensors.

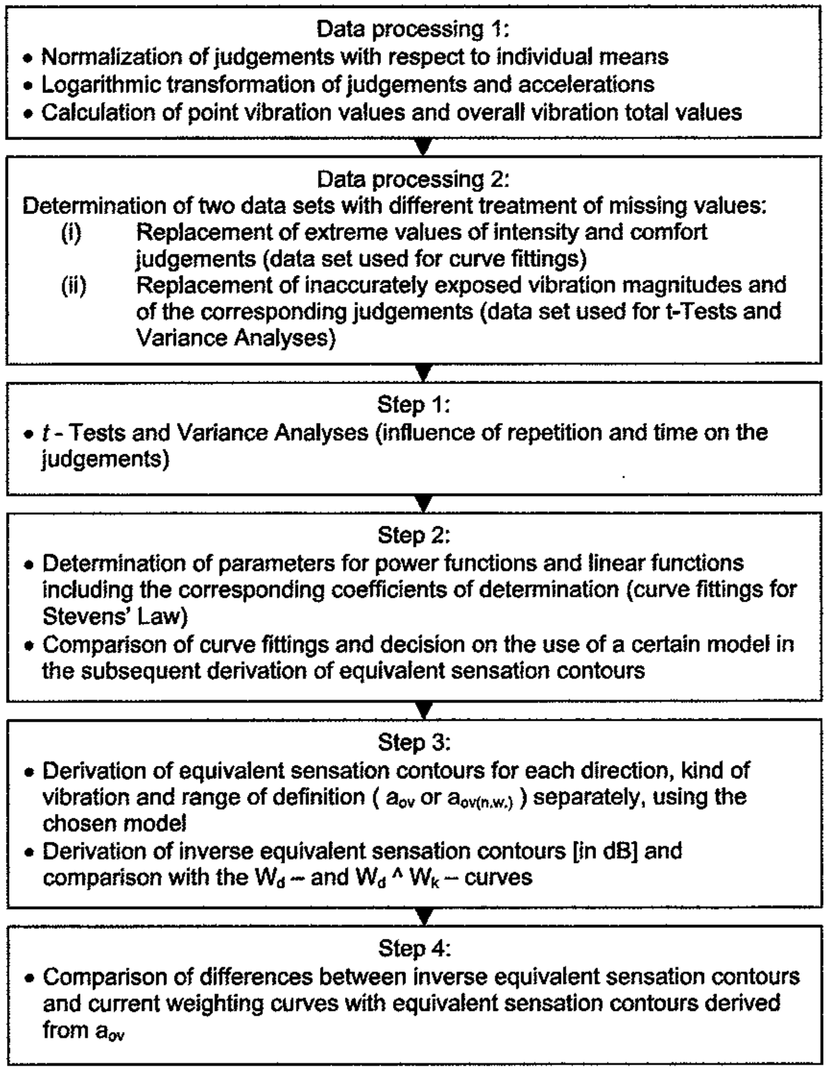

Fig. 4. Order of successive steps in data processing and analyses.

(13)

$$a_{ov} = (a^2_{Wd,x,seat} + a^2_{Wd,y,seat} + a^2_{Wk,z,seat} + 0.25^2 \times a^2_{Wk,x,feet} + 0.25^2 \times a^2_{Wk,y,feet} + 0.4^2 \times a^2_{Wk,z,feet})^{1/2}$$

according to ISO 2631-1

with

$a_{Wd,x,seat}$, $a_{Wd,y,seat}$, $a_{Wk,z,seat}$ = measured weighted acceleration (r.m.s.) on the seat in the x-, y- and z-axis and

$a_{Wk,x,feet}$, $a_{Wk,y,feet}$, $a_{Wk,z,feet}$ = measured weighted acceleration (r.m.s.) at the feet (platform) seat in the x-, y- and z-axis

For curve fittings, only the extreme values of the length of the lines were considered as missing values (intensity: 1 value, comfort: 16 values out of 1,440 single exposures in the main directions x and y without reference stimuli). In contrast to the variance analyses and t-tests, the differing excitations and the corresponding responses were not excluded from the linear regressions analyses.

Values normalized with respect to individual means per experimental day or individual means over all days were derived from the length of the lines measured as pixels. In addition, a logarithmic transformation of data was performed. Because of the simultaneous exposure to vibration on the seat and at the feet in the experiment and the instruction to judge integratively the entire vibration exposure, the judgements were assumed to be reflected more accurately by the overall vibration total value a_{ov} than by the point vibration total value a_v or the vibration in the axis of excitation only. Consequently, the relations between the a_{ov} and the subjective judgements were determined by curve fitting to power functions and linear associations for each frequency, direction and type of vibration signal separately in order to test the agreement with the Stevens' law.

It is a point of discussion, whether the modified overall vibration total value used in this study is valid (Eq. (9) and Eq. (12)). The multiplying factors k for multiple input locations were applied without frequency weighting of the input signals. As mentioned in the discussion later, there seems to be a lack of literature concerning an exact explanation of methods which were used to derive the frequency-weighting curves and the multiplying factors k recommended in ISO 2631-1. An appropriate experiment should strictly differentiate between input location effects and frequency effects and a combination of both influences. Moreover, for estimation of the effect of vibration on the comfort according to the standard, the point vibration total value 'shall be calculated' and the overall vibration total value 'can be determined' (ISO 2631-1, paragraph 8.2.3). Griffin[15] mentioned that there is 'a conceptual problem in the choice of the frequency, axis and input position weightings when evaluating the vibration which occurs at several input positions' (Griffin[15], page 82). The effects of relative motions between body parts due to excitations in different directions and at different input points are complex and hardly predictable. At present, there is no standardised evaluation method which considers this fact. Further considerations seem to be necessary. In fundamental investigations, the body parts are often separately exposed in one direction. The curves of equivalent sensation are subsequently derived on the basis of the point vibration total value on the seat $a_{v,seat,(n.w.)}$ or even the non-weighted acceleration in the main axis only, neglecting the cross-axis vibration. Considering the multiplying factors is not necessary in these studies. In the current investigation, seat and feet were exposed simultaneously and identically. It would have been inaccurate if the effect of the exposure at the feet was not taken into account. The authors decided to suppose an influence of the vibration at the feet to be smaller than that on the seat regardless of whether the input signals were frequency-weighted or not. In the absence of further scientific findings the recommended multiplying factors k=0.25 (x- and y-axis) and k=0.4 (z-axis) were applied (Eq. (12) and (13)). However, for mathematical reasons, applying the non-weighted forms of (i) the overall vibration total value $a_{ov,(n.w.)}$ (Eq. (12)), or (ii) the point vibration total value on the seat $a_{v,seat,(n.w.)}$ or (iii) the root-sum-square of $a_{v,seat,(n.w.)}$ and $a_{v,feet,(n.w.)}$ without using the multiplying factors to the linear regressions (see Eq. (14) and Eq. (16)) do lead to identical results. The difference between the levels of magnitudes always amounts to 6 dB and the logarithmically transformed magnitude levels have equal differences. Hence, linear regression delivers the same slope for all three values mentioned above. The shapes of the derived equivalent sensation contours and the frequency-weighting curves depend only on the slope m of the calculated regression lines, not on the constant n (Table 5). One could hypothesize that the evaluation methods recommended in ISO 2631-1 do not correctly reflect the sensations. Therefore, it was supposed that the shape of the frequency-weighting curves derived from M1 to M3 differed from the W_d-curve. The equivalent intensity contours associated with the weighted accelerations M4 to M6 should deviate from a horizontal and straight line. If the assumption were true, the shape of the derived curves would reflect the deviation from the current evaluation methods.

Results

Step 1: Influence of repetition and time on the judgements

Differences between the judgements from the first and the second repetition were examined with the t-Test for paired samples (normal distribution, Kolmogorov-Smirnov-Test p=0.000 for all variables). No significant difference was found for the judgements of vibration intensity (p=0.122), but the judgements of comfort were significantly lower at the second repetition (p=0.001). Time effects on the reference signals were checked with Variance Analyses for repeated measures. There was no significant influence of time on the judgements ($p \geq 0.165$).

Table 4. Code of prediction method, basic functions, dependent and independent variables

Code of prediction	Function	Independent Variable	Dependent variable
A	power	a_{ov}	$LL_{original}$
B	power	a_{ov}	$LL_{norm,\ day}$
C	power	a_{ov}	$LL_{norm,\ all}$
D	linear	$\lg(a_{ov})+c_1$	$\lg(LL_{original})$
E	linear	$\lg(a_{ov})+c_1$	$\lg(LL_{norm,\ day}+c_2)+c_3$
F	linear	$\lg(a_{ov})+c_1$	$\lg(LL_{norm,\ all}+c_2)+c_3$

$LL_{original}$ – originally measured length of line in pixel, $LL_{norm,\ day}$ – length of line normalized with respect to individual means per experimental day, $LL_{norm,\ all}$ – length of line normalized with respect to individual means over all experimental days (normalized values in arbitrary units), a_{ov} – overall vibration total value, c_1, c_2, c_3 – constants for shifting values into positive ranges.

Step 2: Growth of sensation

According to Stevens' Law, the relation between physical stimulus and response can be described by a power function. Consequently, the relation between the logarithmically transformed stimuli and responses should be a linear function. Six prediction methods (see Table 4) were evaluated by comparing the coefficients of determination using (i) the original length of line and (ii) the normalized data with respect to individual means. The variables and functions are listed in Table 4. The parameters of the functions and the coefficients of determination were determined for each frequency, direction and type of vibration signal separately. In order to decide which model should be used for subsequent determination of equivalent sensation contours, the coefficients of determination of all frequencies, directions and types of vibration were organised according to the kind of function and range of definition. Figure 5 provides the mean values and confidence intervals of the coefficients of determination for the judgements of vibration intensity summarizing all frequencies, directions and types of vibration and divided as explained above.

The prediction models type E with the definition ranges M1–M6 n.w. and M1–M6 w. were used in the subsequent determinations of equivalent sensation contours as these models displayed the highest coefficients of determination (circled values in Fig. 5).

The values were shifted into positive ranges for the logarithmic transformation and the subsequent linear regression. Therefore, the minimum of $LL_{norm,day}$ of the entire data set was identified and used as c_2 (Table 4). Afterwards, the logarithmic transformation was performed. In the next step, the minima of $\lg(a_{ov(n.w.)})$ and $\lg(LL_{norm,day} + c_2)$ were detected and used as c_1 and c_3 (Table 4).

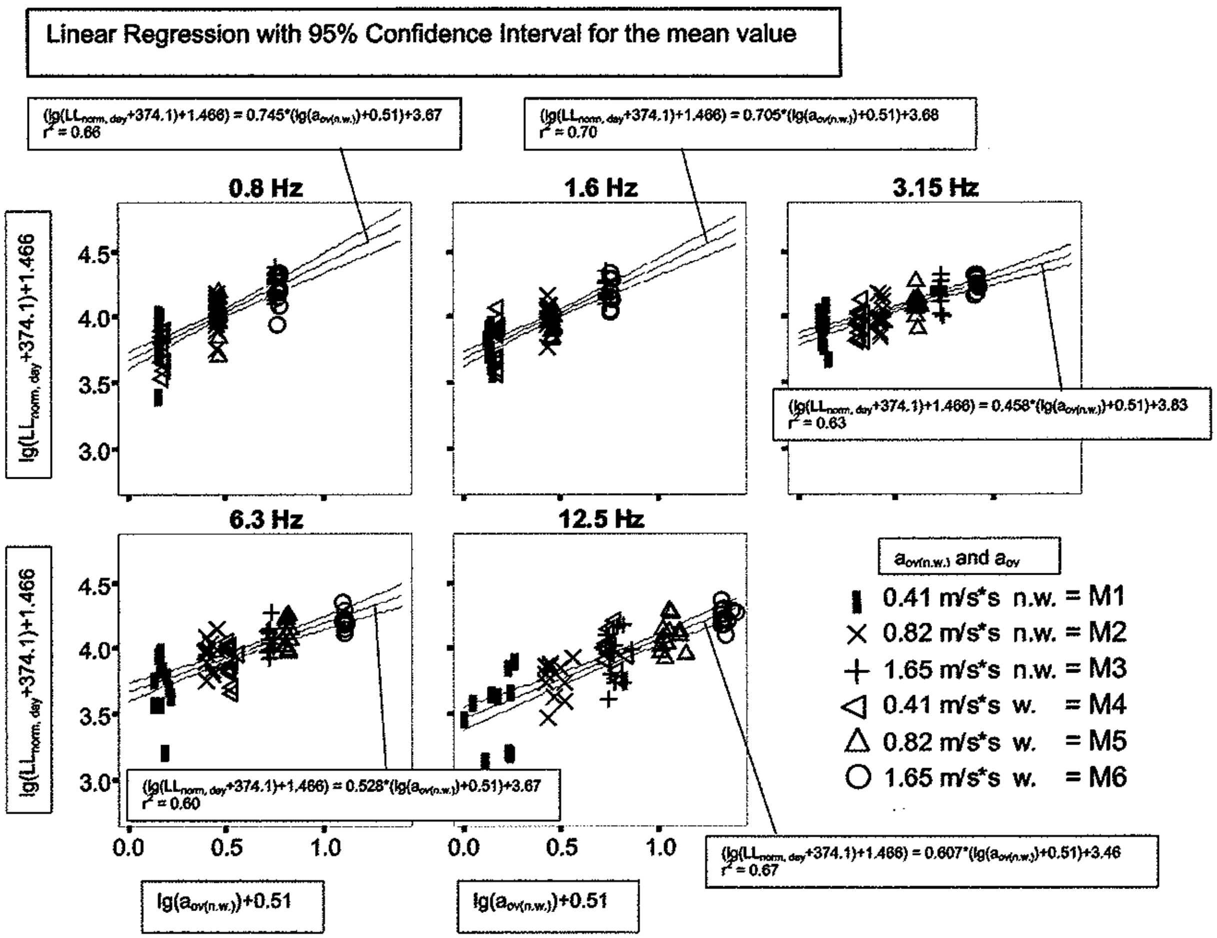

Fig. 6. Linear regression lines, slopes, constants and coefficients of determination for the prediction of judgements of vibration intensity for sinusoidal vibration, excitation in the x-axis, depending on the vibration frequency, range of definition M1–M6 n.w.

Table 5. Slope m, constant n and coefficient of determination r^2 of the linear regression

Type/Direction	Frequency [Hz]	Slope m	Constant n	Coefficient of determination r^2
Sinus X	0.8	0.745	3.67	0.66
	1.6	0.705	3.68	0.70
	3.15	0.458	3.83	0.63
	6.3	0.528	3.67	0.60
	12.5	0.607	3.46	0.67
Sinus Y	0.8	1.036	3.52	0.71
	1.6	0.901	3.61	0.75
	3.15	0.816	3.54	0.67
	6.3	0.565	3.62	0.67
	12.5	0.608	3.46	0.69
Band X	0.8	0.834	3.64	0.72
	1.6	0.784	3.71	0.76
	3.15	0.646	3.74	0.76
	6.3	0.504	3.65	0.56
	12.5	0.685	3.37	0.59
BandY	0.8	1.025	3.56	0.66
	1.6	0.819	3.71	0.79
	3.15	0.749	3.62	0.77
	6.3	0.648	3.55	0.60
	12.5	0.611	3.42	0.60

Equation (14) for the prediction of the judgement of vibration intensity.

Table 6. Slope m, constant n and coefficient of determination r^2 of the linear regression

Type/Direction	Frequency [Hz]	Slope	Constant	Coefficient of determination
Sinus X	0.8	−0.371	4.95	0.48
	1.6	−0.474	4.94	0.58
	3.15	−0.361	4.88	0.42
	6.3	−0.269	4.88	0.27
	12.5	−0.195	4.91	0.25
Sinus Y	0.8	−0.731	5.06	0.44
	1.6	−0.551	4.94	0.49
	3.15	−0.408	4.95	0.44
	6.3	−0.210	4.89	0.22
	12.5	−0.093	4.80	0.08
Band X	0.8	−0.497	4.91	0.53
	1.6	−0.493	4.84	0.52
	3.15	−0.424	4.82	0.38
	6.3	−0.253	4.82	0.35
	12.5	−0.182	4.85	0.27
Band Y	0.8	−0.763	4.96	0.50
	1.6	−0.633	4.82	0.33
	3.15	−0.490	4.85	0.36
	6.3	−0.319	4.88	0.27
	12.5	−0.142	4.83	0.23

Equation (16) for the prediction of the judgement of vibration comfort.

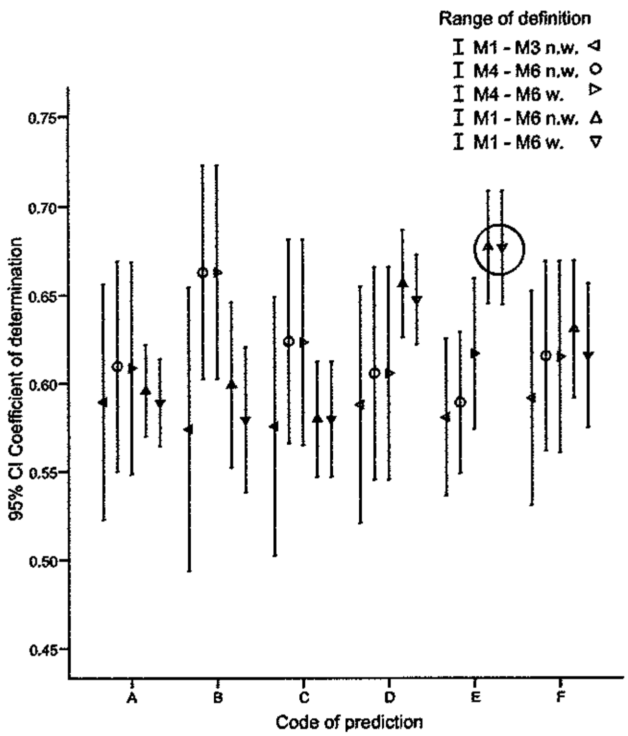

Fig. 5. Mean values and 95% confidence intervals (CI) of the coefficients of determination for the prediction of the judgements of vibration intensity summarizing all frequencies, directions and kinds of vibration, depending on the prediction method and on the range of definition.

The circle indicates the highest mean values of these coefficients of determination.

For the judgements of vibration intensity:

(14) Type E (M1–M6 n.w.):

$$(\lg(LL_{norm,day} + 374.1) + 1.466) = m \times (\lg(a_{ov(n.w.)}) + 0.51) + n$$

(15) Type E (M1–M6 w.):

$$(\lg(LL_{norm,day} + 374.1) + 1.466) = m \times (\lg(a_{ov}) + 1.01) + n$$

For the judgements of vibration comfort:

(16) Type E (M1–M6 n.w.):

$$(\lg(LL_{norm,day} + 428.1) + 2.1) = m \times (\lg(a_{ov(n.w.)}) + 0.51) + n$$

(17) Type E (M1–M6 w.):

$$(\lg(LL_{norm,day} + 428.1) + 2.1) = m \times (\lg(a_{ov}) + 1.01) + n$$

with

$LL_{norm,\ day}$ = length of line normalized with respect to individual means per experimental day

$a_{ov(n.w.)}$ = overall vibration total value, modified, non-weighted

a_{ov} = overall vibration total value, according ISO 2631-1, weighted

m = slope of the regression line

n = constant of the regression line

Figure 6 illustrates as an example the linear regression lines, equations with slopes, constants and coefficients of determination for the prediction of judgements of vibration intensity for sinusoidal vibration excitation in the x-axis (range of definition M1–M6 n.w.), depending on the vibration frequency. The parameters of the regression equations (14) and (16) for both types of signals and directions of excitation are listed in Table 5 (intensity, equation (14)) and Table 6 (comfort, equation (16)).

The coefficients of determination were much lower for the prediction of vibration comfort ($0.08 \le r^2 \le 0.58$) in particular for frequencies higher than 1.6 Hz ($0.08 \le r^2 \le 0.44$) (see Table 6).

Step 3: Equivalent vibration intensity and vibration comfort judgement contours

A model can be assumed to be sufficient when the coefficient of determination reaches a value of $r^2 = 0.5$ or more. Unfortunately, the prediction models for the comfort judgements had much lower coefficients (see Table 6). Therefore, equivalent sensation contours were derived only from the judgements of vibration intensity, not from the judgements of vibration comfort.

Equivalent intensity contours were determined by calculating the vibration acceleration corresponding to the intensity judgement at each frequency according to Equation (14) and Table 5, changing the range of value and the range of definition. Limits of the range of definition were taken into account when calculating the accelerations from the lengths of the lines. Therefore, the range of judgements (range of values) slightly varies between the figures for the different vibration directions and types (Figs. 7 and 8). The lowest and highest values were chosen so that the range of definition was completely filled but not exceeded at each frequency. The equivalent contours were then calculated in 12 steps of equidistant arbitrary units from the lowest to the highest equivalent contour. The equivalent intensity contours illustrate the vibration magnitudes required to produce the same strenght of sensation across the frequency range. They provide information on what frequencies produced greater sensation of intensity. A lower acceleration at a particular frequency indicates greater sensation of vibration intensity at that frequency. The overall shapes and the frequencies of highest sensitivity obviously depended on the magnitude, the direction and the type of vibration.

Figures 9 and 10 show ratios of predicted accelerations for frequencies above 0.8 Hz in relation to those at 0.8 Hz set to 1, and the inverted ratios in order to illustrate the effect of vibration magnitude on frequency weightings (Figs. 9 and 10). All values were multiplied with 1,000 in order to derive values comparable to those in ISO 2631-1 Table 3. The reference frequency $f_{ref} = 0.8$ Hz was selected as it was the frequency closest to that of highest sensitivity of the weighting curves W_d and $W_d \wedge W_k$ ($f_{sens} = 1.0$ Hz, see ISO 2631-1 Table 3 and Eq. (11)) and exposed in this study. Table 7 contains the values for sinusoidal excitation simultaneously exposed on the seat and the platform in the x-direction in 12 steps of equidistant arbitrary units (see Fig. 7(a) and Fig. 9 (a)). Additionally, the table encloses the magnitude independent factors for the W_d- and W_k-frequency weightings of ISO 2631-1 Table 3 and $W_d \wedge W_k$ (see Eq. (11)).

The following paragraph explains an example for the

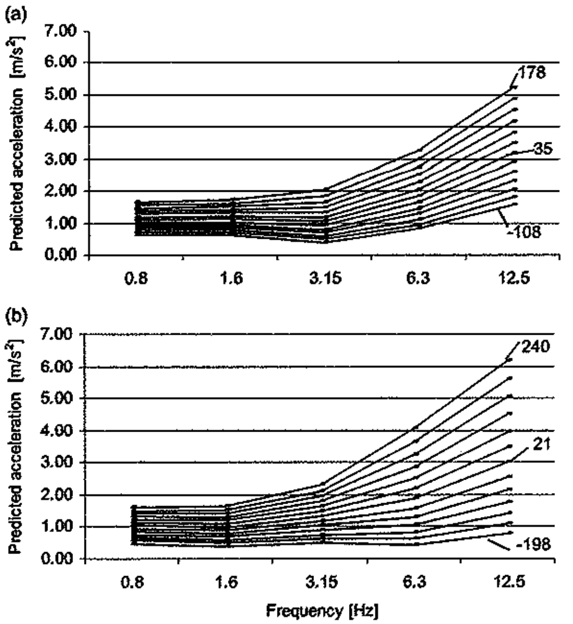

Fig. 7. Equivalent intensity contours for arbitrary sensation units from minimum to maximum of the range of value in order to meet the range of definition (range of actually exposed vibration magnitudes) in steps of 12 equidistant units determined from Eq. (14) and Table 5: (a) sinusoidal excitation in x-axis, (b) sinusoidal excitation in y-axis.

Predicted acceleration in [m/s^2] = overall vibration total value modified without frequency weighting $a_{ov(n.w.)}$ r.m.s.. Numbers attached to the lines: normalized intensity judgements $LL_{norm,\,day}$ (see Eq. (14)).

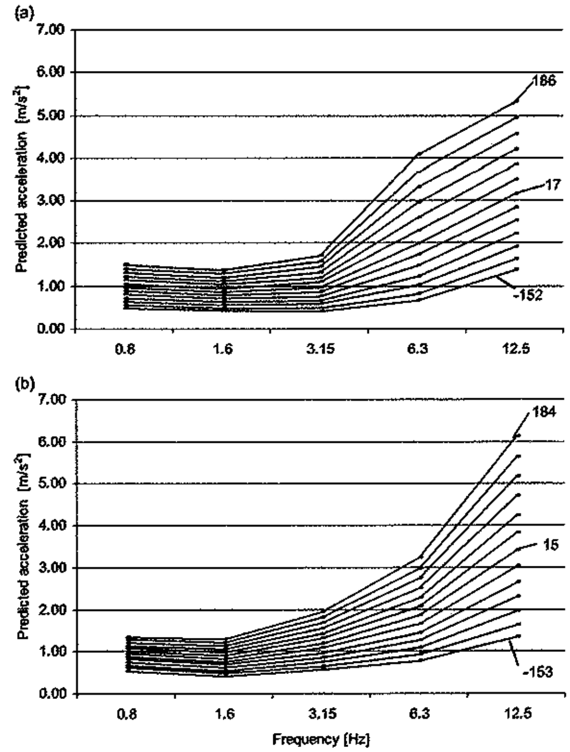

Fig. 8. Equivalent intensity contours for arbitrary sensation units from minimum to maximum of the range of value in order to meet the range of definition (range of actually exposed vibration magnitudes) in steps of 12 equidistant units determined from Eq. (14) and Table 5: (a) random octave band-width white noise excitation in x-axis, (b) random octave band-width white noise excitation in y-axis.

Predicted acceleration in [m/s^2] = overall vibration total value modified without frequency weighting $a_{ov(n.w.)}$ r.m.s..

Numbers attached to the lines: normalized intensity judgements $LL_{norm,\,day}$ (see Eq. (14)).

magnitude-dependence of the filter factors (2nd and 6th rows, marked in grey in Table 7). A sinusoidal vibration stimulus at 3.15 Hz with a magnitude of $a_{ov(n.w.)}$ = 0.49 m/s^2 (0.69 m/s^2 × 0.716) produces a sensation equal to that of a sinusoidal vibration stimulus at 0.8 Hz with a magnitude of 0.69 m/s^2. In order to convert a measured sinusoidal vibration at 3.15 Hz with a magnitude of $a_{ov(n.w.)}$ = 0.49 m/s^2 into a sinusoidal vibration stimulus at 0.8 Hz with equal intensity sensation, the acceleration has to be multiplied with 1.396 (filter factor), i.e. it has to be increased by 2.90 dB (20 × lg(1.396)). When the vibration signal has a magnitude of 0.93 m/s^2 (1.02 m/s^2 × 0.910) it has to be multiplied with 1.099 (filter factor), that means it has to be increased by 0.82 dB (20 × lg(1.099)) only.

Step 4: Equivalent intensity contours derived from weighted overall vibration total values

The equivalent intensity contours associated with the weighted accelerations a_{ov} were determined by the same method as described in step 3 but using Eq. (15). The slopes and constants are not given in detail. Assuming that the evaluation methods recommended in ISO 2631-1 correctly reflect the sensation, the equivalent intensity contours associated with the weighted accelerations a_{ov} should be horizontal and straight lines. But, they differed from straight lines. As expected from the results derived from the non-weighted accelerations, these contours reflected the differences between the contours obtained from the non-weighted accelerations $a_{ov(n.w.)}$ and the combination of the current weighting curves and multiplying factors $W_d \wedge W_k$ (Eq. (11)).

Discussion

Influence of repetition and time on the judgements

One experimental set lasted roughly two hours to two and a half hours. There were some doubts, whether the subjects were able to differentiate between the vibration comfort and the comfort of the entire situation including permanent demands on concentration and sitting a long period of time on the rigid seat without exercise. Schust[21] revealed that the subjects were not able to differentiate between the vibration comfort and the comfort of the entire situation when they had to judge the seat comfort. In Schust[21], the seat comfort decreased significantly with time. So, it could be the case that the vibration comfort judgements were influenced by time. Nevertheless, no significant decrease in comfort judgements of the identical reference stimuli per daily exposure set

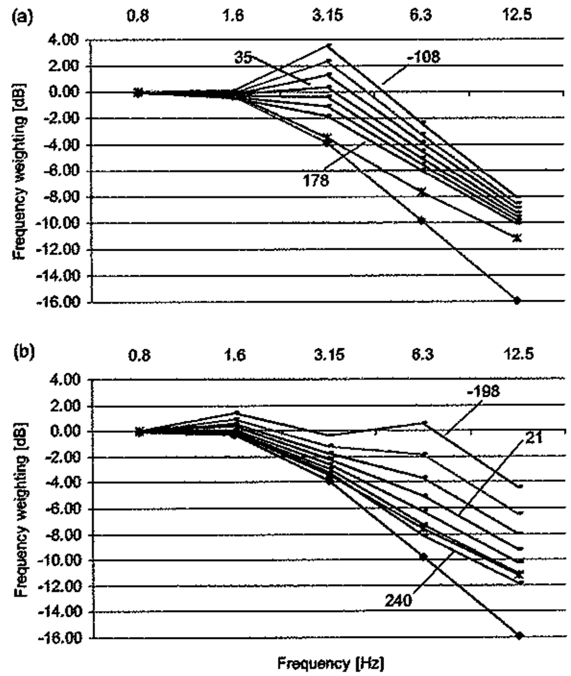

Fig. 9. Effect of vibration magnitude on frequency weightings (inverted equivalent intensity contours in steps of 6 equidistant arbitrary sensation units).

Numbers attached to the lines: normalized intensity judgements $LL_{norm,day}$ – length of line normalized with respect to individual means per experimental day. Curves normalized at 0.8 Hz and converted into dB: (a) sinusoidal excitation simultaneously exposed on the seat and the platform in x-direction, (b) sinusoidal excitation simultaneously exposed on the seat and the platform in y-direction. The results are compared with the frequency weightings.

W_d (–◆–) and $W_d \wedge W_k$ (–✱–) according to Eq. (11).

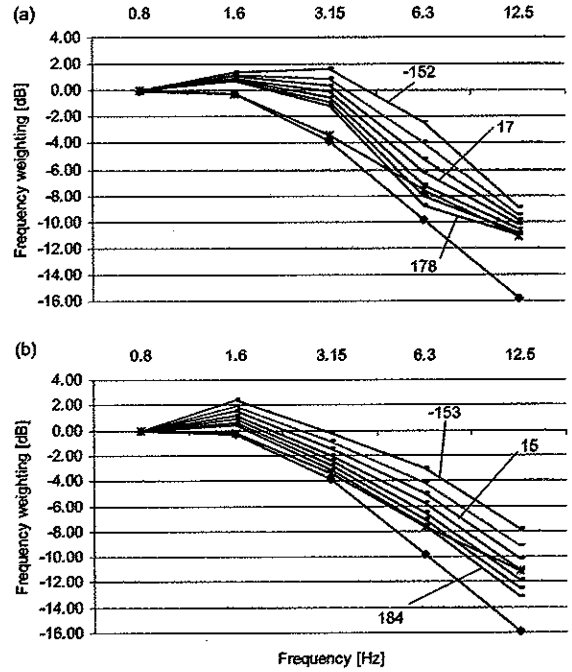

Fig. 10. Effect of vibration magnitude on frequency weightings (inverted equivalent intensity contours in steps of 6 equidistant arbitrary sensation units).

Numbers attached to the lines: normalized intensity judgements $LL_{norm,day}$ – length of line normalized with respect to individual means per experimental day. Curves normalized at 0.8 Hz and converted into dB: (a) octave band-width white noise excitation simultaneously exposed on the seat and the platform in x-direction, (b) octave band-width white noise excitation simultaneously exposed on the seat and the platform in y-direction.

The results are compared with the frequency weightings W_d (–◆–) and $W_d \wedge W_k$ (–✱–) according to Eq. (11).

was found. Moreover, the judgements of vibration intensity remained stable over time. A tendency to judge the very last exposure of the last experimental day less comfortable and more intensive was observed. Because of their four-day experience, the subjects knew that it was the very last exposure, even when it was not explicitly told them. That might be the reason for the slightly different judgement in comparison to the other reference stimuli. However, this tendency did not influence the general time independency of the judgements on one experimental day. The results suggest that the subjects were able to separate the intensity and comfort judgements from other perceptions associated with time effects.

On the other hand, the judgements of vibration comfort were significantly lower at the second repetition which was performed on a separate day. The reasons of this effect are not clear and so the interpretation is difficult. Possibly, the internal reference system concerning 'comfort' might vary from day to day. The topic is discussed more comprehensively in Section 1 and in the following paragraph. However, the results indicate an insufficient repeatability of the vibration comfort judgements.

Growth of sensation and equivalent sensation contours

The theory of cross-modality matching and the importance of Stevens' power law are described in Section 1. The Stevens' exponent was determined by regression analyses. The coefficients of determination for the prediction of comfort judgements were very low (see Table 6), so that these judgements supposed to be not suited for an adequate reflection of growth of sensation with vibration magnitude.

The interpretation of the outcomes relates to the term 'comfort'. As mentioned in Section 1, the term 'discomfort' does not exist in German. A simple inversion of the scale using the term 'comfort' does not seem to be a solution. Probably, 'comfort' is not just the opposite of 'discomfort'. 'Comfort' is rather associated with feelings of relaxation and well-being, whereas discomfort seems to be associated with biomechanical factors (joint angles, muscle contractions, pressure distribution) and tiredness (Zhang[22]). In a pilot study with 12 German speaking subjects (unpublished), the authors of the present investigation found that 'convenient' was the most appropriate word for 'comfortable', followed by cosy, pleasant, homelike, proper and easy. Therefore, the subjects were briefed to judge the vibration comfort bearing in mind all sensations related

Table 7. Ratios derived from equivalent vibration intensity contours dependending on the presented modified non-weighted overall vibration total value $a_{ov(n.w.)}$ at the reference frequency f_{ref} = 0.8 Hz ($a_{ov(n.w.), 0.8 Hz}$) in case of sinusoidal excitation simultaneously presented on the seat and the platform in x-axis

		Ratios of predicted accelerations					Filter factors				
$a_{ov(n.w.)}$	f_{ref}	Ratio $a_{ov(n.w.)}$ / $a_{ov(n.w.), 0.8 Hz}$ × 1,000					Ratio $a_{ov(n.w.), 0.8 Hz}$ / $a_{ov(n.w.)}$ × 1,000				
		Frequency [Hz]					Frequency [Hz]				
		0.8	1.6	3.15	6.3	12.5	0.8	1.6	3.15	6.3	12.5
0.62	0.8	1,000	995	666	1,323	2,538	1,000	1,005	1,501	756	394
0.69	0.8	1,000	1,002	716	1,387	2,606	1,000	998	1,396	721	384
0.77	0.8	1,000	1,008	765	1,449	2,669	1,000	992	1,306	690	375
0.85	0.8	1,000	1,013	814	1,508	2,730	1,000	987	1,229	663	366
0.93	0.8	1,000	1,018	862	1,566	2,787	1,000	982	1,160	639	359
1.02	0.8	1,000	1,023	910	1,622	2,842	1,000	977	1,099	617	352
1.10	0.8	1,000	1,028	957	1,676	2,895	1,000	973	1,045	597	345
1.19	0.8	1,000	1,032	1,003	1,729	2,945	1,000	969	997	578	340
1.28	0.8	1,000	1,036	1,049	1,781	2,994	1,000	965	953	561	334
1.37	0.8	1,000	1,040	1,095	1,832	3,041	1,000	961	913	546	329
1.46	0.8	1,000	1,044	1,141	1,881	3,086	1,000	958	877	532	324
1.56	0.8	1,000	1,048	1,186	1,930	3,130	1,000	954	843	518	319
1.65	0.8	1,000	1,051	1,231	1,977	3,173	1,000	951	813	506	315
	f_{sens}						Factor × 1,000 (ISO 2631-1, Table 3)				
W_d	1.0	-	-	-	-	-	992	968	642	323	161
W_k	10.0	-	-	-	-	-	477	494	804	1,054	902
$W_d \wedge W_k$	1.0	-	-	-	-	-	999	976	673	417	277

Factors for W_d - and W_k - frequency weightings according to ISO 2631-1 Table 3 and for the combination of W_d - and W_k - factors and multiplying factors ($W_d \wedge W_k$) according to Eq. (11). Highest sensitivity of the weighting curve W_d and the combination $W_d \wedge W_k$: f_{sens} = 1.0 Hz. Highest sensitivity of the weighting curve W_k: f_{sens} = 10 Hz (see ISO 2631-1 Table 3 and Eq. (11)).

Table 8. Stevens' exponents for the growth of discomfort derived from magnitude estimation (Howarth[10] and Morioka[14]) and for the vibration intensity derived from cross-modality matching (present study) depending on the frequency and the direction of the exposed sinusoidal vibration

	Howarth[10]	Morioka[14]		Present study	
	y-direction	x-direction	y-direction	x-direction	y-direction
0.8				0.745	1.036
1.6				0.705	0.901
2		0.948	0.635		
2.5		0.668	0.763		
3.15		***0.499***	***0.742***	***0.458***	***0.816***
4	0.68	0.461	0.932		
5		0.468	0.876		
5.6	0.85				
6.3		0.805	0.953	0.528	0.565
8	0.93	0.711	0.716		
10		0.735	0.935		
11.3	1.41				
12.5		0.854	0.907	0.607	0.608

to these terms. Moreover, they were requested to ignore the surrounding influences like climate, noise, demands on concentration and whether the mouse could easily be gripped or not. Notwithstanding this, the vibration comfort judgements seemed to be affected by many influences in addition to the vibration magnitude.

In contrast, coefficients of determination for the prediction of intensity judgements were high enough to presume the linear model to be appropriate for an adequate reflection of growth of sensation with increasing vibration magnitude (see Table 5). It was of interest to see whether the obtained exponents were similar to those derived from discomfort judgements reported by other authors. There are some comparable investigations with horizontal excitations of the seat or simultaneously of the seat and at the feet. Morioka[14] and Howarth[10] reported Stevens' exponents determined by magnitude estimation in their studies (Table 8).

For reasons discussed in the next paragraph, only the exponents derived at 3.15 Hz in the present study were reasonably comparable to those from Morioka[14] at the same frequency (in bold characters in Table 8). In spite of different methods, these exponents are very similar. In all three studies, Stevens' exponents varied within the frequency range, and frequency dependent Stevens' exponents cause magnitude dependent equivalent sensation contours.

In order to compare the results to those from other authors and to reveal a possibly systematic influence of relative body movements on the outcomes, some studies with horizontal vibrations were divided into investigations with and without relative body movements in the following paragraphs.

Griffin[7], Howarth[10] and Morioka[14] performed studies with vibration at the seat only, with stationary feet and hands.

Griffin[7] reported an experiment which determined the levels of fore-and-aft and lateral seat vibrations at seven frequencies (1, 2, 4, 8, 16, 31.5 and 63 Hz) causing discomfort equivalent to 0.5 and 1.25 m/s^2 r.m.s. 10 Hz vertical seat vibration. The vibration magnitudes of the test motions varied from 0.1 to 20 m/s^2. The subjects' feet were not vibrated and there was no backrest. Over the investigated range of levels the differences in equivalent sensation contours were small. The authors concluded that it seems reasonable to determine and apply a single equivalent comfort contour. They did not directly compare their results to the frequency weightings described in standards.

Howarth[10] exposed the subjects to six acceleration levels of sinusoidal vibrations in the y- and z-axes in a very low range from 0.04 m/s^2 to 0.4 m/s^2 at nine frequencies between 4 and 63 Hz. The footrest was stationary and there was no backrest. The authors found a magnitude dependence of the equivalent sensation contours. However, the frequency weightings were averaged over six magnitudes and compared with Wd frequency weighting defined in BSI 6841 (1987)[23] and ISO 2631 (1985)[24]. It was concluded that the averaged frequency weightings for sinusoidal vibration in the y-axis were in good agreement with W_d over the whole frequency range.

In experiments performed by Morioka[14], the subjects judged the discomfort caused by sinusoidal vibration in all three directions at frequencies between 2 and 315 Hz. The magnitudes varied from minimum 0.02 m/s^2 to maximum 1.25 m/s^2 r.m.s. in 3 dB steps. The range of exposed magnitude levels increased with increasing frequency in order to ensure that the stimuli were above the perception thresholds but not likely to be considered excessively unpleasant. There was no backrest and stationary handles and footrests were used. There were some magnitude dependent differences between the derived equivalent sensation contours and the W_d-curve, more pronounced for vibrations in the x-direction than in the y-direction (Fig. 8 in Morioka[14]).

Donati[25] and Corbridge[9] performed studies with identical exposure on the seat and at the feet.

Donati[25] compared the subjective response of seated subjects to sinusoidal vibrations in x-, y- and z-axes in the 1–10 Hz range with those produced by narrow-band random vibration centred at the same frequencies using the 'floating reference vibration' method. The accelerations varied from about 0.6 m/s^2 to about 4.0 m/s^2. The subjects sat on a semi-rigid seat or a rigid seat with and without support by a backrest. Identical vibrations were exposed simultaneously on the seat, the feet (footrest) and the hands (steering wheel). The differences between ISO-weighting and equivalent sensation contours were comparable with those obtained in the present study (Fig. 10 in[25]). The authors concluded that the equivalent sensation contours derived from these experiments related only roughly to the weighting curves in ISO 2631-1, particularly in the x-direction. The magnitude dependence of weighting curves was not systematically investigated in this study. Corbridge[9] conducted experiments with lateral sinusoidal vibration in the 0.5–5.0 Hz range. The magnitudes varied from 0.4 to 3.15 m/s^2. Subjects were seated on a rigid wooden seat and rested their feet on the moving vibrator table. The seat had a flat backrest, but the authors did not exactly describe whether it was used or not. The authors concluded that the experimentally determined contours for lateral vibration were in reasonable agreement with the curve defined in ISO 2631 (1978) (Fig. 9 in[9]). In both studies it remained vague whether the comparisons were related to the W_d- curves or to a combination of multiplying factors and W_d- and W_k-curves because of the simultaneous exposure of seat and feet.

Discussing the influence of relative body movements on the outcomes, one could suppose an increase of vibration sensitivity at least at low frequencies when only the seat was excited. When comparing the results of these studies with the outcomes of investigations with simultaneous vibration on the seat and the feet, a systematic difference at least at low frequencies may be expected. However, both types of experimental design delivered evidence varying from reasonable agreement with the ISO-curves to obvious differences without any systematic divergences. The relative body movements might influence the sensations less than assumed. In experiments with horizontal vibrations (modified signals of mobile machines) and professional driver seats with fixed or activated horizontal suspension, Schust[26] revealed high correlations between judgements of vibration intensity and vibration magnitude but only weak to middle correlations between intensity judgements and movements of the head in the room and the angle velocity of the bending of the trunk, the latter for exposures in y-direction and some exposure conditions only. The authors concluded that the subjective judgement of the intensity seems to depend rather on the vibration magnitude at the buttocks, the back and the feet than on the movements of the body parts in relation to the space coordinates or the relative movements between the body parts. Moreover, in this study twenty different values of acceleration were calculated for analyses of correlation between accelerations and subjective judgements, amongst others the point vibration total value av and the overall vibration total value a_{ov}. Comparing the results for av and aov the authors assumed the vibration measuring point (platform, seat or backrest) to be probably of minor importance for the association between acceleration and judgement of intensity, at least for the exposure conditions tested in this study with no extensively relative movements between these points.

Moreover, there is a lack of literature concerning an exact explanation of methods which were used to derive the frequency-weighting curves and the guide for their application with regard to health, comfort and perception (ISO 2631-1, Table 1) including the multiplying factors k (ISO 2631-1, clauses 7 and 8).

Bearing in mind the facts discussed above, it is difficult to decide whether equivalent sensation contours for the seat should be (i) derived from experiments with excitation on the seat only or with simultaneous exposure on the seat and the

Table 9. Predicted accelerations depending on arbitrary sensation units and on frequency derived by Morioka[14] (first two rows) and in the present study (last seven rows)

Arbitrary units	Frequency [Hz] 0.8	1.6	2	2.5	3.15	4	5	6.3	8	10	12.5
50			0.073	0.062	0.055	0.057	0.071	0.195	0.226	0.308	0.421
25			0.041	0.030	0.023	0.023	0.026	0.091	0.101	0.145	0.219
−108	0.62	0.62			0.41			0.82			1.57
−84	0.69	0.70			0.50			0.96			1.81
−60	0.77	0.78			0.59			1.12			2.06
−36	0.85	0.86			0.69			1.29			2.33
−13	0.93	0.95			0.80			1.46			2.60
11	1.02	1.04			0.93			1.65			2.89
35	1.10	1.13			1.06			1.85			3.19

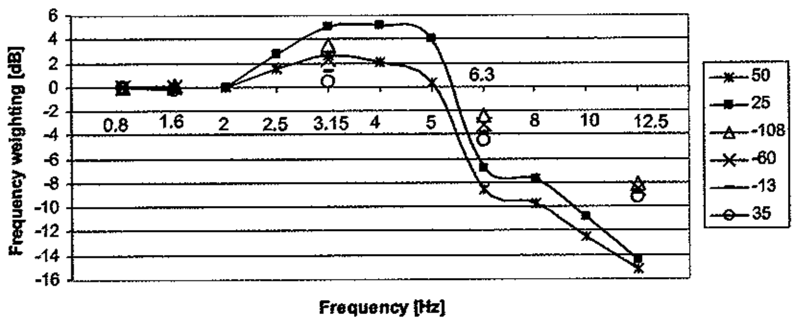

Fig. 11. Frequency weightings for vibration exposure in x-direction depending on arbitrary sensation units derived by Morioka (arbitrary units 25 and 50) and in the present study (arbitrary units −108, −60, −13 and 35).

feet, (ii) derived from the point overall vibration total value or the overall vibration total value (a_v or a_{ov}) and (iii) compared with W_d or $W_d \wedge W_k$.

In the present study, due to technical reasons an excitation merely on the seat was not realizable. That means there was a simultaneous exposure to vibration on the seat and at the feet. Moreover, the subjects were briefed to judge integratively the entire vibration exposure. Therefore, it was supposed that the judgements were reflected more likely by the overall vibration total value a_{ov} than by the point vibration total value av or the vibration in the axis of excitation only. Consequently, the relations between the a_{ov} and the subjective judgements were determined by curve fitting and the obtained equivalent sensation contours were discussed mainly in comparison with $W_d \wedge W_k$. In all Figures with frequency weightings, the W_d -curve is also given. At low frequencies both curves do not differ considerably but at frequencies from 6.3 Hz upwards they diverge by more than 2.2 dB and from 8 Hz upwards they diverge by more than 3 dB due to the effect of WBV acting on the feet. Assuming the current evaluation methods using the weighted overall vibration value a_{ov} adequately reflect the sensations, these differences were surely detectable by the subjects. It might be the case that, the effect of the WBV acting on the feet, when the seat and the feet are simultaneously excited, restricts the examination of the frequency-weighting curve W_d at frequencies above 5 Hz third-octave band mid frequency.

Comparing the results of the present study with these from Morioka[14], there seems to be some evidence for this assumption. Both studies are similar. Morioka[14] also investigated sinusoidal vibration, but no random excitation. The frequencies of standardisation for the frequency-weighting curves differed because of the different lowest frequencies (2 Hz in Morioka[14], 0.8 Hz in the present study). Moreover, there were only 3 common frequencies investigated (3.15, 6.3 and 12.5 Hz) and the magnitudes at the frequency of normalization were much more lower in Morioka[14] (0.041 m/s^2 to 0.417 m/s^2 r.m.s. in x- direction, 0.02 m/s^2 to 0.63 m/s^2 r.m.s. in y-direction) compared with the present study (0.41 m/s^2 to 1.70 m/s^2 r.m.s. in x- and y-directions, see Table 1). However, almost identical Stevens' exponents were obtained for frequencies at 3.15 Hz (see Table 8). Above 3.15 Hz, Morioka's exponents are higher, which indicates a deeper slope of the frequency-weighting curve.

For sinusoidal excitation in y-direction, similar filter factors for 3.15 Hz were derived when similar magnitudes were used at the frequency which was used for normalization (e.g. 0.6 m/s^2 at 2 Hz in Morioka[14] and at 0.8 Hz in the present study). However, above 3.15 Hz Morioka's curves are closer to W_d than the frequency weightings obtained in the present investigation. That might be due to separate vibration of the seat. Morioka[14] found similar shapes for the frequency-weighting curves for sinusoidal excitation in x-direction with the highest sensitivity around 2–3.15 Hz, but for lower vibration magnitudes (0.041 m/s^2 to 0.073 m/s^2 r.m.s. at 2 Hz) compared with the present investigation (0.62 m/s^2 to 1.19 m/s^2 r.m.s. at 0.8 Hz) (Table 9). Figure 11 shows the frequency weightings for vibration exposure in x-direction depending on arbitrary sensation units derived by Morioka (arbitrary units 25 and 50) and in the present study (arbitrary units −108, −60, −13 and 35).

One could be tempted to extrapolate the data to make some studies comparable by exceeding the range of definition but that would assume a questionable linearity in the human response. For instance, Miwa[26)] reported a reduction in the exponent with increasing vibration magnitude.

Some differences in the results might be due to different judgement methods. The present investigation seems to be only one which used cross-modality matching. The method has the advantage not to be dependent on a 'vibration memory', which means that the subjects do not have to keep in mind the sensation regarding a previously exposed reference stimulus in order to judge the current stimulus. On the other hand, cross-modality matching takes more time because of the necessity of a pre-period for vibration sensation (about 20 s) before judging the stimulus. Therefore, the number of conditions (magnitudes, frequencies etc.) realizable in an experimental session is restricted in order not to exceed an acceptable duration.

The weighted magnitude levels M4, M5 and M6 had overall vibration total values numerically equal to the non-weighted magnitudes M1, M2, M3. Therefore, the experiment was performed de facto twice, once with non-weighted magnitudes and repeatedly with weighted values. The multiplying factors were used for calculating both, M1 to M3 and M4 to M6. Assuming that the evaluation methods recommended in ISO 2631-1 correctly reflect the sensations, one could hypothesize that the shape of the frequency-weighting curves derived from M1 to M3 reflected the W_d- curve or the $W_d \wedge W_k$ –curve and the equivalent intensity contours associated with the weighted accelerations M4 to M6 were horizontal and straight lines. If the assumption were not true, the shape of the derived curves would reflect the deviation from the current evaluation methods. The latter was the case (see Fig. 12).

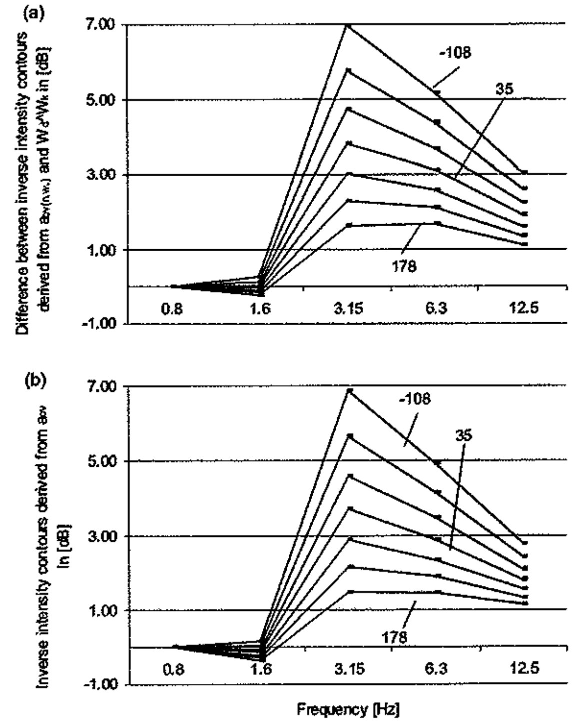

Fig. 12. (a) Difference between inverse intensity contours depending on arbitrary sensation units in 6 equidistant steps, derived from modified non-weighted overall vibration total values $a_{ov(n.w.)}$ (referred to 0.8 Hz) and $W_d \wedge W_k$ in dB for sinusoidal excitation x-direction (see Fig. 9 (a)) (b) Inverse intensity contours derived from weighted overall vibration total values a_{ov} (referred to 0.8 Hz) in dB.

All curves depending on arbitrary sensation units in 6 equidistant steps.

Conclusions

The differences between the obtained equivalent intensity contours and the current frequency weightings according to ISO 2631-1 were the following:

- strong dependency on vibration magnitude
- underestimation of the sensation varying in extent from 2 dB to 8 dB at 1.6, 3.15, 6.3 and 12.5 Hz in comparison with the reference frequency 0.8 Hz for all signals, with the most pronounced effects revealed at the frequencies 3.15 and 6.3 Hz and at lower intensities (a_{ov} around 0.48 m/s^2 to 0.8 m/s^2 r.m.s. at the reference frequency 0.8 Hz).
- some differences in the frequency weightings for sinusoidal and random octave band-width signals which should not be overinterpreted because of the restricted number of exposure conditions investigated in the study

The limitations of the study are the following:

- The study design did not allow differentiation between the frequency weightings W_d and W_k and the multiplying factor 0.25.
- Only five frequencies and six magnitude levels were investigated in order not to exceed an acceptable duration of a daily session.
- There was no multi-axis vibration.

The research on frequency weightings is currently not at a stage to be transferable for use in practice. More effort is needed to investigate the effects of vibrations typical for mobile workplaces, in particular for cases of multi-axis vibration. Moreover, further investigations should try to tackle the problem of evaluation of combined vibration at different input positions and relative movements between the body parts. Although it is commonly supposed that the sensation is a prerequisite for adverse health effects, there are doubts whether the findings from studies using subjective judgements are applicable, for instance, to the prediction of spinal injuries. The association between vibration signals weighted with altered filter factors and health effects should be confirmed.

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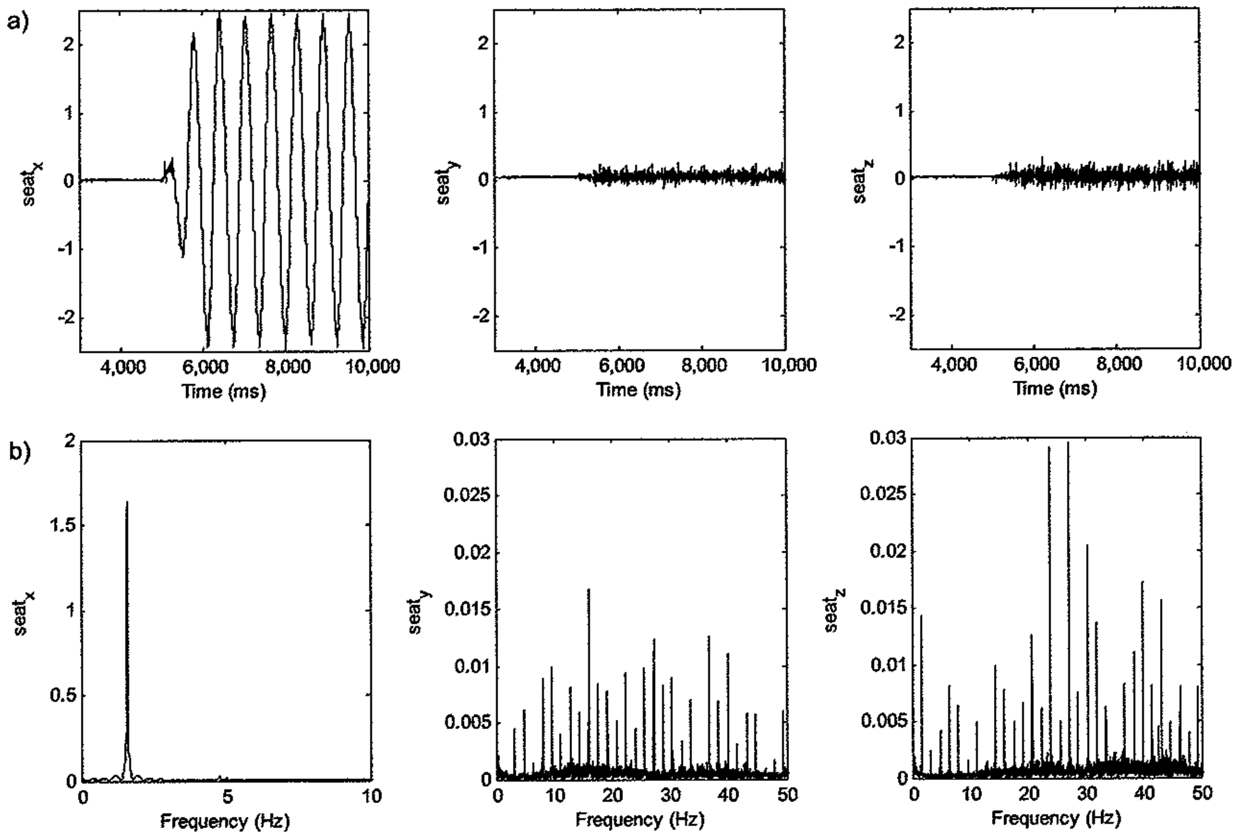
Appendix A

Example of measured non-weighted acceleration in m/s^2 at the seat in x-, y- and z-axes. Subject 36, sinusoidal excitation in x-direction, magnitude M3 (r.m.s. $a_{des,ex,seat}$ = 1.6 m/s^2), frequency F2 (1.6 Hz), repetition 1.
a) time signals (3rd to 10th second: 2 s pre-period + 1 s exposure with tapering + 4 s exposure).
b) FFT-analyses (6th to 69th second: 63 s exposure without tapering) (see also Fig. 2).



Appendix B: Instructions for the experiment

General information
You will sit down on a rigid seat and fasten the seat belt, which is not to be opened without a request by the operator. During the experiment, you will be exposed to vibration. The motions of the simulator will be monitored for the entire duration of the experiment. Minor deviations from the desired motions will lead to deactivation of the device. You will be able to shut the simulator down by using the emergency stop button. After switching off, the platform moves down slowly. During this process, the platform may temporarily remain in an inclined position. You will perceive different vibrations. The test conditions will vary and will be presented in random order. At certain times you will be asked to judge the intensity and the comfort of the vibration. Please follow the instructions given on the screen.

Judgements
A line will appear on the screen shortly after a question. The line will automatically become longer or shorter.

You should try to adjust the length of the line in accordance with your sensation, using the mouse buttons:
The *stronger* the sensation - the *longer* the line.

You can stop the extension and the shortening of the line with the right or the left mouse button. You can adjust the length of the line with the mouse buttons as well. Pressing the right button shortens the line, pressing the left button lengthens it. You can confirm the chosen length with a double click on the middle mouse button (the scroll wheel). Please tell the operator when you have been restricted due to the maximum length of the presented line.
You will be asked to judge the following sensations:

How intensive do you perceive the vibration to be?
This means the intensity of the vibration. Please concentrate on the vibration and disregard all additional influences such as noise, temperature, air quality, illumination or the comfort of the vibration. The latter will be judged separately.
The more intensive the vibration - the longer the line.

How comfortable do you perceive the vibration to be?
This means sensations which may relate to the comfort of vibration, for example sensations that you would associate with a convenient, cosy, pleasant, homely, proper etc. state.

Please, judge the experimental conditions only regarding the vibration comfort, and ignore, for example, the temperature, air quality, noise, accessibility of the mouse or the demands for your attention during the judgement.
The more comfortable the vibration - the longer the line.

g-force

From Wikipedia, the free encyclopedia

The **g-force** (with *g* from *gravitational*) associated with an object is its acceleration relative to free-fall.[1][2] This acceleration experienced by an object is due to the vector sum of non-gravitational forces acting on an object free to move. The accelerations that are not produced by gravity are termed proper accelerations, and it is only these that are measured in g-force units. They cause stresses and strains on objects, which are felt as weight (any g-force can thus be simply described, and measured, as a "weight per unit mass"). Because of these strains (weight forces), large proper accelerations (large g-forces), may be destructive.

This top-fuel dragster can accelerate from zero to 160 kilometres per hour (100 mph) in 0.86 seconds. This is a horizontal acceleration of 5.3 g. Combined with the vertical g-force in the stationary case the Pythagorean theorem yields a g-force of 5.4 g.

The standard gravitational acceleration at the Earth's surface produces g-force only indirectly. The 1 g force on an object sitting on the Earth's surface is caused by mechanical force exerted in the upward direction by the ground, keeping the object from going into free-fall. An object on the Earth's surface is accelerating relative to the free-fall condition, which is the path an object would follow falling freely toward the Earth's center. It is thus experiencing proper acceleration, even without a change in velocity (which is dv/dt, the familiar "coordinate acceleration" of Newton's laws).

Objects allowed to free-fall under the influence of gravity feel no g-force, as demonstrated by the "zero-g" conditions inside a freely-falling elevator falling toward the Earth's center (in vacuum), or (to good approximation) conditions inside a spacecraft in Earth orbit. These are examples of coordinate acceleration (a change in velocity) *without* proper acceleration. Since the g-force felt is always a measure of proper acceleration (which, in these cases, is zero, even though the objects are freely changing velocity due to gravity) all of these conditions of free-fall produce no g-force. The experience of no g-force (zero-g), however it is produced, is synonymous with weightlessness.

In the absence of gravitational fields, or in directions at right angles to them, proper and coordinate accelerations are the same, and any coordinate acceleration must be produced by a corresponding g-force acceleration. An example here is a rocket in free space, in which simple changes in velocity are produced by the engines, and produce g-forces on the rocket and passengers. The same happens in a dragster (see illustration) when it is changing velocity in a direction at right angles to the acceleration of gravity: such changes must be produced by accelerations that are appropriately measured in g-force units in the horizontal direction, since they produce g-force effects in that direction.

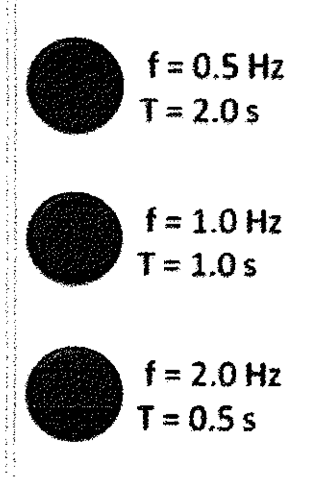
Contents

S

Hertz

From Wikipedia, the free encyclopedia

The **hertz** (symbol: **Hz**) is the SI unit of frequency defined as the number of cycles per second of a periodic phenomenon.[1] One of its most common uses is the description of the sine wave, particularly those used in radio and audio applications.



Lights flash at *frequency* f = 0.5 Hz (Hz = hertz), 1.0 Hz and 2.0 Hz, where x Hz means x flashes per second. T is the *period* and T = y s (s = second) means that y is the number of seconds per flash. T and f are each other's reciprocal: f = 1/T and T = 1/f.

Contents

Definition

The hertz is equivalent to cycles per second.[2] In defining the second the CIPM declared that "the standard to be employed is the transition between the hyperfine levels F = 4, M = 0 and F = 3, M = 0 of the ground state $2S_{1/2}$ of the caesium 133 atom, unperturbed by external fields, and that the frequency of this transition is assigned the value 9 192 631 770 hertz"[3] thereby effectively defining the hertz and the second simultaneously.

In English, hertz is used as a plural. As an SI unit, Hz can be prefixed; commonly used multiples are kHz (kilohertz, 10^3 Hz), MHz (megahertz, 10^6 Hz), GHz (gigahertz, 10^9 Hz) and THz (terahertz, 10^{12} Hz). One hertz simply means "one cycle per second" (typically that which is being counted is a complete cycle); 100 Hz means "one hundred cycles per second", and so on. The unit may be applied to any periodic event—for example, a clock might be said to tick at 1 Hz, or a human heart might be said to beat at 1.2 Hz. The "frequency" (activity) of aperiodic or stochastic events, such as radioactive decay, is expressed in becquerels.

Hertz	
Unit system:	SI derived unit
Unit of...	Frequency
Symbol:	Hz

Even though angular velocity, angular frequency and hertz all have the dimensions of *1/s*, angular velocity and angular frequency are *not* expressed in hertz,[4] but rather in an appropriate angular unit such as radians per second. Thus a disc rotating at 60 revolutions per minute (rpm) is said to be rotating at either

Named after:	Heinrich Hertz
In SI base units:	1 Hz = 1/s

2π rad/s *or* 1 Hz, where the former measures the angular velocity and latter reflects the number of *complete* revolutions per second. The conversion between a frequency *f* measured in hertz and an angular velocity *ω* measured in radians per second are:

$$\omega = 2\pi f \text{ and } f = \omega/(2\pi).$$

This SI unit is named after Heinrich Hertz. As with every SI unit whose name is derived from the proper name of a person, the first letter of its symbol is upper case (**Hz**). When an SI unit is spelled out in English, it should always begin with a lower case letter (**hertz**), except where *any* word would be capitalized, such as at the beginning of a sentence or in capitalized material such as a title. Note that "degree Celsius" conforms to this rule because the "d" is lowercase. —Based on *The International System of Units (http://www.bipm.org/en/si/si_brochure/chapter5/5-2.html)*, section 5.2.

History

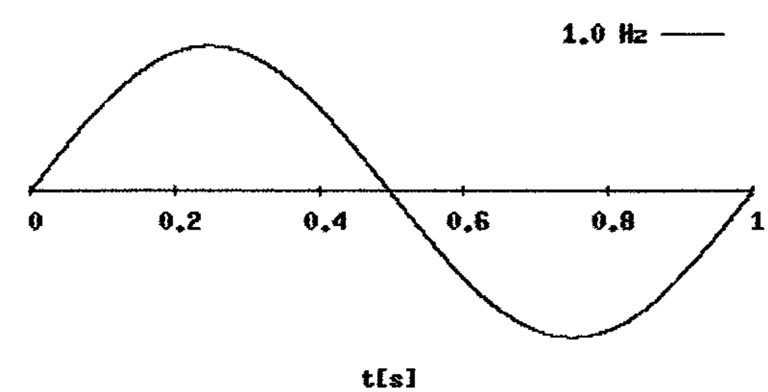
The hertz is named after the German physicist Heinrich Hertz, who made important scientific contributions to the study of electromagnetism. The name was established by the International Electrotechnical Commission (IEC) in 1930.[5] It was adopted by the General Conference on Weights and Measures (CGPM) (*Conférence générale des poids et mesures*) in 1960, replacing the previous name for the unit, *cycles per second* (cps), along with its related multiples, primarily *kilocycles per second* (kc/s) and *megacycles per second* (Mc/s), and occasionally *kilomegacycles per second* (kMc/s). The term *cycles per second* was largely replaced by *hertz* by the 1970s.

The term "gigahertz", most commonly used in computer processor clock rates and radio frequency (RF) applications, can be pronounced either /ˈɡɪɡəhɜrts/, with a hard /ɡ/ sound, or /ˈdʒɪɡəhɜrts/, with a soft /dʒ/.[6] The prefix "giga-" is derived directly from the Greek "γιγας."

Applications

Vibration

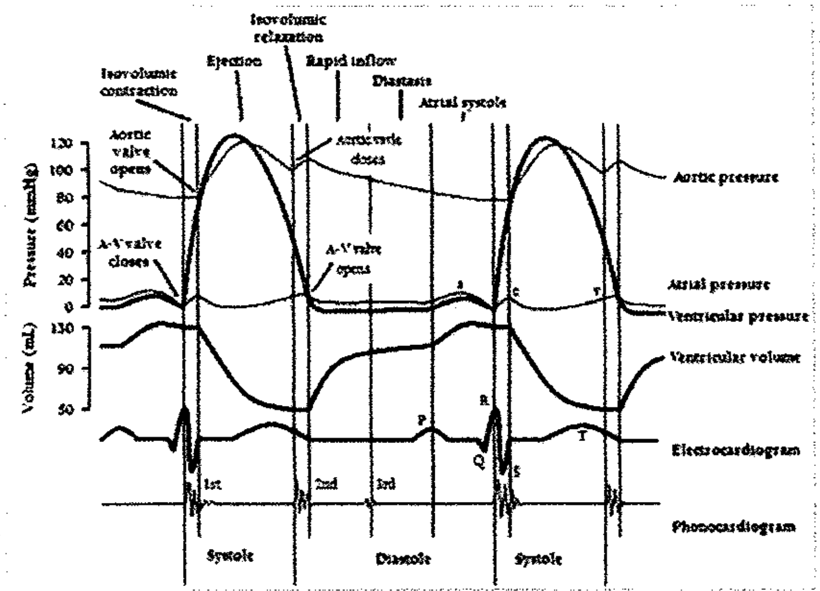
Sound is a traveling wave which is an oscillation of pressure. Humans perceive frequency of sound waves as pitch. Each musical note corresponds to a particular frequency which can be measured in hertz. An infant's ear is able to perceive frequencies ranging from 20 Hz to 20,000 Hz; the average adult human can hear sounds between 20 Hz and 16,000 Hz.[7] The range of ultrasound, infrasound and other physical vibrations such as molecular vibrations extends into the megahertz range and well beyond.



Waves of different frequency.

Electromagnetic radiation

Electromagnetic radiation is often described by its frequency—the number of oscillations of the perpendicular electric and magnetic fields per second—expressed in hertz.



Details of a heartbeat as an example of a non-sinusoidal periodic phenomenon that can be described in terms of hertz. Two complete cycles are illustrated.

Radio frequency radiation is usually measured in kilohertz, megahertz, or gigahertz; this is why radio dials are commonly labeled with kHz, MHz, and GHz. Light is electromagnetic radiation that is even higher in frequency, and has frequencies in the range of tens (infrared) to thousands (ultraviolet) of terahertz. Electromagnetic radiation with frequencies in the low terahertz range, (intermediate between those of the highest normally usable radio frequencies and long-wave infrared light), is often called terahertz radiation. Even higher frequencies exist, such as that of gamma rays, which can be measured in exahertz. (For historical reasons, the frequencies of light and higher frequency electromagnetic radiation are more commonly specified in terms of their wavelengths or photon energies: for a more detailed treatment of this and the above frequency ranges, see electromagnetic spectrum.)

Computing

In computing, most central processing units (CPU) are labeled in terms of their clock rate expressed in megahertz or gigahertz (10^9 hertz). This number refers to the frequency of the CPU's master clock signal ("Clock rate"). This signal is simply an electrical voltage which changes from low to high and back again at regular intervals. This signal is also referred to as a square wave. Hertz has become the primary unit of measurement accepted by the general populace to determine the performance of a CPU, but many experts have criticized this approach, which they claim is an easily manipulable benchmark.[8] For home-based personal computers, the CPU has ranged from approximately 1 megahertz in the late 1970s (Atari, Commodore, Apple computers) to up to 6 GHz in the present (IBM POWER processors).

Various computer buses, such as the front-side bus connecting the CPU and northbridge, also operate at different frequencies in the megahertz range (for modern products).

CRT television and monitor refresh rates are measured in hertz.

SI multiples

SI multiples for hertz (Hz)

Submultiples			Multiples		
Value	**Symbol**	**Name**	**Value**	**Symbol**	**Name**
10^{-1} Hz	dHz	decihertz	10^{1} Hz	daHz	decahertz
10^{-2} Hz	cHz	centihertz	10^{2} Hz	hHz	hectohertz
10^{-3} Hz	mHz	millihertz	10^{3} Hz	**kHz**	**kilohertz**
10^{-6} Hz	µHz	microhertz	10^{6} Hz	**MHz**	**megahertz**
10^{-9} Hz	nHz	nanohertz	10^{9} Hz	**GHz**	**gigahertz**
10^{-12} Hz	pHz	picohertz	10^{12} Hz	**THz**	**terahertz**
10^{-15} Hz	fHz	femtohertz	10^{15} Hz	PHz	petahertz
10^{-18} Hz	aHz	attohertz	10^{18} Hz	EHz	exahertz
10^{-21} Hz	zHz	zeptohertz	10^{21} Hz	ZHz	zettahertz
10^{-24} Hz	yHz	yoctohertz	10^{24} Hz	YHz	yottahertz
Common prefixed units are in bold face.					

Frequencies not expressed in hertz

Even higher frequencies are believed to occur naturally, in the frequencies of the quantum-mechanical wave functions of high-energy (or, equivalently, massive) particles, although these are not directly observable, and must be inferred from their interactions with other phenomena. For practical reasons, these are typically not expressed in hertz, but in terms of the equivalent quantum energy, which is proportional to the frequency by the factor of Planck's constant.

See also

- Alternating current
- Electronic tuner
- Frequency changer
- Normalized frequency
- Orders of magnitude (frequency)
- Radian per second
- Signal bandwidth

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4. ^ "SI brochure, Section 2.2.2, paragraph 6" (http://www.bipm.org/en/si/derived_units/2-2-2.html) . http://www.bipm.org/en/si/derived_units/2-2-2.html.

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6. ^ "Gigahertz (http://dictionary.reference.com/browse/gigahertz) " in Dictionary.com Unabridged. *Dictionary*.
7. ^ Dominant spectral region (http://www.mmk.e-technik.tu-muenchen.de/persons/ter/top/dominant.html)
8. ^ Good Riddance, Gigahertz (http://www.wired.com/news/business/0,1367,62851,00.html)

External links

- BIPM Cesium ion f_{Cs} definition (http://www.bipm.org/en/si/si_brochure/chapter2/2-1/second.html)
- National Research Council of Canada: *Generation of the Hz* (http://inms-ienm.nrc-cnrc.gc.ca/research/frequency_time_projects_e.html#gen)
- National Research Council of Canada: *Cesium fountain clock* (http://inms-ienm.nrc-cnrc.gc.ca/research/cesium_clock_e.html)
- National Physical Laboratory: *Trapped ion optical frequency standards* (http://www.npl.co.uk/server.php?show=ConWebDoc.1086)
- National Research Council of Canada: *Optical frequency standard based on a single trapped ion* (http://inms-ienm.nrc-cnrc.gc.ca/research/optical_frequency_projects_e.html#optical)
- National Research Council of Canada: *Optical frequency comb* (http://inms-ienm.nrc-cnrc.gc.ca/research/optical_frequency_projects_e.html#femtosecond)
- One Hertz in Radians per Second (Google). Note, as of 06 May 2009 there is an error of 2π. (http://www.google.com/search?q=one+hertz+in+radians+per+second)

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Categories: SI derived units | Units of frequency

T

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Pulmonary Disorders
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Multimedia
Selected Links

ICHD-2

Main article: International Classification of Headache Disorders

The International Classification of Headache Disorders (ICHD) is an in-depth hierarchical classification of headaches published by the International Headache Society. It contains explicit (operational) diagnostic criteria for headache disorders. The first version of the classification, ICHD-1, was published in 1988. The current revision, ICHD-2, was published in 2004.[6]

The classification uses numeric codes. The top, one-digit diagnostic level includes 14 headache groups. The first four of these are classified as primary headaches, groups 5-12 as secondary headaches, cranial neuralgia, central and primary facial pain and other headaches for the last two groups.[7]

NIH

Main article: NIH classification of headaches

The NIH classification consists of brief definitions of a limited number of headaches.[2]

Symptoms and signs

Headache associated with specific symptoms may warrant urgent medical attention, particularly sudden, severe headache or sudden headache associated with a stiff neck; headaches associated with fever, convulsions or accompanied by confusion or loss of consciousness; headaches following a blow to the head, or associated with pain in the eye or ear; persistent headache in a person with no previous history of headaches; and recurring headache in children.

Pathophysiology

The brain in itself is not sensitive to pain, because it lacks nociceptors. However, several areas of the head and neck do have nociceptors, and can thus sense pain. These include the extracranial arteries, large veins, cranial and spinal nerves, head and neck muscles and the meninges.[8]

Diagnosis

In 2008, the American College of Emergency Physicians updated their guidelines on the evaluation and management of adult patients who have a nontraumatic headache of acute onset.[8]

While, statistically, headaches are most likely to be primary (harmless and self-limiting), some specific secondary headache syndromes may demand specific treatment or may be warning signals of more serious disorders. Differentiating between primary and secondary headaches can be difficult.

As it is often difficult for patients to recall the precise details regarding each headache, it is often useful for the sufferer to fill-out a "headache diary" detailing the characteristics of the headache.

Imaging

When the headache does not clearly fit into one of the recognized primary headache syndromes or when atypical symptoms or signs are present then further investigations are justified.[9] Neuroimaging (noncontrast head CT) is recommended if there are new neurological problems such as decreased level of consciousness, one sided weakness, pupil size difference, etc or if the pain is of sudden onset and severe, or if the person is known HIV positive.[8] People over the age of 50 years may also warrant a CT scan.[8]

Treatment

Acute headaches

Not all headaches require medical attention, and most respond with simple analgesia (painkillers) such as paracetamol/acetaminophen or members of the NSAID class (such as aspirin/acetylsalicylic acid, diclofenac or ibuprofen).

A small 2009 study found that 100% oxygen at 15 l / min was effective at relieving undifferentiated headache pain in the emergency department.[10]

Chronic headaches

See also: Management of chronic headaches

In recurrent unexplained headaches keeping a "headache diary" with entries on type of headache, associated symptoms, precipitating and aggravating factors may be helpful. This may reveal specific patterns, such as an association with medication, menstruation or absenteeism or with certain foods. It was reported in March 2007 by two separate teams of researchers that stimulating the brain with implanted electrodes appears to help ease the pain of cluster headaches.[11]

Acupuncture has been found to be beneficial in chronic headaches[12] of both tension type[13] and migraine type.[14] Whether or not there is a difference between true acupuncture and sham acupuncture however is yet to be determined.[14]

Epidemiology

During a given year, 90% of people suffer with headaches. Of the ones who are seen in the ER, about 1% have a serious underlying problem.[15]

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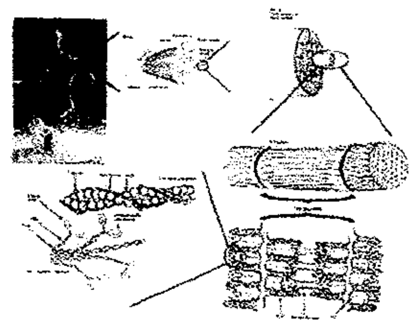
External links

- National Headache Foundation
- IHS - The International Headache Classification (ICHD-2)
- American Headache Society
- Withdrawal related headache information

Muscle

From Wikipedia, the free encyclopedia


A top-down view of skeletal muscle

Muscle (from Latin *musculus*, diminutive of *mus* "mouse"[1]) is the contractile tissue of animals and is derived from the mesodermal layer of embryonic germ cells. Muscle cells contain contractile filaments that move past each other and change the size of the cell. They are classified as skeletal, cardiac, or smooth muscles. Their function is to produce force and cause motion. Muscles can cause either locomotion of the organism itself or movement of internal organs. Cardiac and smooth muscle contraction occurs without conscious thought and is necessary for survival. Examples are the contraction of the heart and peristalsis which pushes food through the digestive system. Voluntary contraction of the skeletal muscles is used to move the body and can be finely controlled. Examples are movements of the eye, or gross movements like the quadriceps muscle of the thigh. There are two broad types of voluntary muscle fibers: slow twitch and fast twitch. Slow twitch fibers contract for long periods of time but with little force while fast twitch fibers contract quickly and powerfully but fatigue very rapidly.

Muscles are predominately powered by the oxidation of fats and carbohydrates, but anaerobic chemical reactions are also used, particularly by fast twitch fibers. These chemical reactions produce adenosine triphosphate (ATP) molecules which are used to power the movement of the myosin heads.

Contents

Embryology

All muscles derive from paraxial mesoderm. The paraxial mesoderm is divided along the embryo's length into somites, corresponding to the segmentation of the body (most obviously seen in the vertebral column. Each somite has 3 divisions, sclerotome (which forms vertebrae), dermatome (which forms skin), and myotome (which forms muscle). The myotome is divided into two sections, the epimere and hypomere, which form epaxial and hypaxial muscles, respectively. Epaxial muscles in humans are only the erector spinae and small intervertebral muscles, and are innervated by the dorsal rami of the spinal nerves. All other muscles, including limb muscles, are hypaxial muscles, formed from the hypomere, and inervated by the ventral rami of the spinal nerves.

During development, myoblasts (muscle progenitor cells) either remain in the somite to form muscles associated with the vertebral column or migrate out into the body to form all other muscles. Myoblast migration is preceded by the formation of connective tissue frameworks, usually formed from the somatic lateral plate mesoderm. Myoblasts follow chemical signals to the appropriate locations, where they fuse into elongate skeletal muscle cells.

Types

There are three types of muscle:


Types of muscle (shown at different magnifications)

- Skeletal muscle or "voluntary muscle" is anchored by tendons (or by aponeuroses at a few places) to bone and is used to effect skeletal movement such as locomotion and in maintaining posture. Though this postural control is generally maintained as a subconscious reflex, the muscles responsible react to conscious control like non-postural muscles. An average adult male is made up of 42% of skeletal muscle and an average adult female is made up of 36% (as a percentage of body mass).[2]
- Smooth muscle or "involuntary muscle" is found within the walls of organs and structures such as the esophagus, stomach, intestines, bronchi, uterus, urethra, bladder, blood vessels, and the arrector pili in the skin (in which it controls erection of body hair). Unlike skeletal muscle, smooth muscle is not under conscious control.
- Cardiac muscle is also an "involuntary muscle" but is more akin in structure to skeletal muscle, and is found only in the heart.

Cardiac and skeletal muscles are "striated" in that they contain sarcomeres and are packed into highly-regular arrangements of bundles; smooth muscle has neither. While skeletal muscles are arranged in regular, parallel bundles, cardiac muscle connects at branching, irregular angles (called intercalated discs). Striated muscle contracts and relaxes in short, intense bursts, whereas smooth muscle sustains longer or even near-permanent contractions.

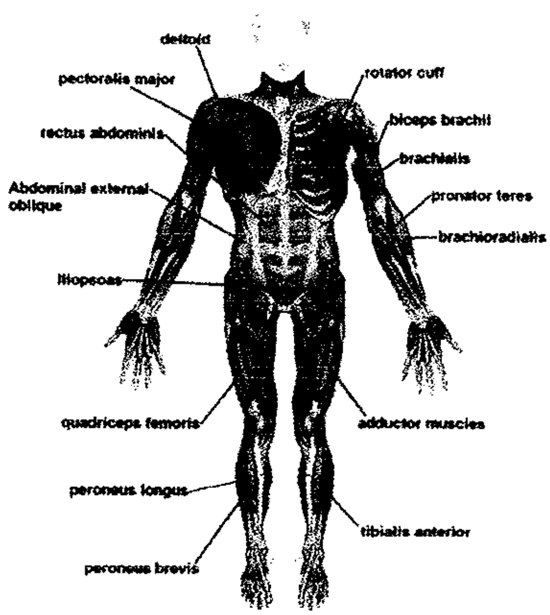
Skeletal muscle is further divided into several subtypes:

- Type I, slow oxidative, slow twitch, or "red" muscle is dense with capillaries and is rich in mitochondria and myoglobin, giving the muscle tissue its characteristic red color. It can carry more oxygen and sustain aerobic activity.
- Type II, fast twitch muscle, has three major kinds that are, in order of increasing contractile speed:[3]
  - Type IIa, which, like slow muscle, is aerobic, rich in mitochondria and capillaries and appears red.
  - Type IIx (also known as type IId), which is less dense in mitochondria and myoglobin. This is the fastest muscle type in humans. It can contract more quickly and with a greater amount of force than oxidative muscle, but can sustain only short, anaerobic bursts of activity before muscle contraction becomes painful (often incorrectly attributed to a build-up of lactic acid). N.B. in some books and articles this muscle in humans was, confusingly, called type IIB.[4]
  - Type IIb, which is anaerobic, glycolytic, "white" muscle that is even less dense in mitochondria and myoglobin. In small animals like rodents this is the major fast muscle type, explaining the pale color of their flesh.

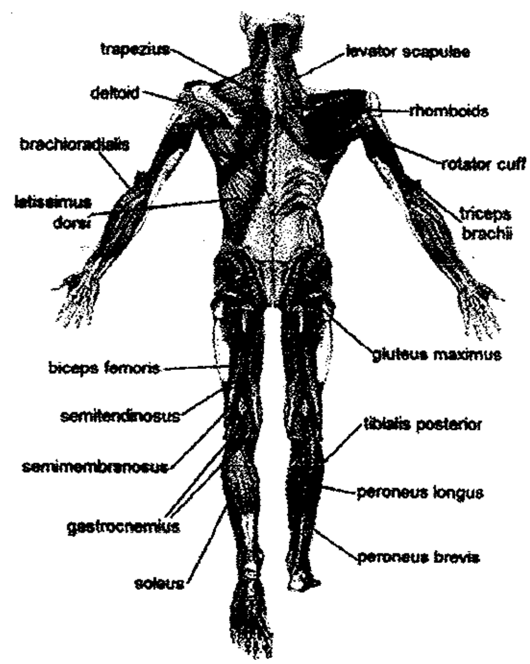
Anatomy

The anatomy of muscles includes both gross anatomy, comprising all the muscles of an organism, and, on the other hand, microanatomy, which comprises the structures of a single muscle.

Gross anatomy



Muscles, anterior view (*See Gray's muscle pictures for detailed pictures*)



Muscles, posterior view (*See Gray's muscle pictures for detailed pictures*)

The gross anatomy of a muscle is the most important indicator of its role in the body. The action a muscle generates is determined by the origin and insertion locations. The cross-sectional area of a muscle (rather than volume or length) determines the amount of force it can generate by defining the number of sarcomeres which can operate in parallel. The amount of force applied to the external environment is determined by lever mechanics, specifically the ratio of in-lever to out-lever. For example, moving the insertion point of the biceps more distally on the radius (farther from the joint of rotation) would increase the force generated during flexion (and, as a result, the maximum weight lifted in this movement), but decrease the maximum speed of flexion. Moving the insertion point proximally (closer to the joint of rotation) would result in decreased force but increased velocity. This can be most easily seen by comparing the limb of a mole to a horse - in the former, the insertion point is positioned to maximize force (for digging), while in the latter, the insertion point is positioned to maximize speed (for running).

One particularly important aspect of gross anatomy of muscles is pennation or lack thereof. In most muscles, all the fibers are oriented in the same direction, running in a line from the origin to the insertion. In pennate muscles, the individual fibers are oriented at an angle relative to the line of action, attaching to the origin and insertion tendons at each end. Because the contracting fibers are pulling at an angle to the overall action of the muscle, the change in length is smaller, but this same orientation allows for more fibers (thus more force) in a muscle of a given size. Pennate muscles are usually found where their length change is less important than maximum force, such as the rectus femoris.

There are approximately 639 skeletal muscles in the human body. However, the exact number is difficult to define because different sources group muscles differently.

Main article: Table of muscles of the human body

Microanatomy

Muscle is mainly composed of muscle cells. Within the cells are myofibrils; myofibrils contain sarcomeres, which are composed of actin and myosin. Individual muscle fibres are surrounded by endomysium. Muscle fibers are bound together by perimysium into bundles called fascicles; the bundles are then grouped together to form muscle, which is enclosed in a sheath of epimysium. Muscle spindles are distributed throughout the muscles and provide sensory feedback information to the central nervous system.

Skeletal muscle is arranged in discrete muscles, an example of which is the *biceps brachii*. It is connected by tendons to processes of the skeleton. Cardiac muscle is similar to skeletal muscle in both composition and action, being comprised of myofibrils of sarcomeres, but anatomically different in that the muscle fibers are typically branched like a tree and connect to other cardiac muscle fibers through intercalcated discs, and form the appearance of a syncytium.

Physiology

Main article: muscle contraction

The three types of muscle (skeletal, cardiac and smooth) have significant differences. However, all three use the movement of actin against myosin to create contraction. In skeletal muscle, contraction is stimulated by electrical impulses transmitted by the nerves, the motor nerves and motoneurons in particular. Cardiac and smooth muscle contractions are stimulated by internal pacemaker cells which regularly contract, and propagate contractions to other muscle cells they are in contact with. All skeletal muscle and many smooth muscle contractions are facilitated by the neurotransmitter acetylcholine.

Muscular activity accounts for much of the body's energy consumption. All muscle cells produce adenosine triphosphate (ATP) molecules which are used to power the movement of the myosin heads. Muscles conserve energy in the form of creatine phosphate which is generated from ATP and can regenerate ATP when needed with creatine kinase. Muscles also keep a storage form of glucose in the form of glycogen. Glycogen can be rapidly converted to glucose when energy is required for sustained, powerful contractions. Within the voluntary skeletal muscles, the glucose molecule can be metabolized anaerobically in a process called glycolysis which produces two ATP and two lactic acid molecules in the process (note that in aerobic conditions, lactate is not formed; instead pyruvate is formed and transmitted through the citric acid cycle). Muscle cells also contain globules of fat, which are used for energy during aerobic exercise. The aerobic energy systems take longer to produce the ATP and reach peak efficiency, and requires many more biochemical steps, but produces significantly more ATP than anaerobic glycolysis. Cardiac muscle on the other hand, can readily consume any of the three macronutrients (protein, glucose and fat) aerobically without a 'warm up' period and always extracts the maximum ATP yield from any molecule involved. The heart, liver and red blood cells will also consume lactic acid produced and excreted by skeletal muscles during exercise.

Nervous control

Efferent leg

The efferent leg of the peripheral nervous system is responsible for conveying commands to the muscles and glands, and is ultimately responsible for voluntary movement. Nerves move muscles in response to voluntary and autonomic (involuntary) signals from the brain. Deep muscles, superficial muscles, muscles of the face and internal muscles all correspond with dedicated regions in the primary motor cortex of the brain, directly anterior to the central sulcus that divides the frontal and parietal lobes.

In addition, muscles react to reflexive nerve stimuli that do not always send signals all the way to the brain. In this case, the signal from the afferent fiber does not reach the brain, but produces the reflexive movement by direct connections with the efferent nerves in the spine. However, the majority of muscle activity is volitional, and the result of complex interactions between various areas of the brain.

Nerves that control skeletal muscles in mammals correspond with neuron groups along the primary motor cortex of the brain's cerebral cortex. Commands are routed though the basal ganglia and are modified by input from the cerebellum before being relayed through the pyramidal tract to the spinal cord and from there to the motor end plate at the muscles. Along the way, feedback, such as that of the extrapyramidal system contribute signals to influence muscle tone and response.

Deeper muscles such as those involved in posture often are controlled from nuclei in the brain stem and basal ganglia.

Afferent leg

The afferent leg of the peripheral nervous system is responsible for conveying sensory information to the brain, primarily from the sense organs like the skin. In the muscles, the muscle spindles convey information about the degree of muscle length and stretch to the central nervous system to assist in maintaining posture and joint position. The sense of where our bodies are in space is called proprioception, the perception of body awareness. More easily demonstrated than explained, proprioception is the "unconscious" awareness of where the various regions of the body are located at any one time. This can be demonstrated by anyone closing their eyes and waving their hand around. Assuming proper proprioceptive function, at no time will the person lose awareness of where the hand actually is, even though it is not being detected by any of the other senses.

Several areas in the brain coordinate movement and position with the feedback information gained from proprioception. The cerebellum and red nucleus in particular continuously sample position against movement and make minor corrections to assure smooth motion.

Exercise

Exercise is often recommended as a means of improving motor skills, fitness, muscle and bone strength, and joint function. Exercise has several effects upon muscles, connective tissue, bone, and the nerves that stimulate the muscles.

Various exercises require a predominance of certain muscle fiber utilization over another. Aerobic exercise involves long, low levels of exertion in which the muscles are used at well below their maximal contraction strength for long periods of time (the most classic example being the marathon). Aerobic events, which rely primarily on the aerobic (with oxygen) system, use a higher percentage of Type I (or slow-twitch) muscle fibers, consume a mixture of fat, protein and carbohydrates for energy, consume large amounts of oxygen and produce little lactic acid. Anaerobic exercise involves short bursts of higher intensity contractions at a much greater percentage of their maximum contraction strength. Examples of anaerobic exercise include sprinting and weight lifting. The anaerobic energy delivery system uses predominantly Type II or fast-twitch muscle fibers, relies mainly on ATP or glucose for fuel, consumes relatively little oxygen, protein and fat, produces large amounts of lactic acid and can not be sustained for as long a period as aerobic exercise. The presence of lactic acid has an inhibitory effect on ATP generation within the muscle; though not producing fatigue, it can inhibit or even stop performance if the intracellular concentration becomes too high. However, long-term training causes neovascularization within the muscle, increasing the ability to move waste products out of the muscles and maintain contraction. Once moved out of muscles with high concentrations within the sarcomere, lactic acid can be used by other muscles or body tissues as a source of energy, or transported to the liver where it is converted back to pyruvate. The ability of the body to export lactic acid and use it as a source of energy depends on training level.

Humans are genetically predisposed with a larger percentage of one type of muscle group over another. An individual born with a greater percentage of Type I muscle fibers would theoretically be more suited to endurance events, such as triathlons, distance running, and long cycling events, whereas a human born with a greater percentage of Type II muscle fibers would be more likely to excel at anaerobic events such as a 200 meter dash, or weightlifting.

Delayed onset muscle soreness is pain or discomfort that may be felt one to three days after exercising and subsides generally within two to three days later. Once thought to be caused by lactic acid buildup, a more recent theory is that it is caused by tiny tears in the muscle fibers caused by eccentric contraction, or unaccustomed training levels. Since lactic acid disperses fairly rapidly, it could not explain pain experienced days after exercise.[5]

Muscular, spinal and neural factors all affect muscle building. Sometimes a person may notice an increase in strength in a given muscle even though only its opposite has been subject to exercise, such as when a bodybuilder finds her left biceps stronger after completing a regimen focusing only on the right biceps. This phenomenon is called cross education.

Disease

Main article: Neuromuscular disease

Symptoms of muscle diseases may include weakness, spasticity, myoclonus and myalgia. Diagnostic procedures that may reveal muscular disorders include testing creatine kinase levels in the blood and electromyography (measuring electrical activity in muscles). In some cases, muscle biopsy may be done to identify a myopathy, as well as genetic testing to identify DNA abnormalities associated with specific myopathies and dystrophies.

Neuromuscular diseases are those that affect the muscles and/or their nervous control. In general, problems with nervous control can cause spasticity or paralysis, depending on the location and nature of the problem. A large proportion of neurological disorders leads to problems with movement, ranging from cerebrovascular accident (stroke) and Parkinson's disease to Creutzfeldt-Jakob disease.

A non-invasive elastography technique that measures muscle noise is undergoing experimentation to provide a way of monitoring neuromuscular disease. The sound produced by a muscle comes from the shortening of actomyosin filaments along the axis of the muscle. During contraction, the muscle shortens along its longitudinal axis and expands across the transverse axis, producing vibrations at the surface.[6]

Atrophy

Main article: Muscle atrophy

There are many diseases and conditions which cause a decrease in muscle mass, known as muscle atrophy. Examples include cancer and AIDS, which induce a body wasting syndrome called cachexia. Other syndromes or conditions which can induce skeletal muscle atrophy are congestive heart disease and some diseases of the liver.

During aging, there is a gradual decrease in the ability to maintain skeletal muscle function and mass, known as sarcopenia. The exact cause of sarcopenia is unknown, but it may be due to a combination of the gradual failure in the "satellite cells" which help to regenerate skeletal muscle fibers, and a decrease in sensitivity to or the availability of critical secreted growth factors which are necessary to maintain muscle mass and satellite cell survival. Sarcopenia is a normal aspect of aging, and is not actually a disease state yet can be linked to many injuries in the elderly population as well as decreasing quality of life[7].

Physical inactivity and atrophy

Inactivity and starvation in mammals lead to atrophy of skeletal muscle, accompanied by a smaller number and size of the muscle cells as well as lower protein content.[8] In humans, prolonged periods of immobilization, as in the cases of bed rest or astronauts flying in space, are known to result in muscle weakening and atrophy. Such consequences are also noted in small hibernating mammals like the golden-mantled ground squirrels and brown bats.[9]

Bears are an exception to this rule; species in the family Ursidae are famous for their ability to survive unfavorable environmental conditions of low temperatures and limited nutrition availability during winter by means of hibernation. During that time, bears go through a series of physiological, morphological and behavioral changes.[10] Their ability to maintain skeletal muscle number and size at time of disuse is of a significant importance.

During hibernation, bears spend four to seven months of inactivity and anorexia without undergoing muscle atrophy and protein loss.[9] There are a few known factors that contribute to the sustaining of muscle tissue. During the summer period, bears take advantage of the nutrition availability and accumulate muscle protein. The protein balance at time of dormancy is also maintained by lower levels of protein breakdown during the winter time.[9] At times of immobility, muscle wasting in bears is also suppressed by a proteolytic inhibitor that is released in circulation.[8] Another factor that contributes to the sustaining of muscle strength in hibernating bears is the occurrence of periodic voluntary contractions and involuntary contractions from shivering during torpor.[11] The three to four daily episodes of muscle activity are responsible for the maintenance of muscle strength and responsiveness in bears during hibernation.[11]

Strength

A display of "strength" (e.g. lifting a weight) is a result of three factors that overlap: **physiological strength** (muscle size, cross sectional area, available crossbridging, responses to training), **neurological strength** (how strong or weak is the signal that tells the muscle to contract), and **mechanical strength** (muscle's force angle on the lever, moment arm length, joint capabilities). Contrary to popular belief, the number of muscle fibres cannot be increased through exercise; instead the muscle cells simply get bigger. Muscle fibres have a limited capacity for growth through hypertrophy and some believe they split through hyperplasia if subject to increased demand.

The "strongest" human muscle

Since three factors affect muscular strength simultaneously and muscles never work individually, it is misleading to compare strength in individual muscles, and state that one is the "strongest". But below are several muscles whose strength is noteworthy for different reasons.

- In ordinary parlance, muscular "strength" usually refers to the ability to exert a force on an external object—for example, lifting a weight. By this definition, the masseter or jaw muscle is the strongest. The 1992 Guinness Book of Records records the achievement of a bite strength of 4,337 N (975 lb_f) for 2 seconds. What distinguishes the masseter is not anything special about the muscle itself, but its advantage in working against a much shorter lever arm than other muscles.
- If "strength" refers to the force exerted by the muscle itself, e.g., on the place where it inserts into a bone, then the strongest muscles are those with the largest cross-sectional area. This is because the tension exerted by an individual skeletal muscle fiber does not vary much. Each fiber can exert a force on the order of 0.3 micronewton. By this definition, the strongest muscle of the body is usually said to be the quadriceps femoris or the gluteus maximus.
- A shorter muscle will be stronger "pound for pound" (i.e., by weight) than a longer muscle. The myometrial layer of the uterus may be the strongest muscle by weight in the human body. At the time when an infant is delivered, the entire human uterus weighs about 1.1 kg (40 oz). During childbirth, the uterus exerts 100 to 400 N (25 to 100 lbf) of downward force with each contraction.
- The external muscles of the eye are conspicuously large and strong in relation to the small size and weight of the eyeball. It is frequently said that they are "the strongest muscles for the job they have to do" and are sometimes claimed to be "100 times stronger than they need to be." However, eye movements (particularly saccades used on facial scanning and reading) do require high speed movements, and eye muscles are exercised nightly during rapid eye movement sleep.
- The statement that "the tongue is the strongest muscle in the body" appears frequently in lists of surprising facts, but it is difficult to find any definition of "strength" that would make this statement true. Note that the tongue consists of sixteen muscles, not one.
- The heart has a claim to being the muscle that performs the largest quantity of physical work in the course of a lifetime. Estimates of the power output of the human heart range from 1 to 5 watts. This is much less than the maximum power output of other muscles; for example, the quadriceps can produce over 100 watts, but only for a few minutes. The heart does its work continuously over an entire lifetime without pause, and thus does "outwork" other muscles. An output of one watt continuously for eighty years yields a total work output of two and a half gigajoules.

Efficiency

The efficiency of human muscle has been measured (in the context of rowing and cycling) at 18% to 26%.[12] The efficiency is defined as the ratio of mechanical work output to the total metabolic cost, as can be calculated from oxygen consumption. This low efficiency is the result of about 40% effency of generating ATP from food energy, losses in converting energy from ATP into mechanical work inside the muscle, and mechanical losses inside the body. The latter two losses are dependent on the type of exercise and the type of muscle fibers being used (fast-twitch or slow-twitch). For an overal efficiency of 20 percent, one watt of mechanical power is equivalent to 4.3 kcal per hour. For example, a manufacturer of rowing equipment shows burned calories as four times the actual mechanical work, plus 300 kcal per hour,[13] which amounts to about 20 percent efficiency at 250 watts of mechanical output.

Density of muscle tissue compared to adipose tissue

The density of mammalian skeletal muscle tissue is about 1.06 kg/liter[14]. This can be contrasted with the density of adipose tissue (fat), which is 0.9196 kg/liter[15]. This makes muscle tissue approximately 15% denser than fat tissue.

Muscle evolution

Evolutionarily, specialized forms of skeletal and cardiac muscles predated the divergence of the vertebrate/arthropod evolutionary line.[16] This indicates that these types of muscle developed in a common ancestor sometime before 700 million years ago (mya). Vertebrate smooth muscle was found to have evolved independently from the skeletal and cardiac muscles.

See also

- Atrophy
- Bodybuilding
- Cross education
- Electroactive polymers (materials that behave like muscles, used in robotics research)
- Fascia
- Hand strength
- List of muscles of the human body
- Muscle atrophy
- Muscle memory
- Muscle tone (residual muscle tension)
- Musculoskeletal system
- Myopathy (pathology of muscle cells)
- Myotomy
- Phonomyography
- Preflexes
- Rapid plant movement
- Rohmert's law

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- University of Dundee article on performing neurological examinations (Quadriceps "strongest")
- Muscle efficiency in rowing
- Human Muscle Tutorial (clear pictures of main human muscles and their Latin names, good for orientation)
- Microscopic stains of skeletal and cardiac muscular fibers to show striations. Note the differences in myofibrilar arrangements.

Retrieved from "http://en.wikipedia.org/wiki/Muscle"
Categories: Muscular system | Tissues | Exercise physiology

List of neurological disorders

From Wikipedia, the free encyclopedia

This is a list of major and frequently observed neurological disorders (e.g., Alzheimer's disease), symptoms (e.g., back pain), signs (e.g., aphasia) and syndromes (e.g., Aicardi syndrome).

Contents: Top - 0–9 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A

- Abarognosis
- Acquired Epileptiform Aphasia
- Acute disseminated encephalomyelitis
- Adrenoleukodystrophy
- Agenesis of the corpus callosum
- Agnosia
- Aicardi syndrome
- Alexander disease
- Alpers' disease
- Alternating hemiplegia
- Alzheimer's disease
- Amyotrophic lateral sclerosis (see Motor Neurone Disease)
- Anencephaly
- Angelman syndrome
- Angiomatosis
- Anoxia
- Aphasia
- Apraxia
- Arachnoid cysts
- Arachnoiditis
- Arnold-Chiari malformation
- Arteriovenous malformation
- Asperger syndrome
- Ataxia Telangiectasia
- Attention Deficit Hyperactivity Disorder
- Autism
- Auditory processing disorder
- Autonomic Dysfunction

B

- Back Pain
- Batten disease
- Behcet's disease
- Bell's palsy
- Benign Essential Blepharospasm
- Benign Focal Amyotrophy
- Benign Intracranial Hypertension

- Bilateral frontoparietal polymicrogyria
- Binswanger's disease
- Blepharospasm
- Bloch-Sulzberger syndrome
- Brachial plexus injury
- Brain abscess
- Brain damage
- Brain injury
- Brain tumor
- Spinal tumor
- Brown-Séquard syndrome

C

- Canavan disease
- Carpal tunnel syndrome (CTS)
- Causalgia
- Central pain syndrome
- Central pontine myelinolysis
- Centronuclear myopathy
- Cephalic disorder
- Cerebral aneurysm
- Cerebral arteriosclerosis
- Cerebral atrophy
- Cerebral gigantism
- Cerebral palsy
- Cerebral vasculitis
- Charcot-Marie-Tooth disease
- Chiari malformation
- Chorea
- Chronic fatigue syndrome
- Chronic inflammatory demyelinating polyneuropathy (CIDP)
- Chronic pain
- Coffin Lowry syndrome
- Coma
- Complex regional pain syndrome
- Compression neuropathy
- Congenital facial diplegia
- Corticobasal degeneration
- Cranial arteritis
- Craniosynostosis
- Creutzfeldt-Jakob disease
- Cumulative trauma disorders
- Cushing's syndrome
- Cytomegalic inclusion body disease (CIBD)
- Cytomegalovirus Infection

D

- Dandy-Walker syndrome

- Dawson disease
- De Morsier's syndrome
- Dejerine-Klumpke palsy
- Dejerine-Sottas disease
- Delayed sleep phase syndrome
- Dementia
- Dermatomyositis
- Developmental dyspraxia
- Diabetic neuropathy
- Diffuse sclerosis
- Dysautonomia
- Dyscalculia
- Dysgraphia
- Dyslexia
- Dystonia

E

- Empty sella syndrome
- Encephalitis
- Encephalocele
- Encephalotrigeminal angiomatosis
- Encopresis
- Epilepsy
- Erb's palsy
- Erythromelalgia
- Essential tremor

F

- Fabry's disease
- Fahr's syndrome
- Fainting
- Familial spastic paralysis
- Febrile seizures
- Fibromyalgia
- Fisher syndrome
- Friedreich's ataxia

G

- Gaucher's disease
- Gerstmann's syndrome
- Giant cell arteritis
- Giant cell inclusion disease
- Globoid Cell Leukodystrophy
- Gray matter heterotopia
- Guillain-Barré syndrome

H

- HTLV-1 associated myelopathy
- Hallervorden-Spatz disease
- Head injury
- Headache
- Hemifacial Spasm
- Hereditary Spastic Paraplegia
- Heredopathia atactica polyneuritiformis
- Herpes zoster oticus
- Herpes zoster
- Hirayama syndrome
- Holoprosencephaly
- Huntington's disease
- Hydranencephaly
- Hydrocephalus
- Hypercortisolism
- Hypoxia

I

- Immune-Mediated encephalomyelitis
- Inclusion body myositis
- Incontinentia pigmenti
- Infantile phytanic acid storage disease
- Infantile Refsum disease
- Infantile spasms
- Inflammatory myopathy
- Intracranial cyst
- Intracranial hypertension

J

- Joubert syndrome

K

- Karak syndrome
- Kearns-Sayre syndrome
- Kennedy disease
- Kinsbourne syndrome
- Klippel Feil syndrome
- Krabbe disease
- Kugelberg-Welander disease
- Kuru

L

- Lafora disease
- Lambert-Eaton myasthenic syndrome
- Landau-Kleffner syndrome
- Lateral medullary (Wallenberg) syndrome
- Learning disabilities
- Leigh's disease
- Lennox-Gastaut syndrome
- Lesch-Nyhan syndrome
- Leukodystrophy
- Lewy body dementia
- Lissencephaly
- Locked-In syndrome
- Lou Gehrig's disease (See Motor Neurone Disease)
- Lumbar disc disease
- Lyme disease - Neurological Sequelae

M

- **Machado-Joseph disease** (Spinocerebellar ataxia type 3)
- Macrencephaly
- Macropsia
- Megalencephaly
- Melkersson-Rosenthal syndrome
- Menieres disease
- Meningitis
- Menkes disease
- Metachromatic leukodystrophy
- Microcephaly
- Micropsia
- Migraine
- Miller Fisher syndrome
- Mini-stroke (transient ischemic attack)
- Mitochondrial myopathy
- Mobius syndrome
- Monomelic amyotrophy
- Motor Neurone Disease
- Motor skills disorder
- Moyamoya disease
- Mucopolysaccharidoses
- Multi-infarct dementia
- Multifocal motor neuropathy
- Multiple sclerosis
- Multiple system atrophy
- Muscular dystrophy
- Myalgic encephalomyelitis
- Myasthenia gravis
- Myelinoclastic diffuse sclerosis
- Myoclonic Encephalopathy of infants
- Myoclonus
- Myopathy

- Myotubular myopathy
- Myotonia congenita

N

- Narcolepsy
- Neurofibromatosis
- Neuroleptic malignant syndrome
- Neurological manifestations of AIDS
- Neurological sequelae of lupus
- Neuromyotonia
- Neuronal ceroid lipofuscinosis
- Neuronal migration disorders
- Niemann-Pick disease
- Non 24-hour sleep-wake syndrome
- Nonverbal learning disorder

O

- O'Sullivan-McLeod syndrome
- Obsessive-compulsive diorder
- Occipital Neuralgia
- Occult Spinal Dysraphism Sequence
- Ohtahara syndrome
- Olivopontocerebellar atrophy
- Opsoclonus myoclonus syndrome
- Optic neuritis
- Orthostatic Hypotension
- Overuse syndrome

P

- Palinopsia
- Paresthesia
- Parkinson's disease
- Paramyotonia Congenita
- Paraneoplastic diseases
- Paroxysmal attacks
- Parry-Romberg syndrome
- Pelizaeus-Merzbacher disease
- Periodic Paralyses
- Peripheral neuropathy
- Persistent Vegetative State
- Pervasive developmental disorders
- Photic sneeze reflex
- Phytanic acid storage disease
- Pick's disease
- Pinched nerve
- Pituitary tumors

- PMG
- Polio
- Polymicrogyria
- Polymyositis
- Porencephaly
- Post-Polio syndrome
- Postherpetic Neuralgia (PHN)
- Postinfectious Encephalomyelitis
- Postural Hypotension
- Prader-Willi syndrome
- Primary Lateral Sclerosis
- Prion diseases
- Progressive hemifacial atrophy
- Progressive multifocal leukoencephalopathy
- Progressive Sclerosing Poliodystrophy
- Progressive Supranuclear Palsy
- Pseudotumor cerebri

Q

R

- Rabies
- Ramsay-Hunt syndrome (Type I and Type II)
- Rasmussen's encephalitis
- Reflex sympathetic dystrophy syndrome
- Refsum disease
- Repetitive motion disorders
- Repetitive stress injury
- Restless legs syndrome
- Retrovirus-associated myelopathy
- Rett syndrome
- Reye's syndrome
- Romberg syndrome

S

- Saint Vitus dance
- Sandhoff disease
- Schizophrenia
- Schilder's disease
- Schizencephaly
- Sensory integration dysfunction
- Septo-optic dysplasia
- Shaken baby syndrome
- Shingles
- Shy-Drager syndrome
- Sjögren's syndrome
- Sleep apnea

- Sleeping sickness
- Snatiation
- Sotos syndrome
- Spasticity
- Spina bifida
- Spinal cord injury
- Spinal cord tumors
- Spinal muscular atrophy
- Spinal stenosis
- Spinocerebellar ataxia
- Steele-Richardson-Olszewski syndrome
- Stiff-person syndrome
- Stroke
- Sturge-Weber syndrome
- Subacute sclerosing panencephalitis
- Subcortical arteriosclerotic encephalopathy
- Superficial siderosis
- Sydenham's chorea
- Syncope
- Synesthesia
- Syringomyelia

T

- Tardive dyskinesia
- Tay-Sachs disease
- Temporal arteritis
- Tetanus
- Tethered spinal cord syndrome
- Thomsen disease
- Thoracic outlet syndrome
- Tic Douloureux
- Todd's paralysis
- Tourette syndrome
- Toxic encephalopathy
- Transient ischemic attack
- Transmissible spongiform encephalopathies
- Transverse myelitis
- Traumatic brain injury
- Tremor
- Trigeminal neuralgia
- Tropical spastic paraparesis
- Trypanosomiasis
- Tuberous sclerosis
- bilateral schizencephaly

U

V

Y

Vascular Disorders

Vascular disorders that affect vision include central and branch retinal artery or vein occlusion, ischemic optic neuropathy, amaurosis fugax, occipital lobe stroke, and temporal arteritis (which occurs primarily in the elderly).

Atherosclerotic cardiovascular risk factors underlie almost all ophthalmic vascular disorders, and treatment focuses on management of these risk factors. The leading cause of death in patients with an ophthalmic vascular disorder is a cardiovascular disorder.

Retinal Artery Occlusion

Retinal artery occlusion causes painless, sudden, unilateral blindness.

The most common cause of retinal artery occlusion in the elderly is embolization of a thrombus or an atheroma from the carotid artery to the central retinal artery in the optic nerve head. Less common causes include temporal arteritis, optic neuritis, hypercoagulability, and, rarely, severely elevated intraocular pressure (IOP). Within an hour of occlusion, reactive arterial spasm ceases, and some blood flow is restored to the retina, which then appears relatively normal through an ophthalmoscope. However, within several hours the retina becomes edematous and gray because ischemia continues and retinal ganglion cells die. Because the retina in the foveal area contains no ganglion cells, the reddish underlying choroid remains visible, accounting for the characteristic, central, cherry-red spot surrounded by the gray retina. In 2 to 3 wk, the cherry-red spot disappears, and as the ganglion cells and their axons die, the optic nerve becomes white--the hallmark of primary optic atrophy.

A retinal artery branch may become occluded when an atheroma breaks off and passes through the central retinal artery. The occlusion (called a Hollenhorst plaque) can usually be seen as a refractile object in the branch. This finding indicates embolic activity, usually originating in the carotid system. The portion of the retina supplied by the occluded vessel stops functioning, resulting in a visual field defect that may not affect central vision.

Intervention is rarely possible because it is needed within 90 min of the occlusion to prevent retinal cell death. Rapidly reducing IOP by paracentesis plus vasodilators occasionally induces the embolus to move more peripherally, limiting vision loss in the affected area. Other treatments (eg, eyeball massage to improve O_2 delivery to tissues, CO_2 therapy to promote vasodilation, oral anticoagulants, thrombolytics) may be attempted. None has proved effective, and thrombolytics may have serious adverse effects. Patients should also be evaluated for atherosclerotic risk factors, which should be managed. Anticoagulants may help decrease risk of future emboli.

Retinal Vein Occlusion

Retinal vein occlusion causes painless, sudden, usually unilateral blindness.

Retinal vein occlusion (RVO) is probably the most common ophthalmic vascular disorder and occurs most commonly among people with atherosclerosis or glaucoma. Less common causes include leukemia and lymphoma, autoimmune disorders, and hypercoagulability disorders. RVO is classified as nonischemic or ischemic and may affect the central retinal vein or a branch.

Central RVO: Symptoms are similar to those of central retinal artery occlusion--sudden, painless, typically severe, unilateral vision loss. After central RVO occurs, some minimal vision may remain. About 10% of patients who develop central RVO in one eye later develop central RVO in the other eye.

Diagnosis is by ophthalmoscopy. Findings include distended, tortuous veins with massive hemorrhages and edema throughout the retina. The margins of the optic nerve become blurred, and the disk becomes swollen. Complete resorption of the hemorrhages and edema may take months or even years.

Fluorescein angiography helps differentiate nonischemic from ischemic forms. Ischemic RVO is characterized by relatively large retinal areas of capillary nonperfusion (which may require retinal laser photocoagulation if neovascularization occurs).

Prognosis is poor for elderly patients. About 25% develop a fibrovascular membrane that seals the aqueous humor outflow channels in the anterior chamber, resulting in a painful, secondary neovascular glaucoma in 3 to 6 mo; without treatment, blindness occurs within weeks. Patients with the nonischemic form have a better visual prognosis than those with the ischemic form.

Central RVO is most often treated with retinal laser photocoagulation, but its effectiveness is still being assessed. Systemic anticoagulation is not typically recommended. Intravitreal injection of triamcinolone acetonide may help decrease macular edema and improve visual acuity in some patients with central RVO.

Branch RVO: This disorder is similar to central RVO, but a branch of the central retinal vein is obstructed, most often the superior temporal branch. Vision is usually unaffected unless the retinal swelling impinges on the macula. Visual field defects, if present, depend on which retinal quadrant is involved. Neovascular glaucoma develops much less often in branch RVO than in central RVO.

Diagnosis is similar to that for central RVO. Ophthalmoscopic findings include exudates and hemorrhages confined to the involved retinal quadrant. Laser photocoagulation helps preserve vision.

Ischemic Optic Neuropathy

Ischemic optic neuropathy is inadequate blood supply to the optic nerve, sometimes causing blindness.

Ischemic optic neuropathy (ION) usually occurs only in people > 60. Most cases are nonarteritic and attributed to the effects of atherosclerosis, diabetes, or hypertension on optic nerve perfusion. Temporal arteritis causes about 5% of cases (arteritic ION).

Symptoms and signs are sudden, partial or complete vision loss, accompanied by swelling of the optic nerve head and often hemorrhage. Visual field defects may manifest as loss of half the visual field with a horizontal demarcation or as central or centrocecal (surrounding the natural blind spot) scotomata. Decreased vision is soon followed by pallor of the optic disk. When temporal arteritis is the cause, tenderness along the temporal artery may be noted, as well as headache, jaw pain while chewing, fever, malaise, anorexia, weight loss, and joint and muscle pain.

Diagnosis of nonarteritic ION is presumptive based on symptoms, signs, and presence of atherosclerotic risk factors. Diagnosis of arteritic ION is suggested by symptoms and signs and supported by a dramatically elevated Westergren ESR (normal: <= [age + 10]/2 for women and age/2 for men), an elevated C-reactive protein level, or both. Diagnosis is confirmed by temporal artery biopsy showing granulomatous inflammatory changes.

For nonarteritic ION, treatment does not help, but atherosclerotic risk factors should be managed. Most patients have at least some return of vision. Vision loss in the other eye may occur months or years later.

For arteritic ION, treatment is IV methylprednisolone (1 g/day for the first 3 to 5 days), after which oral prednisone (60 mg/day) can be used and tapered slowly over 3 to 12 mo or more, depending on response. Corticosteroids should be started immediately to protect the other eye; treatment should not be postponed for confirmation by biopsy. Long-term anticoagulant therapy may help selected elderly patients with a history of amaurosis fugax suggesting atheromatosis.

Amaurosis Fugax

Amaurosis fugax is acute vision loss lasting minutes to hours. It usually involves only part of a visual field of one eye.

Amaurosis fugax is a symptom that suggests retinal or optic nerve ischemia caused by atherosclerosis or an embolus in a carotid or thoracic aortic artery; this symptom occasionally indicates migraine headache. Patients > 50 are most susceptible. Risk factors are those for atherosclerosis and a family history of stroke.

Amaurosis fugax manifests as a dimming of vision in one eye, sometimes perceived as a window shade being partially or completely drawn over the eye. Recovery of clear vision begins within 5 to 10 min and occurs in the reverse order from the onset pattern. Several episodes may precede an attack of ischemic optic neuropathy or stroke. The annual risk of stroke after amaurosis fugax is about 2%. Amaurosis fugax can be bilateral if associated with low BP.

If amaurosis fugax is accompanied by hemiplegia on the side opposite the affected eye (indicating a transient ischemic attack), carotid stenosis on the side of the affected eye should be strongly suspected. Early recognition of severe carotid stenosis is important because without appropriate medical (eg, daily aspirin) and surgical (eg, carotid endarterectomy) intervention, permanent vision loss or hemiplegia often results. Aortic arch syndrome may be suspected if blackouts become increasingly frequent and are related to changes in posture (eg, suddenly sitting up or standing).

Occipital Lobe Stroke

Occipital lobe stroke is caused by a vascular lesion in the vertebral-basilar system and causes sudden, sometimes total blindness.

Infarction in one or both occipital lobes may result from local atheromas or emboli in the vertebral-basilar system. An occipital lobe stroke, usually resulting from posterior cerebral artery infarction, is characterized by sudden onset of congruous homonymous hemianopia. Total blindness occurs suddenly; however, within minutes, some vision returns in the ipsilateral homonymous visual field. Bilateral posterior occlusions usually occur simultaneously. Thrombosis of the basilar artery also causes bilateral homonymous hemianopia.

As with any ischemic stroke, treatment with aspirin or other anticoagulants is indicated. Some vision returns in almost all patients with cortical blindness.

This topic was last updated May 2006.

Symptoms

PAIN

Pain is the chief symptom of most musculoskeletal disorders. The pain may be mild or severe, local or widespread (diffuse). Although pain may be acute and short-lived, as is the case with most injuries, pain may be ongoing with chronic illnesses, such as rheumatoid arthritis.

Causes

Musculoskeletal pain can be caused by damage to bones, joints, muscles, tendons, ligaments, bursae, or nerves. Injuries are the most common cause. If no injury has occurred or if pain persists for more than a few days, then another cause is often responsible.

Bone pain is usually deep, penetrating, or dull. It commonly results from injury. Other less common causes of bone pain include bone infection (osteomyelitis) and tumors.

Muscle pain is often less intense than that of bone pain but can be very unpleasant. For example, a muscle spasm or cramp (a sustained painful muscle contraction) in the calf is an intense pain that is commonly called a charleyhorse. Pain can occur when a muscle is affected by an injury, an autoimmune reaction (for example, polymyositis or dermatomyositis), loss of blood flow to the muscle, infection, or invasion by a tumor.

Tendon and ligament pain is often less intense than bone pain. It is often worse when the affected tendon or ligament is stretched or moved. Common causes of tendon pain include tendinitis, tenosynovitis, lateral and medial epicondylitis, and tendon injuries. Common causes of ligament pain include injuries (sprains).

Fibromyalgia may cause pain in the muscles, tendons, or ligaments. The pain is usually in multiple locations and may be difficult to describe precisely. Affected people usually have other symptoms.

Virtually all joint injuries and diseases produce a stiff, aching pain, often referred to as "arthritic" pain. The pain is worse when the joint is moved and may range from mild to severe. With some conditions, there may be swelling of the joint along with the pain. Joint inflammation (arthritis) is a common cause of joint pain. There are many types of arthritis, including rheumatoid and other types of inflammatory arthritis, osteoarthritis, infectious arthritis, and arthritis due to gout or pseudogout. Other causes of joint pain include autoimmune and vasculitic disorders (for example, systemic lupus erythematosus, polymyalgia rheumatica, and polyarteritis nodosa), avascular necrosis of bone, and injuries (for example, dislocations, sprains, and fractures affecting the portion of the bone inside the joint). Sometimes, pain originating in structures near the joint, such as tendons and bursae, seems to be coming from the joint.

Some musculoskeletal disorders cause pain by compressing nerves. These conditions include the "tunnel syndromes" (for example, carpal tunnel syndrome, cubital tunnel syndrome, and tarsal tunnel syndrome). The pain tends to radiate along the path supplied by the nerve and may be burning.

Bursal pain can be caused by bursitis or fibromyalgia. Usually, bursal pain is worse with movement involving the bursa. There may be swelling.

Sometimes, pain that seems to be musculoskeletal is actually caused by a disorder in another organ system. For instance, shoulder pain may be caused by a disorder affecting the spleen or gallbladder. Back pain may be caused by an abdominal aortic aneurysm. Arm pain may be caused by a heart attack (myocardial infarction). Additionally, sometimes pain that seems to be coming from one part of the musculoskeletal system actually comes from another part. For instance, knee pain in an adolescent may be caused by a disorder of the hip called slipped capital femoral epiphysis.

Evaluation and Treatment

Sometimes, the type of pain suggests where the pain has originated. For example, pain that worsens with motion suggests a musculoskeletal disorder. Pain with muscle spasm suggests that pain is caused by a muscle disorder. The site of swelling or the location of tenderness when the doctor palpates the area (for example, a joint, ligament, or bursa) often indicates the source of pain. However, often these characteristics of pain do not indicate its origin or cause. Thus, doctors usually base a specific diagnosis on the presence of other symptoms and often on the results of laboratory tests and x-rays. For example, Lyme disease often produces joint pain and a bull's eye—like skin rash; blood tests show antibodies to the bacteria that cause Lyme disease. Gout is characterized by a sudden attack of pain, swelling, and redness in the joint at the base of the big toe or other joints; tests of the joint fluid generally show the presence of uric acid crystals.

Blood tests are useful only in supporting the diagnosis made by the doctor after an examination. A diagnosis is not made or confirmed by a blood test alone. Examples of such blood tests include rheumatoid factor and antinuclear antibodies, which are used to help diagnose many of the common causes of arthritis, such as rheumatoid arthritis and systemic lupus erythematosus. Usually, such tests are recommended only if symptoms specifically suggest such a disorder or are persistent or unusually severe.

X-rays are primarily used to take images of bones; they do not show muscles, tendons and ligaments. X-rays are usually taken if the doctor suspects a fracture or, less commonly, a bone tumor or infection or to look for changes that confirm a person has a certain kind of arthritis (for example, rheumatoid arthritis or osteoarthritis).

A computed tomography (CT) scan is more sensitive than an x-ray and is often used to obtain more detail about a fracture or bone problem that was found with plain x-rays.

Unlike plain x-rays, magnetic resonance imaging (MRI) can identify abnormalities of soft tissues such as muscles, bursae, ligaments, and tendons. Thus, MRI may be used when the doctor suspects damage to a major ligament or tendon, or damage to important structures inside a joint.

Pain is usually best relieved by treating its cause. In addition, the doctor may recommend analgesics (see Pain: Treatment) such as acetaminophen , nonsteroidal anti-inflammatory drugs (NSAIDs), or, if pain is severe, opioids. Depending on the cause, applying cold or heat or immobilizing the joint may help relieve musculoskeletal pain.

DIFFICULTY MOVING

A person may have difficulty moving all or part of the body.

Causes

Moving may be difficult because of disorders that restrict joint motion or that produce weakness. Movement may also be limited when motion causes pain. Certain nervous system abnormalities interfere with movement without causing pain or weakness. For example, Parkinson's disease causes muscle stiffness, tremor, and difficulty initiating movement.

Joint Disorders: A joint that is stiffened by scar tissue from a previous injury can have limited range and speed of motion. When a normal joint is not used, it may stiffen. For example when a person's arm is paralyzed by a stroke or even placed in a sling for a period of time, the joints in the shoulder and elbow may develop scar tissue that freezes the joint in place if the arm is not regularly flexed and stretched. Fluid that accumulates in a joint from arthritis or an acute injury can interfere with joint motion. A piece of torn cartilage from an injury (typically in the knee) may block joint motion.

Weakness: Although many people complain of weakness when they feel tired or run down, true weakness means that full effort does not generate normal muscle contractions. Normal voluntary muscle contraction requires that the brain generate a signal that then travels through the spinal cord and nerves to reach a normally functioning muscle. Therefore, true weakness can result from injury or disease affecting the nervous system, muscles, or connections between them (neuromuscular junction).

Brain problems include strokes, injuries, tumors, and degenerative disorders (such as multiple sclerosis, which also can affect the spinal cord and nerves). Spinal cord disorders include injury, bleeding, and tumors. Spinal nerve roots can be affected by a ruptured intervertebral disk, and peripheral nerves by injury or polyneuropathy. The neuromuscular junction can be affected by myasthenia gravis, drugs such as botulinum toxin injections, and certain poisons such as organophosphates (used in nerve gas and many insecticides).

Muscle disorders causing weakness include muscular dystrophy and polymyositis. The muscle weakness that commonly occurs following immobilization (in a cast or from prolonged bed rest) and in old age is due to a reduction in muscle mass (sarcopenia) and results from lack of use. The remaining muscle mass functions normally, but there is not an adequate amount.

Weakness may be limited to one extremity or part of an extremity, as is typically the case when a single nerve, joint, or muscle is affected, or diffuse, as occurs in widespread neurologic or muscular diseases.

Pain: People with pain in the muscles, ligaments, bones, or joints tend to consciously and unconsciously limit motion. This often gives the impression of weakness even though the nervous system and muscles are able to generate movement.

Evaluation and Treatment

Doctors can often diagnose weakness based on the person's symptoms and the results of the physical examination. Doctors first try to determine whether the person can contract the muscles normally. If the person can contract the muscles normally but has trouble moving a joint, the doctor tries to move the joint for the person while the person relaxes (passive motion). If motion is painful, inflammation may be the problem. If passive motion causes little pain but is blocked, joint contracture (for example, due to scar tissue) may be the problem.

If passive motion is neither painful nor blocked, the person is giving full effort, and there is no sign of Parkinson's disease or other neurologic disorder causing difficulty initiating movement, then true muscle weakness is likely. The cause of true muscle weakness can often be determined by noting the person's symptoms, which muscles are affected, whether muscles have shrunk, and muscle tone and by testing the person's reflexes with a reflex hammer. For example, if weakness affects mainly the large muscles such as the hips, thighs, and shoulders, the cause may be a disorder producing widespread damage to muscles. If weakness affects mainly the eye muscles (causing double vision), the cause may be a disorder of the neuromuscular junction. If weakness affects mainly the fingers, hands, and feet, particularly if there is loss of sensation, the cause may be a disorder that damages many nerves (polyneuropathy). The nerves to the fingers, hands, and feet are the body's longest and thus the most vulnerable peripheral nerves. If muscles have shrunk, the disorder causing the problem has been present for months or years. If the person's reflexes are decreased or slow, the cause may be nerve damage. If reflexes are increased or more rapid than expected, the cause may be spinal cord or brain damage. The doctor checks muscle tone by testing passive movement. Muscle tone may be decreased when weakness results from a peripheral nerve disorder. Muscle tone may be increased when weakness results from a spinal cord or brain disorder.

If the cause is still not clear, other tests can help. Disorders of the brain or spinal cord are diagnosed using neuroimaging tests such as CT or MRI. To differentiate between weakness caused by damage to the peripheral nerves, muscles, and neuromuscular junction, tests such as electromyography and nerve conduction velocity (see Diagnosis of Brain, Spinal Cord, and Nerve Disorders: Electromyography and Nerve Conduction Studies) usually help. Certain other disorders (for example, low blood levels of potassium or vitamin D) are diagnosed with blood tests.

For joints that are fixed, joint flexibility can be maximized by stretching exercises and physical therapy. If the joint's range of motion is severely restricted by scar tissue, surgery may be necessary. The only way to relieve weakness is to treat the disorder causing it.

Classifying Weakness

Underlying Problem	Example	Description
Muscle disease	Muscular dystrophies	A group of inherited muscle disorders that leads to muscle weakness of varying severity
	Infections or inflammatory disorders (acute viral myositis, polymyositis)	Muscles tender or painful and weak
Widespread muscle damage caused by use of a drug (drug-induced myopathy)	Myopathy due to corticosteroids, statins, lithium, alcohol, clofibrate, colchicine	Weakness usually begins at the hips and may spread to other muscles; pain may be absent
Low blood levels of potassium	Hypokalemic myopathy (caused by certain disorders or use of diuretics)	The person experiences periods of weakness throughout the body
Abnormal levels of thyroid hormone	High levels of thyroid hormone (hyperthyroidism) or low levels of thyroid hormone (hypothyroidism)	High or low levels of thyroid hormone produce weakness that is usually more pronounced in the shoulders and hips than in the hands and feet
Low levels of vitamin D	Osteomalacia	Pain in the back, with weakness in the legs; rarely pain throughout the body
Disease of the neuromuscular junction	Myasthenia gravis, curare toxicity, Eaton-Lambert syndrome, insecticide poisoning, botulism, diphtheria	Weakness or paralysis affecting all or many muscles; sometimes affects mainly eye muscles
Damage to a single nerve (mononeuropathy)	Diabetic neuropathy, local pressure	Weakness or paralysis of muscles and loss of sensation in the area served by the injured nerve
Damage to many nerves (polyneuropathy)	Diabetes, Guillain Barre syndrome, folate deficiency, toxins, drugs	Weakness or paralysis of muscles and loss of sensation in the areas served by the affected nerves

Spinal nerve root damage	Ruptured disk in the spine of the neck or lower back	Pain in the neck and weakness or numbness in an arm, low back pain shooting down the leg (sciatica), and leg weakness or numbness
Degeneration of nerve cell bodies in the spinal cord	Amyotrophic lateral sclerosis	Progressive loss of muscle bulk and strength, but no loss of sensation
Spinal cord damage	Trauma to the neck or back spinal cord tumors, spinal stenosis, multiple sclerosis, transverse myelitis, vitamin B_{12} deficiency	Weakness or paralysis of the arms and legs below the level of injury, progressive loss of sensation below the level of injury, back pain; bowel, bladder, and sexual function are affected
Brain damage	Strokes, tumors, head trauma, multiple sclerosis, infections	Weakness or paralysis of muscles in the area served by the injured part of the brain, often with other symptoms of brain damage
Psychologic problems	Depression, imagined symptoms or hysteria (conversion reaction)	Complaint of whole-body weakness or paralysis with no evidence of nerve damage

JOINT STIFFNESS

Stiffness is the feeling that motion of a joint is limited or difficult. The feeling is not caused by weakness or reluctance to move the joint due to pain. Some people with stiffness are capable of moving the joint through its full range of motion. Joint stiffness usually occurs or is worse immediately after awakening or resting. Stiffness is common with arthritis. Morning stiffness commonly occurs with rheumatoid arthritis and other types of inflammatory arthritis in which stiffness typically occurs on arising and gradually lessens with activity only after an hour or two.

Doctors can sometimes diagnose the cause of stiffness by the person's symptoms and the results of a physical examination. The person is examined to make sure that the problem is not pain with motion or weakness. Because arthritis is often the cause, blood tests (for example, rheumatoid factor and antinuclear antibodies) and x-rays may be done.

Stiffness is relieved by treating the disorder causing it. Stretching, physical therapy, and taking a hot shower on arising may improve the ability to perform activities that require flexibility.

JOINT NOISES

Joint noises, such as creaks and clicks, are common in many people, but they can also occur with specific problems of the joints. For example, the base of the knee cap may creak when it is damaged by osteoarthritis, and the jaw may click in a person who has temporomandibular joint disorder. Doctors ask about the person's symptoms and perform an examination to determine whether a joint noise is a symptom of a certain disorder. Further evaluation and treatment are needed only if the evaluation suggests a significant joint problem. Joint noises themselves do not require treatment.

Last full review/revision September 2006 by Michael Jacewicz, MD

Back to Top

Previous Diagnosis

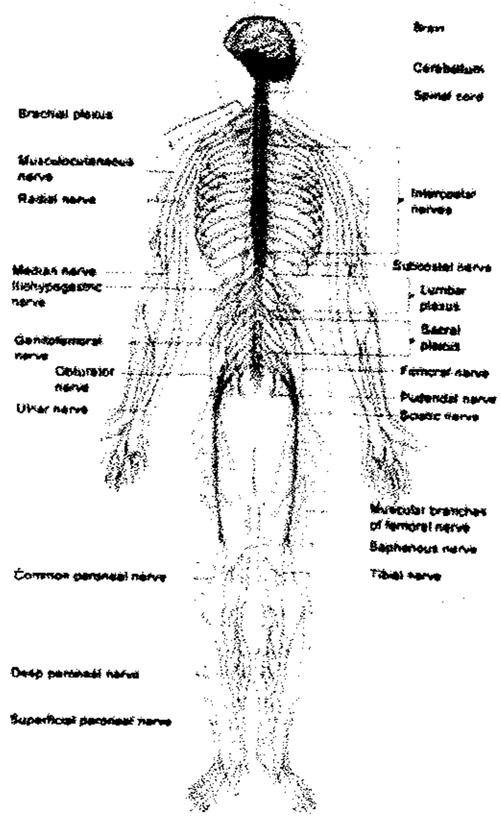
Audio Figures Photographs Pronunciations Sidebar Tables Videos

Peripheral nervous system

From Wikipedia, the free encyclopedia

The **peripheral nervous system (PNS)** resides or extends outside the central nervous system (CNS), which consists of the brain and spinal cord.[1] The main function of the PNS is to connect the CNS to the limbs and organs. Unlike the central nervous system, the PNS is not protected by bone or by the blood-brain barrier, leaving it exposed to toxins and mechanical injuries. The peripheral nervous system is divided into the somatic nervous system and the autonomic nervous system; some textbooks also include sensory systems.[2]

Brain: Peripheral nervous system



The Human Nervous System. Blue is PNS while red is CNS.

Latin *Pars peripherica; Systema nervosum periphericum*

Contents

General classification

By direction

There are two types of directions of the neurons: sensory neurons are afferent (i.e. relaying impulses TO the central nervous system), motor neurons are efferent (i.e. relaying impulses FROM the central nervous system). However, there are relay neurons in the CNS as well .

By function

The peripheral nervous system is functionally as well as structurally divided into the somatic nervous system and autonomic nervous system. The somatic nervous system is responsible for coordinating the body movements, and also for receiving external stimuli. It is the system that regulates activities that are under conscious control. The autonomic nervous system is then split into the sympathetic division, parasympathetic division, and enteric division. The *sympathetic nervous system* responds to impending danger or stress, and is responsible for the increase of one's heartbeat and blood pressure, among other

Headache

From Wikipedia, the free encyclopedia

In medicine a **headache** or **cephalalgia** is a symptom of a number of different conditions of the head[1]. Some of the causes are benign while others are medical emergencies.

There are a number of different classification systems for headaches. The most well-recognized is that of the International Headache Society.

Treatment of a headache depends on the underlying etiology or cause, but commonly involves analgesics.

Headache

ICD-10	G43.-G44., R51.
ICD-9	339, 784.0
DiseasesDB	19825
MedlinePlus	003024
eMedicine	neuro/517 neuro/70
MeSH	D006261

Contents

Classification

The first recorded classification system that resembles the modern ones was published by Thomas Willis, in *De Cephalagia* in 1672. In 1787 Christian Baur generally divided headaches into idiopathic (primary headaches) and symptomatic (secondary ones), and defined 84 categories.[2]

Today headaches are most thoroughly classified by the International Headache Society's International Classification of Headache Disorders (ICHD), which published the second edition in 2004.[3] This classification is accepted by the WHO.[4]

Other classification systems exist. One of the first published attempts was in 1951.[5] The National Institutes of Health developed a classification system in 1962.

Headaches can also be classified by severity and acuity of onset. Headaches that are both severe and acute are known as thunderclap headaches.

Before forming three cords

The first nerve off the brachial plexus, or plexus brachialis, is the dorsal scapular nerve, arising from C5 nerve root, and innervating the rhomboids and the levator scapulae muscles. The long thoracic nerve arises from C5, C6 and C7 to innervate the serratus anterior. The brachial plexus first forms three trunks, the superior trunk, composed of the C5 and C6 nerve roots, the middle trunk, made of the C7 nerve root, and the inferior trunk, made of the C8 and T1 nerve roots. The suprascapular nerve is an early branch of the superior trunk. It innervates the suprascapular and infrascapular muscles, part of the rotator cuff. The trunks reshuffle as they traverse towards the arm into cords. There are three of them. The lateral cord is made up of fibers from the superior and middle trunk. The posterior cord is made up of fibers from all three trunks. The medial cord is composed of fibers solely from the inferior trunk.

Lateral cord

The lateral cord gives rise to the following nerves:

- The lateral pectoral nerve, C5, C6 and C7 to the pectoralis major muscle, or musculus pectoralis major.
- The musculocutaneous nerve which innervates the biceps muscle
- The median nerve, partly. The other part comes from the medial cord. See below for details.

Posterior cord

The posterior cord gives rise to the following nerves:

- The upper subscapular nerve, C7 and C8, to the subscapularis muscle, or musculus supca of the rotator cuff.
- The lower subscapular nerve, C5 and C6, to the teres major muscle, or the musculus teres major.
- The thoracodorsal nerve, C6, C7 and C8, to the latissimus dorsi muscle, or musculus latissimus dorsi.
- The axillary nerve, which supplies sensation to the shoulder and motor to the deltoid muscle or musculus deltoideus, and the teres minor muscle, or musculus teres minor, also of the rotator cuff.
- The radial nerve, or nervus radialis, which innervates the triceps brachii muscle, the brachioradialis muscle, or musculus brachioradialis,, the extensor muscles of the fingers and wrist (extensor carpi radialis muscle), and the extensor and abductor muscles of the thumb. See radial nerve injuries.

Medial cord

The medial cord gives rise to the following nerves:

- The median pectoral nerve, C8 and T1, to the pectoralis muscle
- The medial brachial cutaneous nerve, T1
- The medial antebrachial cutaneous nerve, C8 and T1
- The median nerve, partly. The other part comes from the lateral cord. C7, C8 and T1 nerve roots. The first branch of the median nerve is to the pronator teres muscle, then the flexor carpi radialis, the palmaris longus and the flexor digitorum superficialis. The median nerve provides sensation to the anterior palm, the anterior thumb, index finger and middle finger. It is the nerve compressed in carpal tunnel syndrome.
- The ulnar nerve originates in nerve roots C7, C8 and T1. It provides sensation to the ring and

physiological changes, along with the sense of excitement one feels due to the increase of adrenaline in the system. The *parasympathetic nervous system*, on the other hand, is evident when a person is resting and feels relaxed, and is responsible for such things as the constriction of the pupil, the slowing of the heart, the dilation of the blood vessels, and the stimulation of the digestive and genitourinary systems. The role of the *enteric nervous system* is to manage every aspect of digestion, from the esophagus to the stomach, small intestine and colon.

Naming of specific nerves

Ten out of the twelve cranial nerves originate from the brainstem, and mainly control the functions of the anatomic structures of the head with some exceptions. The nuclei of cranial nerves I and II lie in the forebrain and thalamus, respectively, and are thus not considered to be true cranial nerves. CN X (10) receives visceral sensory information from the thorax and abdomen, and CN XI (11) is responsible for innervating the sternocleidomastoid and trapezius muscles, neither of which is exclusively in the head.

Spinal nerves take their origins from the spinal cord. They control the functions of the rest of the body. In humans, there are 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal. In the cervical region, the spinal nerve roots come out *above* the corresponding vertebrae (i.e. nerve root between the skull and 1st cervical vertebrae is called spinal nerve C1). From the thoracic region to the coccygeal region, the spinal nerve roots come out *below* the corresponding vertebrae. It is important to note that this method creates a problem when naming the spinal nerve root between C7 and T1 (so it is called spinal nerve root C8). In the lumbar and sacral region, the spinal nerve roots travel within the dural sac and they travel below the level of L2 as the cauda equina.

Cervical spinal nerves (C1-C4)

Further information: Cervical plexus

The first 4 cervical spinal nerves, C1 through C4, split and recombine to produce a variety of nerves that subserve the neck and back of head.

Spinal nerve C1 is called the suboccipital nerve which provides motor innervation to muscles at the base of the skull. C2 and C3 form many of the nerves of the neck, providing both sensory and motor control. These include the greater occipital nerve which provides sensation to the back of the head, the lesser occipital nerve which provides sensation to the area behind the ears, the greater auricular nerve and the lesser auricular nerve. See occipital neuralgia. The phrenic nerve arises from nerve roots C3, C4 and C5. It innervates the diaphragm, enabling breathing. If the spinal cord is transected above C3, then spontaneous breathing is not possible. See myelopathy

Brachial plexus (C5-T1)

Further information: Brachial plexus

The last four cervical spinal nerves, C5 through C8, and the first thoracic spinal nerve, T1,combine to form the brachial plexus, or plexus brachialis, a tangled array of nerves, splitting, combining and recombining, to form the nerves that subserve the arm and upper back. Although the brachial plexus may appear tangled, it is highly organized and predictable, with little variation between people. See brachial plexus injuries.

pinky fingers. It innervates the flexor carpi ulnaris muscle, the flexor digitorum profundus muscle to the ring and pinky fingers, and the intrinsic muscles of the hand (the interosseous muscle, the lumbrical muscles and the flexor pollicus brevis muscle). This nerve traverses a groove on the elbow called the cubital tunnel, also known as the funny bone. Striking the nerve at this point produces an unpleasant sensation in the ring and little finger.

Neurotransmitters

The main neurotransmitters of the peripheral nervous system are acetylcholine and noradrenaline. However, there are several other neurotransmitters as well, jointly labeled Non-noradrenergic, non-cholinergic (NANC) transmitters. Examples of such transmitters include non-peptides: ATP, GABA, dopamine, NO, and peptides: neuropeptide Y, VIP, GnRH, Substance P and CGRP. [3]

References

1. ^ *peripheral nervous system* at Dorland's Medical Dictionary
2. ^ Maton, Anthea; Jean Hopkins, Charles William McLaughlin, Susan Johnson, Maryanna Quon Warner, David LaHart, Jill D. Wright (1993). *Human Biology and Health*. Englewood Cliffs, New Jersey, USA: Prentice Hall. pp. 132–144. ISBN 0-13-981176-1.
3. ^ Pharmacology, (Rang, Dale, Ritter & Moore, ISBN 0443071454, 5:th ed., Churchill Livingstone 2003). Page 132.

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Symptoms

PAIN

Pain is the chief symptom of most musculoskeletal disorders. The pain may be mild or severe, local or widespread (diffuse). Although pain may be acute and short-lived, as is the case with most injuries, pain may be ongoing with chronic illnesses, such as rheumatoid arthritis.

Pronunciations
acetaminophen
amyotrophic lateral sclerosis
aneurysm
aortic aneurysm
arteritis

Causes

Musculoskeletal pain can be caused by damage to bones, joints, muscles, tendons, ligaments, bursae, or nerves. Injuries are the most common cause. If no injury has occurred or if pain persists for more than a few days, then another cause is often responsible.

Bone pain is usually deep, penetrating, or dull. It commonly results from injury. Other less common causes of bone pain include bone infection (osteomyelitis) and tumors.

Muscle pain is often less intense than that of bone pain but can be very unpleasant. For example, a muscle spasm or cramp (a sustained painful muscle contraction) in the calf is an intense pain that is commonly called a charleyhorse. Pain can occur when a muscle is affected by an injury, an autoimmune reaction (for example, polymyositis or dermatomyositis), loss of blood flow to the muscle, infection, or invasion by a tumor.

Tendon and ligament pain is often less intense than bone pain. It is often worse when the affected tendon or ligament is stretched or moved. Common causes of tendon pain include tendinitis, tenosynovitis, lateral and medial epicondylitis, and tendon injuries. Common causes of ligament pain include injuries (sprains).

Fibromyalgia may cause pain in the muscles, tendons, or ligaments. The pain is usually in multiple locations and may be difficult to describe precisely. Affected people usually have other symptoms.

Virtually all joint injuries and diseases produce a stiff, aching pain, often referred to as "arthritic" pain. The pain is worse when the joint is moved and may range from mild to severe. With some conditions, there may be swelling of the joint along with the pain. Joint inflammation (arthritis) is a common cause of joint pain. There are many types of arthritis, including rheumatoid and other types of inflammatory arthritis, osteoarthritis, infectious arthritis, and arthritis due to gout or pseudogout. Other causes of joint pain include autoimmune and vasculitic disorders (for example, systemic lupus erythematosus, polymyalgia rheumatica, and polyarteritis nodosa), avascular necrosis of bone, and injuries (for example, dislocations, sprains, and fractures affecting the portion of the bone inside the joint). Sometimes, pain originating in structures near the joint, such as tendons and bursae, seems to be coming from the joint.

Some musculoskeletal disorders cause pain by compressing nerves. These conditions include the "tunnel syndromes" (for example, carpal tunnel syndrome, cubital tunnel syndrome, and tarsal tunnel syndrome). The pain tends to radiate along the path supplied by the nerve and may be burning.

Bursal pain can be caused by bursitis or fibromyalgia. Usually, bursal pain is worse with movement involving the bursa. There may be swelling.

Sometimes, pain that seems to be musculoskeletal is actually caused by a disorder in another organ system. For instance, shoulder pain may be caused by a disorder affecting the spleen or gallbladder. Back pain may be caused by an abdominal aortic aneurysm. Arm pain may be caused by a heart attack (myocardial infarction). Additionally, sometimes pain that seems to be coming from one part of the musculoskeletal system actually comes from another part. For instance, knee pain in an adolescent may be caused by a disorder of the hip called slipped capital femoral epiphysis.

Evaluation and Treatment

Sometimes, the type of pain suggests where the pain has originated. For example, pain that worsens with motion suggests a musculoskeletal disorder. Pain with muscle spasm suggests that pain is caused by a muscle disorder. The site of swelling or the location of tenderness when the doctor palpates the area (for example, a joint, ligament, or bursa) often indicates the source of pain. However, often these characteristics of pain do not indicate its origin or cause. Thus, doctors usually base a specific diagnosis on the presence of other symptoms and often on the results of laboratory tests and x-rays. For example, Lyme disease often produces joint pain and a bull's eye—like skin rash; blood tests show antibodies to the bacteria that cause Lyme disease. Gout is characterized by a sudden attack of pain, swelling, and redness in the joint at the base of the big toe or other joints; tests of the joint fluid generally show the presence of uric acid crystals.

Blood tests are useful only in supporting the diagnosis made by the doctor after an examination. A diagnosis is not made or confirmed by a blood test alone. Examples of such blood tests include rheumatoid factor and antinuclear antibodies, which are used to help diagnose many of the common causes of arthritis, such as rheumatoid arthritis and systemic lupus erythematosus. Usually, such tests are recommended only if symptoms specifically suggest such a disorder or are persistent or unusually severe.

X-rays are primarily used to take images of bones; they do not show muscles, tendons and ligaments. X-rays are usually taken if the doctor suspects a fracture or, less commonly, a bone tumor or infection or to look for changes that confirm a person has a certain kind of arthritis (for example, rheumatoid arthritis or osteoarthritis).

A computed tomography (CT) scan is more sensitive than an x-ray and is often used to obtain more detail about a fracture or bone problem that was found with plain x-rays.

Unlike plain x-rays, magnetic resonance imaging (MRI) can identify abnormalities of soft tissues such as muscles, bursae, ligaments, and tendons. Thus, MRI may be used when the doctor suspects damage to a major ligament or tendon, or damage to important structures inside a joint.

Pain is usually best relieved by treating its cause. In addition, the doctor may recommend analgesics (see Pain: Treatment) such as acetaminophen , nonsteroidal anti-inflammatory drugs (NSAIDs), or, if pain is severe, opioids. Depending on the cause, applying cold or heat or immobilizing the joint may help relieve musculoskeletal pain.

DIFFICULTY MOVING

A person may have difficulty moving all or part of the body.

Causes

Moving may be difficult because of disorders that restrict joint motion or that produce weakness. Movement may also be limited when motion causes pain. Certain nervous system abnormalities interfere with movement without causing pain or weakness. For example, Parkinson's disease causes muscle stiffness, tremor, and difficulty initiating movement.

Joint Disorders: A joint that is stiffened by scar tissue from a previous injury can have limited range and speed of motion. When a normal joint is not used, it may stiffen. For example when a person's arm is paralyzed by a stroke or even placed in a sling for a period of time, the joints in the shoulder and elbow may develop scar tissue that freezes the joint in place if the arm is not regularly flexed and stretched. Fluid that accumulates in a joint from arthritis or an acute injury can interfere with joint motion. A piece of torn cartilage from an injury (typically in the knee) may block joint motion.

Weakness: Although many people complain of weakness when they feel tired or run down, true weakness means that full effort does not generate normal muscle contractions. Normal voluntary muscle contraction requires that the brain generate a signal that then travels through the spinal cord and nerves to reach a normally functioning muscle. Therefore, true weakness can result from injury or disease affecting the nervous system, muscles, or connections between them (neuromuscular junction).

Brain problems include strokes, injuries, tumors, and degenerative disorders (such as multiple sclerosis, which also can affect the spinal cord and nerves). Spinal cord disorders include injury, bleeding, and tumors. Spinal nerve roots can be affected by a ruptured intervertebral disk, and peripheral nerves by injury or polyneuropathy. The neuromuscular junction can be affected by myasthenia gravis, drugs such as botulinum toxin injections, and certain poisons such as organophosphates (used in nerve gas and many insecticides).

Muscle disorders causing weakness include muscular dystrophy and polymyositis. The muscle weakness that commonly occurs following immobilization (in a cast or from prolonged bed rest) and in old age is due to a reduction in muscle mass (sarcopenia) and results from lack of use. The remaining muscle mass functions normally, but there is not an adequate amount.

Weakness may be limited to one extremity or part of an extremity, as is typically the case when a single nerve, joint, or muscle is affected, or diffuse, as occurs in widespread neurologic or muscular diseases.

Pain: People with pain in the muscles, ligaments, bones, or joints tend to consciously and unconsciously limit motion. This often gives the impression of weakness even though the nervous system and muscles are able to generate movement.

Evaluation and Treatment

Doctors can often diagnose weakness based on the person's symptoms and the results of the physical examination. Doctors first try to determine whether the person can contract the muscles normally. If the person can contract the muscles normally but has trouble moving a joint, the doctor tries to move the joint for the person while the person relaxes (passive motion). If motion is painful, inflammation may be the problem. If passive motion causes little pain but is blocked, joint contracture (for example, due to scar tissue) may be the problem.

If passive motion is neither painful nor blocked, the person is giving full effort, and there is no sign of Parkinson's disease or other neurologic disorder causing difficulty initiating movement, then true muscle weakness is likely. The cause of true muscle weakness can often be determined by noting the person's symptoms, which muscles are affected, whether muscles have shrunk, and muscle tone and by testing the person's reflexes with a reflex hammer. For example, if weakness affects mainly the large muscles such as the hips, thighs, and shoulders, the cause may be a disorder producing widespread damage to muscles. If weakness affects mainly the eye muscles (causing double vision), the cause may be a disorder of the neuromuscular junction. If weakness affects mainly the fingers, hands, and feet, particularly if there is loss of sensation, the cause may be a disorder that damages many nerves (polyneuropathy). The nerves to the fingers, hands, and feet are the body's longest and thus the most vulnerable peripheral nerves. If muscles have shrunk, the disorder causing the problem has been present for months or years. If the person's reflexes are decreased or slow, the cause may be nerve damage. If reflexes are increased or more rapid than expected, the cause may be spinal cord or brain damage. The doctor checks muscle tone by testing passive movement. Muscle tone may be decreased when weakness results from a peripheral nerve disorder. Muscle tone may be increased when weakness results from a spinal cord or brain disorder.

If the cause is still not clear, other tests can help. Disorders of the brain or spinal cord are diagnosed using neuroimaging tests such as CT or MRI. To differentiate between weakness caused by damage to the peripheral nerves, muscles, and neuromuscular junction, tests such as electromyography and nerve conduction velocity (see Diagnosis of Brain, Spinal Cord, and Nerve Disorders: Electromyography and Nerve Conduction Studies) usually help. Certain other disorders (for example, low blood levels of potassium or vitamin D) are diagnosed with blood tests.

For joints that are fixed, joint flexibility can be maximized by stretching exercises and physical therapy. If the joint's range of motion is severely restricted by scar tissue, surgery may be necessary. The only way to relieve weakness is to treat the disorder causing it.

Classifying Weakness

Underlying Problem	Example	Description
Muscle disease	Muscular dystrophies	A group of inherited muscle disorders that leads to muscle weakness of varying severity
	Infections or inflammatory disorders (acute viral myositis, polymyositis)	Muscles tender or painful and weak
Widespread muscle damage caused by use of a drug (drug-induced myopathy)	Myopathy due to corticosteroids, statins, lithium, alcohol, clofibrate, colchicine	Weakness usually begins at the hips and may spread to other muscles; pain may be absent
Low blood levels of potassium	Hypokalemic myopathy (caused by certain disorders or use of diuretics)	The person experiences periods of weakness throughout the body
Abnormal levels of thyroid hormone	High levels of thyroid hormone (hyperthyroidism) or low levels of thyroid hormone (hypothyroidism)	High or low levels of thyroid hormone produce weakness that is usually more pronounced in the shoulders and hips than in the hands and feet
Low levels of vitamin D	Osteomalacia	Pain in the back, with weakness in the legs; rarely pain throughout the body
Disease of the neuromuscular junction	Myasthenia gravis, curare toxicity, Eaton-Lambert syndrome, insecticide poisoning, botulism, diphtheria	Weakness or paralysis affecting all or many muscles; sometimes affects mainly eye muscles
Damage to a single nerve (mononeuropathy)	Diabetic neuropathy, local pressure	Weakness or paralysis of muscles and loss of sensation in the area served by the injured nerve
Damage to many nerves (polyneuropathy)	Diabetes, Guillain-Barré syndrome, folate deficiency, toxins, drugs	Weakness or paralysis of muscles and loss of sensation in the areas served by the affected nerves
Spinal nerve root damage	Ruptured disk in the spine of	Pain in the neck and

	the neck or lower back	weakness or numbness in an arm, low back pain shooting down the leg (sciatica), and leg weakness or numbness
Degeneration of nerve cell bodies in the spinal cord	Amyotrophic lateral sclerosis	Progressive loss of muscle bulk and strength, but no loss of sensation
Spinal cord damage	Trauma to the neck or back, spinal cord tumors, spinal stenosis, multiple sclerosis, transverse myelitis, vitamin B_{12} deficiency	Weakness or paralysis of the arms and legs below the level of injury, progressive loss of sensation below the level of injury, back pain; bowel, bladder, and sexual function are affected
Brain damage	Strokes, tumors, head trauma, multiple sclerosis, infections	Weakness or paralysis of muscles in the area served by the injured part of the brain, often with other symptoms of brain damage
Psychologic problems	Depression, imagined symptoms or hysteria (conversion reaction)	Complaint of whole-body weakness or paralysis with no evidence of nerve damage

JOINT STIFFNESS

Stiffness is the feeling that motion of a joint is limited or difficult. The feeling is not caused by weakness or reluctance to move the joint due to pain. Some people with stiffness are capable of moving the joint through its full range of motion. Joint stiffness usually occurs or is worse immediately after awakening or resting. Stiffness is common with arthritis. Morning stiffness commonly occurs with rheumatoid arthritis and other types of inflammatory arthritis in which stiffness typically occurs on arising and gradually lessens with activity only after an hour or two.

Doctors can sometimes diagnose the cause of stiffness by the person's symptoms and the results of a physical examination. The person is examined to make sure that the problem is not pain with motion or weakness. Because arthritis is often the cause, blood tests (for example, rheumatoid factor and antinuclear antibodies) and x-rays may be done.

Stiffness is relieved by treating the disorder causing it. Stretching, physical therapy, and taking a hot shower on arising may improve the ability to perform activities that require flexibility.

JOINT NOISES

Joint noises, such as creaks and clicks, are common in many people, but they can also occur with specific problems of the joints. For example, the base of the knee cap may creak when it is damaged by osteoarthritis, and the jaw may click in a person who has temporomandibular joint disorder. Doctors ask about the person's symptoms and perform an examination to determine whether a joint noise is a symptom of a certain disorder. Further evaluation and treatment are needed only if the evaluation suggests a significant joint problem. Joint noises themselves do not require treatment.

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Back to Top

Previous: Diagnosis

Audio Figures Photographs Pronunciations Sidebar Tables Videos