Hand-Arm Vibration at a U.S. Army Installation

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Presentation Format

- Background
- Methodology
- Results
- Discussion
- Conclusion

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Literature

- Vibration from hand-held tools have negative impact on workers' health (Bernard, 1997, Griffin, 1990)
- Type of work determines vibration transmission to the hands and arms of operators. (ISO 5349-1)
- Many gloves claim to be anti-vibration gloves that don't meet ANSI S3.40/ISO 10819.
- Glove design will influence vibration exposure. (Pinto, 2001)
- Glove design will influence grip strength. (Fleming, 1997)

Background

- Bradley Fighting Vehicle Disassembly
- Expanding civilian workforce
- Physically demanding job
- Variety of vibrating tools
  - Grinders
  - Impact wrenches
- Variety of gloves used
  - Mechanic's gloves*
  - "Anti-vibration" gloves

*Preferred Gloves

Study Goal

- Test currently procured gloves at a Army Installation for vibration reducing effectiveness and productivity.
- Test as close to working conditions as possible.
- Determine optimum solution that incorporates both protection and productivity.
- Educate workers on the findings

Methodology

- Grip Strength Eval./Vibration Testing
  - Dependent variable
  - Participants
  - Test Apparatus/Equipment
  - Test procedures
  - Gloves

Grip Strength Evaluation

- Dependent Variables: Grip Strength (lbs_f)
- Test equipment JAMAR® grip strength meter

Grip Strength Participants

- Nine Volunteer Participants
  - Screened for medical conditions
  - Mechanics
  - Male, 8 Right-handed
  - 20 – 50 yrs old

    21-30 (3),

    31-40 (2),

    41-50 (4)

Test Procedure

- Gloves randomly assigned to worker for approx. 4 hour period (over three days)
  - Grip strength tested upon issuance
  - Grip strength tested upon return
  - Bare hand test beginning, middle end of each day
- Both left and right hand tested
- Average of three trials

Vibration Dependent Variable

- Vibration Exposure (m/s^2)
  - As measured in accordance with ANSI S2.73-2002 / ISO 10819:1996
  - Root sum of squares of measured r.m.s. ISO frequency-weighted acceleration values in three axes.

Vibration Participants

- Six Volunteer Participants*
  - Screened for medical conditions
  - Mechanics
  - Male
  - 20 – 50 yrs old

    21-30 (2), 31-40 (3), 41-50 (1)
  - Right handed

*3 of 6 from grip strength study

Vibration Test Equipment

- Larson Davis™ IHVM 100 Industrial Hygiene Vibration Monitor (IHVM)
- PCB Piezotronics™ Model 356A02 Triaxial Accelerometer with a sensitivity of 10 millivolts per gravity (mv/g)
- Hand Held Adapter (ISO 5349-2)
- PCB Piezotronics™

  Model 394B06 Calibrator
- PSI Gauge
- Calibrated Torque Wrench

Test Apparatus

- Armor plate from Bradley Fighting Vehicle (BFV)
- Six ¾ inch spacer bolts
- Ingersoll-Rand™ 2135Ti-2, ½ inch impact wrench
- Shop air used to power impact wrench

Test Procedure

- Each of the 6 bolts was pretorqued to 90 ft-lbs.
- Each participant was assigned a random sequence of the 7 conditions (6 gloves + bare hand).
- Line pressure (PSI) recorded before/after each run
- Accelerometer, adaptor and hand set into position
  - Slit made on side of glove
  - Adaptor placed on palmer side of metatarsal (fingers meet palm) (taped)
  - Hand placed on tool handle via predetermined position
- 6 bolt tightened for 7 seconds, middle 5 seconds recorded.
- Reglove/5 minute break/inspection of bolts/loosen/Retorque

Gloves

1. Black Maxx® by Viscolas®
2. Decade® by Chase Ergonomics#
3. Antivibration Air Glove™ by Impacto™ #
4. Griptec® by Ironclad®
5. Proflex® glove liner by Ergodyne® *
6. Authentic Mechanics Glove by Ringers®

ANSI S2.73-2002/
ISO 10819:1996
Certified Gloves

* Same material as in their ANSI Glove

Grip Strength Findings

- ANOVA to determine significant difference in:
  - Time of Day
  - Gloves

Time of Day

Tukey HSD

Time of Day	N	Subset 1
08:00:00	54	104.5123
12:00:00	81	104.0700
04:00:00	54	106.3827
p=		0.749

Time of Day	N	Subset 1
08:00:00	54	111.5123
12:00:00	81	108.9053
04:00:00	54	113.4568
p =		0.357

Glove Strength ANOVA

Tests of left Glove Effects

Dependent Variable: Average Left

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29756.369[a]	6	4959.395	32.187	.000
Intercept	1408522.593	1	1408522.593	9141.432	.000
Name	29756.369	6	4959.395	32.187	.000
Error	28042.774	182	154.081		
Total	2135858.000	189			
Corrected Total	57799.143	188			

a. R Squared = .515 (Adjusted R Squared = .499)

Tests of Right Glove Effects

Dependent Variable: Average Right

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	30031.302[a]	6	5005.217	27.871	.000
Intercept	1562548.760	1	1562548.760	8700.949	.000
Name	30031.302	6	5005.217	27.871	.000
Error	32684.237	182	179.584		
Total	2389313.000	189			
Corrected Total	62715.539	188			

a. R Squared = .479 (Adjusted R Squared = .462)

Glove Strength Post Hoc

Post Hoc Left Hand Glove

Tukey HSD

Name	N	Subset 2	3	4	5	1
Impacto	18	81.19				
Decade	18	83.89	83.89			
Black Max	18		95.52	95.52		
Ringer w liner	18			101.78	101.78	
Griptec Ironclad	18			106.98	106.98	106.98
Ringer	18				113.22	113.22
Bare Hand	81					115.21
Sig.		0.993	0.050	0.056	0.057	0.352

Post Hoc Right Hand Glove

Tukey HSD

Name	N	Subset 2	3	4	1
Impacto	18	90.81			
Decade	18	91.04			
Black Max	18	98.17	98.17		
Ringer w liner	18		106.15	106.15	
Griptec Ironclad	18		108.91	108.91	
Ringer	18			117.00	117.00
Bare Hand	81				122.87
Sig.		0.586	0.148	0.139	0.805

Vibration Results

Mean Vibration Exposure for Gloves

Dependent Variable: sum

Glove2	Mean	95% Confidence Interval	
		Lower Bound	Upper Bound
Bare hand	5.598	5.385	5.810
Blackmax	5.087	4.874	5.299
Decade	4.835	4.622	5.048
Impacto	5.087	4.874	5.299
ironclad	5.181	4.968	5.394
ringer	5.373	5.161	5.586
ringer liner	5.028	4.815	5.241

	Blackmax	Impacto
Mean	5.0867	5.0867
Median	5.125	5.035
Variance	0.647	0.879
Std. Dev.	0.80412	0.93754
Minimum	3.58	3.38
Maximum	6.76	7.47
Range	3.18	4.09

Vibration Results

ANOVA for Vibration Exposure

Dependent Variable: sum

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	80.397[a]	41	1.961	4.678	.000
Intercept	6735.166	1	6735.166	16068.352	.000
Glove2	13.346	6	2.224	5.307	.000
Subject	36.777	5	7.355	17.548	.000
Glove2 * Subject	30.274	30	1.009	2.408	.000
Error	88.023	210	.419		
Total	6903.586	252			
Corrected Total	168.420	251			

a. R Squared = .477 (Adjusted R Squared = .375)

Vibration Results

Post Hoc Test for Vibration Exposure

Tukey HSD[a,b]

Glove2	N	Subset 1	Subset 2	Subset 3
Decade	36	4.8350		
ringer liner	36	5.0281	5.0281	
Impacto	36	5.0867	5.0867	
Blackmax	36	5.0867	5.0867	
ironclad	36	5.1811	5.1811	5.1811
ringer	36		5.3733	5.3733
Bare hand	36			5.5978
Sig.		.265	.267	.096

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .419.

a. Uses Harmonic Mean Sample Size = 36.000.

b. Alpha = .05.

Discussion

Ansi limits

Daily Exposure Action Value = 2.5 m/s^2

Daily Exposure Limit Value = 5.0 m/s^2

Mean Vibration Exposure for Gloves

Dependent Variable: sum

Glove2	Mean	95% Confidence Interval	
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Bare hand	5.598	5.385	5.810
Blackmax	5.087	4.874	5.299
Decade	4.835	4.622	5.048
Impacto	5.087	4.874	5.299
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ringer	5.373	5.161	5.586
ringer liner	5.028	4.815	5.241

Discussion

Bare hand vib value = 5.60 m/s^2
Decade vib glove = 4.83 m/s^2

14 % decrease

Bare hand grip strength = 122.87 lbs_f
Decade grip strength = 90.81 lbs_f

26 % decrease

Bare hand vib value = 5.60 m/s^2
Ringer w/ liner vib glove* = 5.03 m/s^2

10 % decrease

Bare hand grip strength = 122.87 lbs_f
Ringer w/ liner grip strength = 106.15 lbs_f

14 % decrease

* Vib protection doesn't extend to fingers

Conclusions

- Current gloves used to protect the workers' hands from cuts and scrapes are ill-equipped to provide protection against hand-arm vibration.
- Statistical analysis showed that vibration exposure by workers using the current glove was similar to that of bare handed contact.
- Gloves that met ANSI standard statistically better than bare hand condition for vibration exposure but performed the poorest on grip strength tests.

Conclusions

- Current technology in anti-vibration gloves cause workers to chose between grip strength and vibration protection.
- Glove technology needs to improve.
- Based on study findings: use of mechanics glove with anti-vibration insert is the current “Best” solution.

Lessons Learned

- More trials
- More extensive variety of tools
- Longer duration of measurement
- Same subject pool

Future

- Evaluate and report on subjective assessments
- Evaluate and report on dexterity tests

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Questions?