Preliminary Characterization of Head-Supported Mass Exposure in a Simulated Dismounted Operating Environment

Bethany L. Shivers, Ph.D.[1], Adrienne M. Madison, Ph.D.[1,2], Patrick N. Estep[1,2], Frederick Brozoski[1], M. Reid Holderfield[1,3], Valeta Carol Chancey, Ph.D.[1]

[1]U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, AL
[2]Laulima Government Solutions, LLC, Orlando, FL
[3]Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, TN

Disclaimer

The opinions, interpretations, conclusions, and recommendations are those of the presenter and are not necessarily endorsed by the U.S. Army and/or the U.S. Department of Defense. Citation of trade names in this presentation does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Acknowledgements

- Equipment used in this study was provided by PEO Soldier.
- This work was supported by U.S. Army Medical Research and Materiel Command (USAMRMC).
- This research was supported in part by an appointment to the Postgraduate Research Participation Program at the U.S. Army Aeromedical Research Laboratory administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and USAMRC.

Head-Supported Mass

Head-Supported Mass (HSM) = helmets and helmet-mounted systems

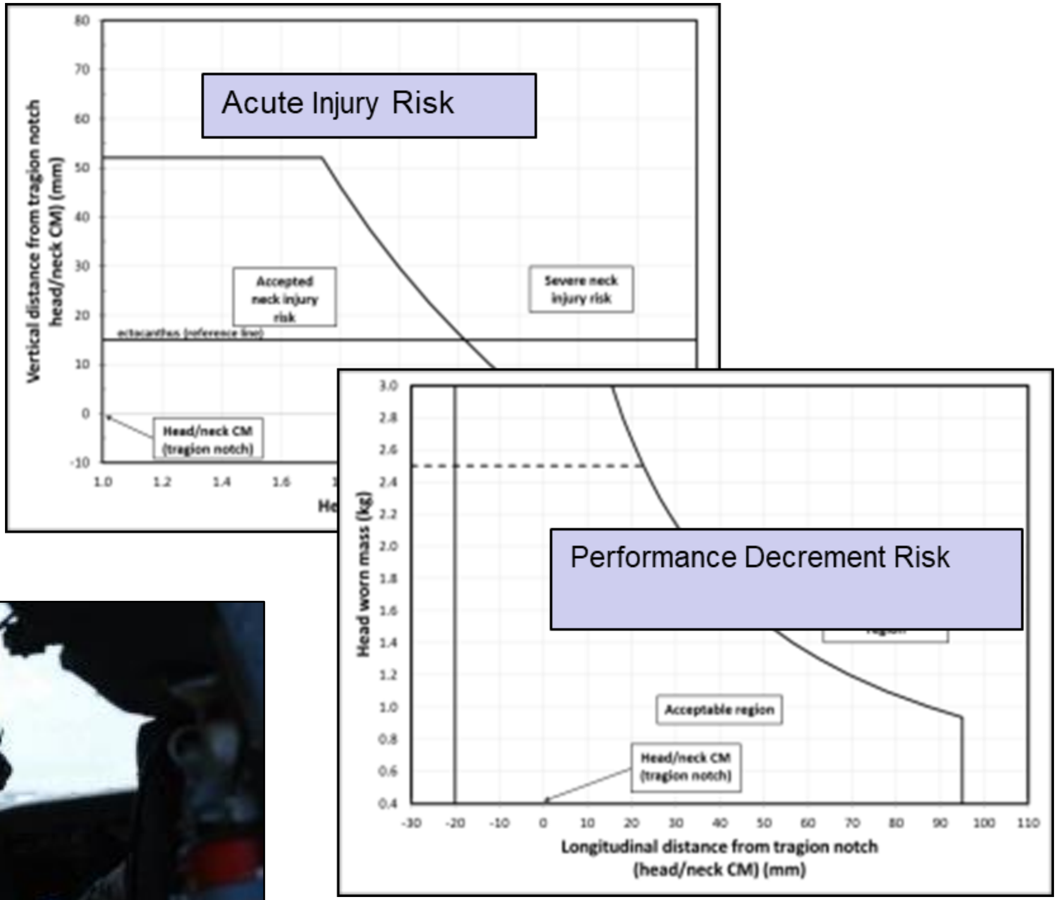



- Military helmets provide Soldier protection and enable use of advanced electronic systems, e.g., night vision goggles or communications systems
- Head-supported mass has been linked with decreased performance and increased injury risk
  - 90,456 (12%) Army Ground Soldiers in Infantry, Armor, and Amphibious MOSs sought treatment for spine-related conditions between 2006-2015 (Defense Medical Epidemiology Database)
  - 70% of those Soldiers were under the age of 30 at the time of the treatment
- Existing HSM criteria do not include guidance for rapid technology advancements
- **No** HSM criteria exist for **mounted** or **dismounted** Ground Soldiers

We must know the performance effects and injury risk of HSM to establish helmet and helmet-mounted device performance specifications for emerging technology.

Existing HSM Guidance

- Existing HSM guidelines developed by USAARL around aviation-type exposures (McEntire, 1998)
  - Acute Injury Risk
  - Performance Decrement



Operational Need

- Different operating environments have different exposures and movement requirements
- PEO Soldier needs HSM guidelines for dismounted Soldiers

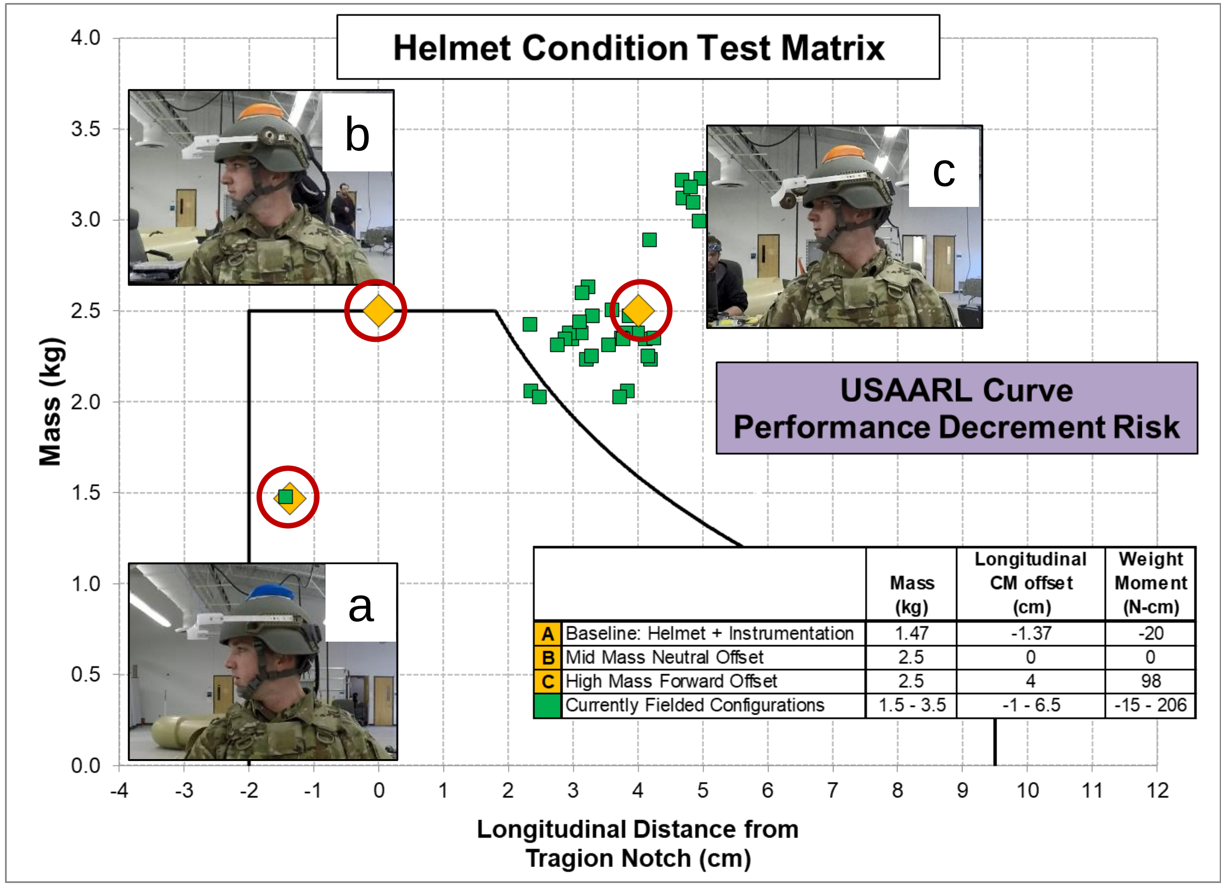
Pictures from Defense Visual Information Distribution System (DVIDS)

<u>#1 Research Gap:</u> Characterize the operating environment relative to exposures received during individual maneuvers (HSM Expert Panel Working Group, 2016)

Methods: Overview

- USAMRMC IRB-approved volunteer research protocol
- Load Effects Assessment Program-Army (LEAP-A), Fort Benning, GA
- TRADOC non-medical holdovers
- Body armor (IOTV3 in basic rifleman configuration)
- Simulated HSM conditions: Varied mass and center of mass offset*
  - a) Baseline ACH (1.5 kg, -1.4 cm rearward offset)
  - b) Mid-mass/neutral offset (2.5 kg, neutral offset)
  - c) Mid-mass/forward offset (2.5 kg, 4 cm forward offset)

  *Center of mass offset = longitudinal distance from tragion notch
- Multiple metrics from four variable groups:
  - Kinematic: Helmet-mounted instrumentation package (acceleration, angular rotation, position)
  - Performance: Marksmanship task
  - Physiologic/Biomechanical: Muscle activation, neck strength, range of motion
  - Subjective: Pain, fatigue, exertion, user acceptance



		Mass (kg)	Longitudinal CM offset (cm)	Weight Moment (N-cm)
A	Baseline: Helmet + Instrumentation	1.47	-1.37	-20
B	Mid Mass Neutral Offset	2.5	0	0
C	High Mass Forward Offset	2.5	4	98
	Currently Fielded Configurations	1.5 - 3.5	-1 - 6.5	-15 - 206

All subjects provided written consent for use of identifiable pictures and video.

LEAP-A

Course Operationally Configured

Obstacles not presented in order of testing

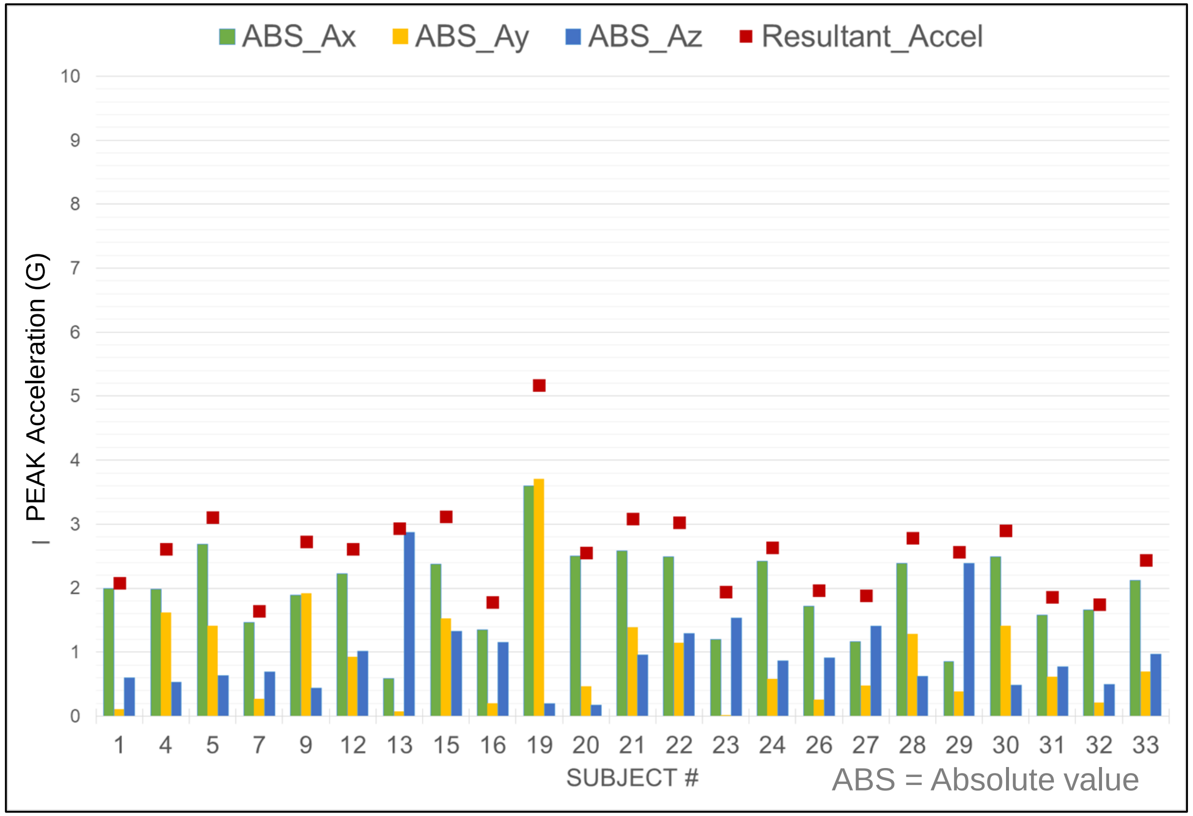
Methods: Data Down-select

- Acceleration
  - X, Y, Z, resultant
  - Captured at 2500 Hz
  - Time synced with video
- Only 2 of the 12 main LEAP-A obstacles
  - Dive to prone
  - High Wall
- Single HSM configuration
  - 2.5 kg with 4 cm forward offset
  - Representative of common dismounted Soldier configuration used for night operations
- Data reported for 23 subjects
  - 33 volunteers enrolled
    - 31 males
    - 2 females
  - 6 subjects withdrew before study completion
  - 4 subjects excluded for bad data

All subjects provided written consent for use of identifiable pictures and video.

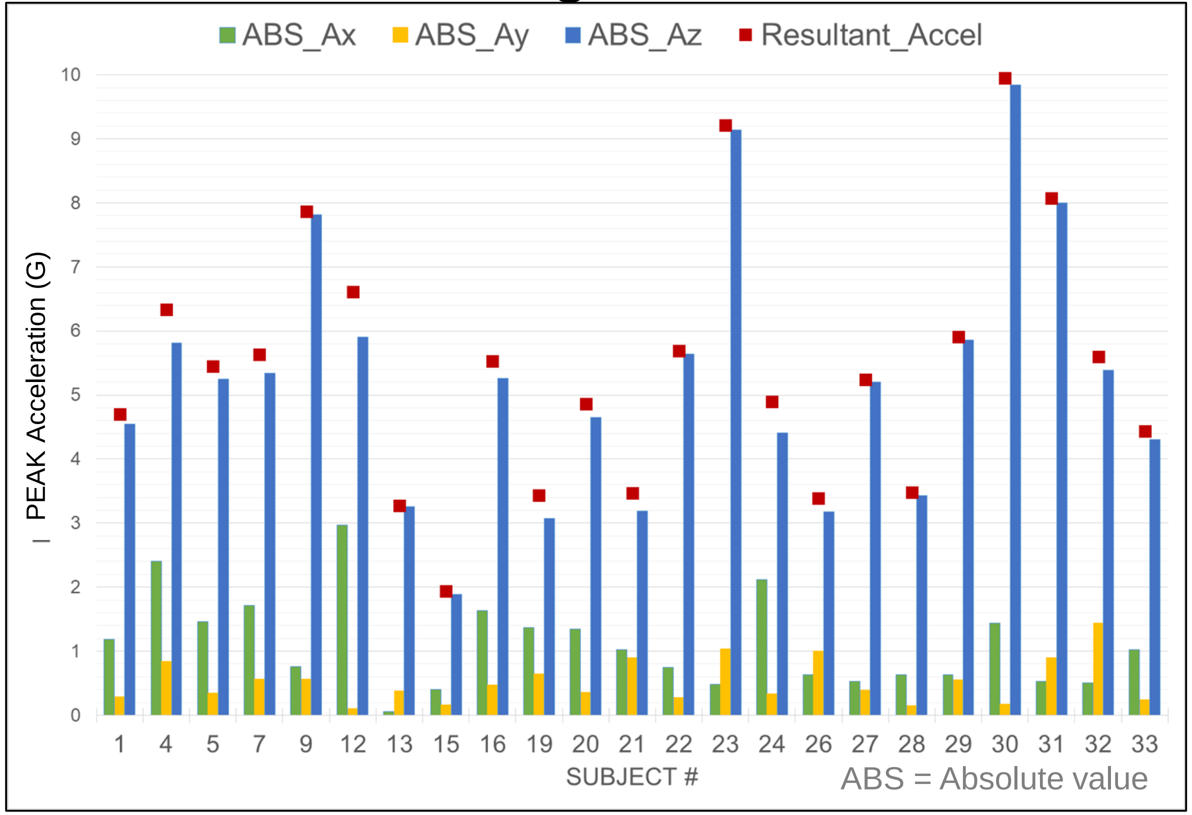
Head Resultant Acceleration Dominant Axes

Dive to Prone



- Peak acceleration summary:
  - X axis – 0.6 to 3.6G; average = 2.0G
  - Y axis – 0.02 to 3.7G; average = 0.9G
  - Z axis – 0.2 to 2.9G; average = 1.0G
  - Resultant – 1.6 to 5.2G; average = 2.6G

High Wall

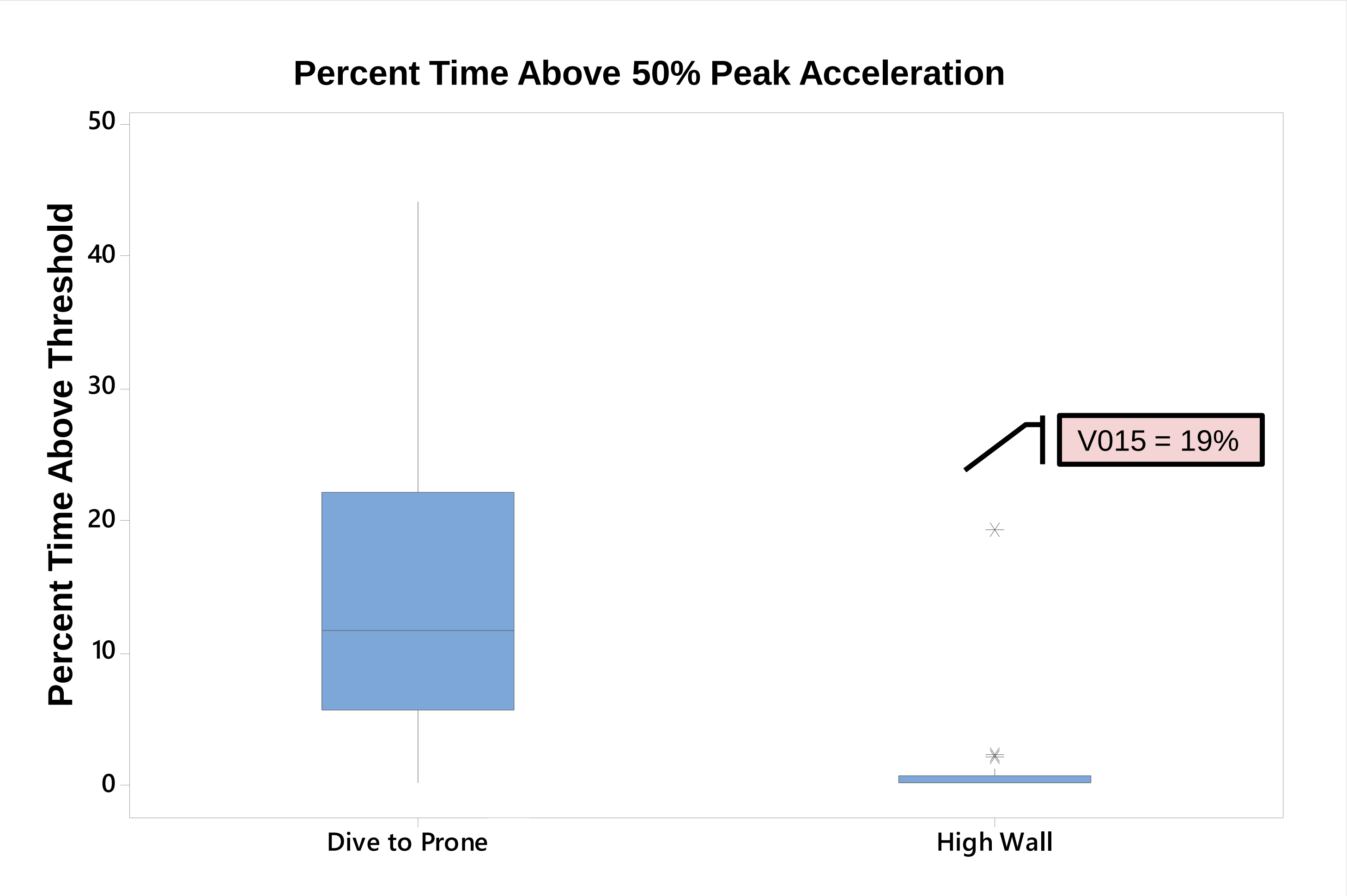


- Peak acceleration summary:
  - X axis – 0.1 to 3.0G; average = 1.1G
  - Y axis – 0.1 to 0.9G; average = 0.5G
  - Z axis – 1.9 to 9.8G; average = 5.2G
  - Resultant – 1.9 to 9.9G; average = 5.4G

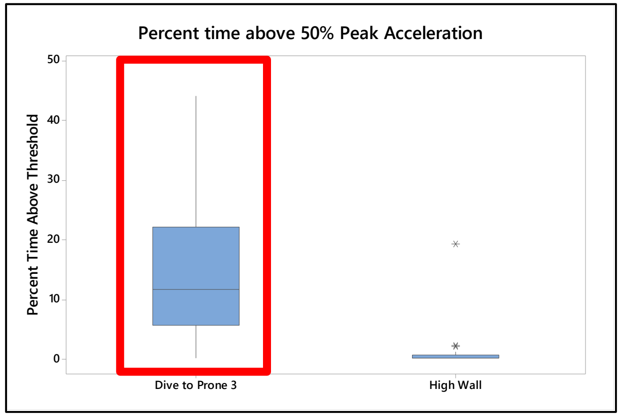
Duration Above 50% Max Head Resultant Acceleration

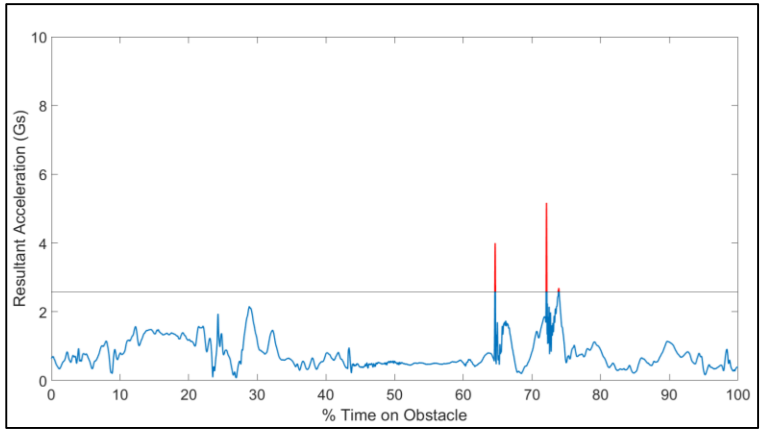
- Significant difference between obstacles for average duration of head resultant acceleration (Ar)
  - Dive to prone
    - 14% of total obstacle time
  - High wall
    - 1.4% of total obstacle time with
    - **Drops to 0.5% when outlier (V015) removed**

Technique matters



Duration Above 50% Max Head Resultant Acceleration: Dive to Prone



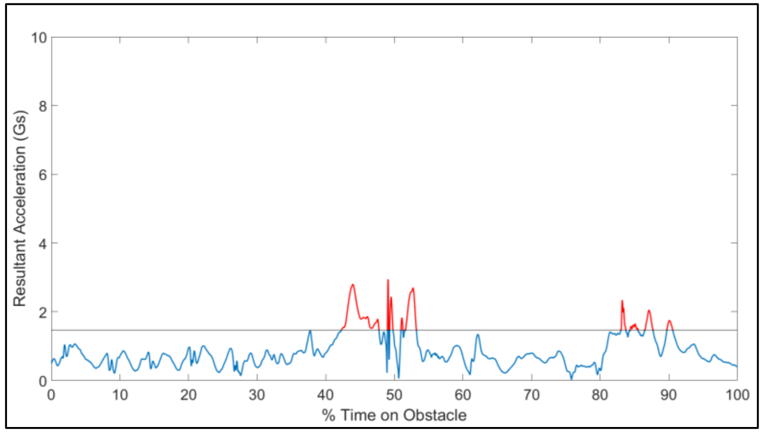


Subject 019

- Max Head Ar – 5.2G
- Duration above 50% Max Head Ar – 0.3%
- Time on Obstacle – 8.19 sec

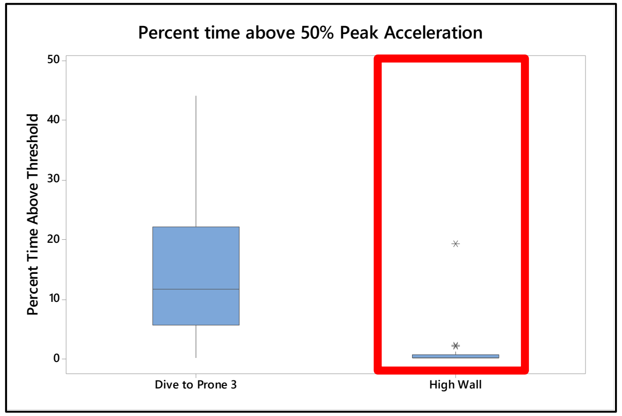
Subject 013

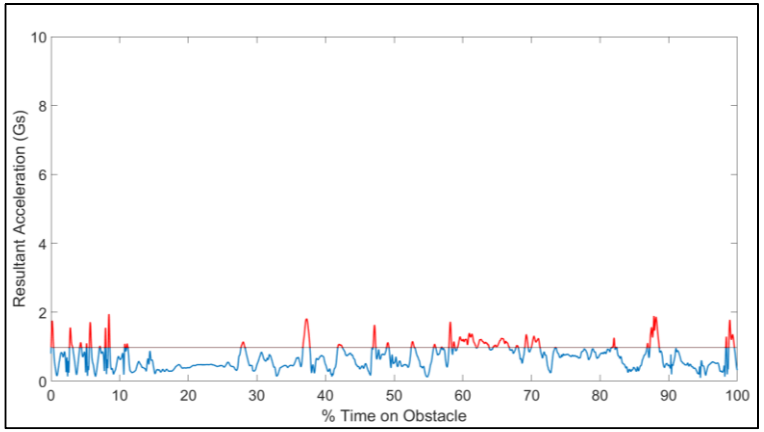
- Max Head Ar – 2.9G
- Duration above 50% Max Head Ar – 11.8%
- Time on obstacle – 6.44 sec



All subjects provided written consent for use of identifiable pictures and video.

Duration Above 50% Max Head Resultant Acceleration: High Wall



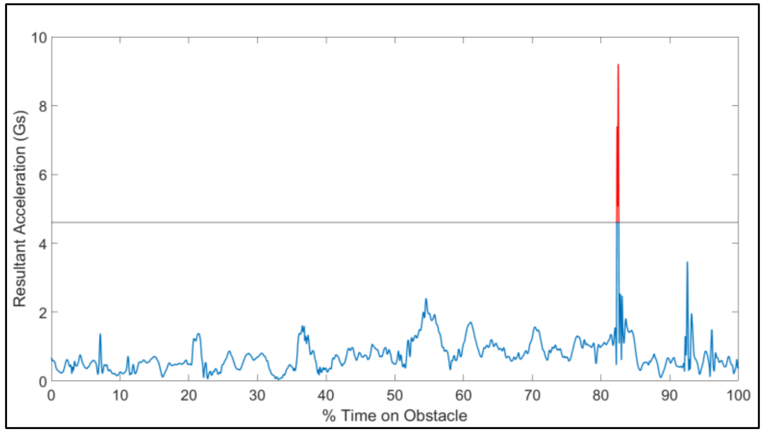


Subject 015

- Max Head Ar – 1.9 G
- Duration above 50% Max Head Ar – 19.2%
- Time on obstacle – 14.03 sec

Subject V023

- Max Head Ar – 9.2G
- Duration above 50% Max Head Ar – 0.28%
- Time on obstacle – 10.87 sec



All subjects provided written consent for use of identifiable pictures and video.

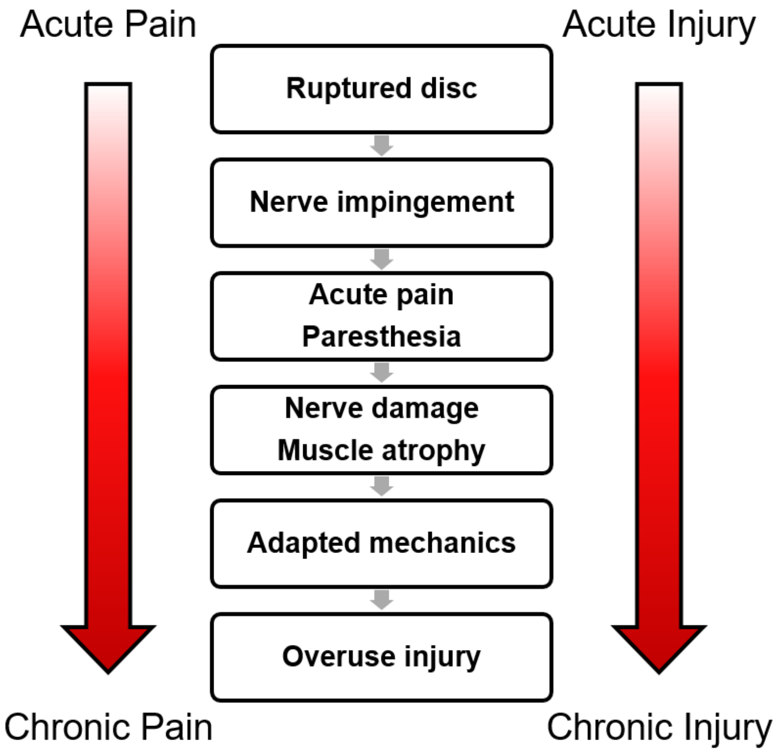
Discussion

- Unique study to characterize head acceleration in a simulated dismounted operating environment
  - First use of the LEAP-A course for research instead of test and evaluation
  - First effort to characterize the dismounted Soldier operating environment
- Resultant acceleration was low compared to previously studied environments (aviation or automotive crash), but frequency of exposure is greater.
  - Peaks were 3.5 times less than aviation crash, but higher than expected
  - Magnitude and duration varied greatly within obstacle and individual
- Study Limitations
  - Population experience – TRADOC Soldiers with limited experience performing individual movement techniques
  - Usable data on 23/33 subjects – volunteer dropout and instrumentation issues
  - Only analyzed 2 of the 12 obstacles – data analysis for remaining obstacles is underway

Conclusions

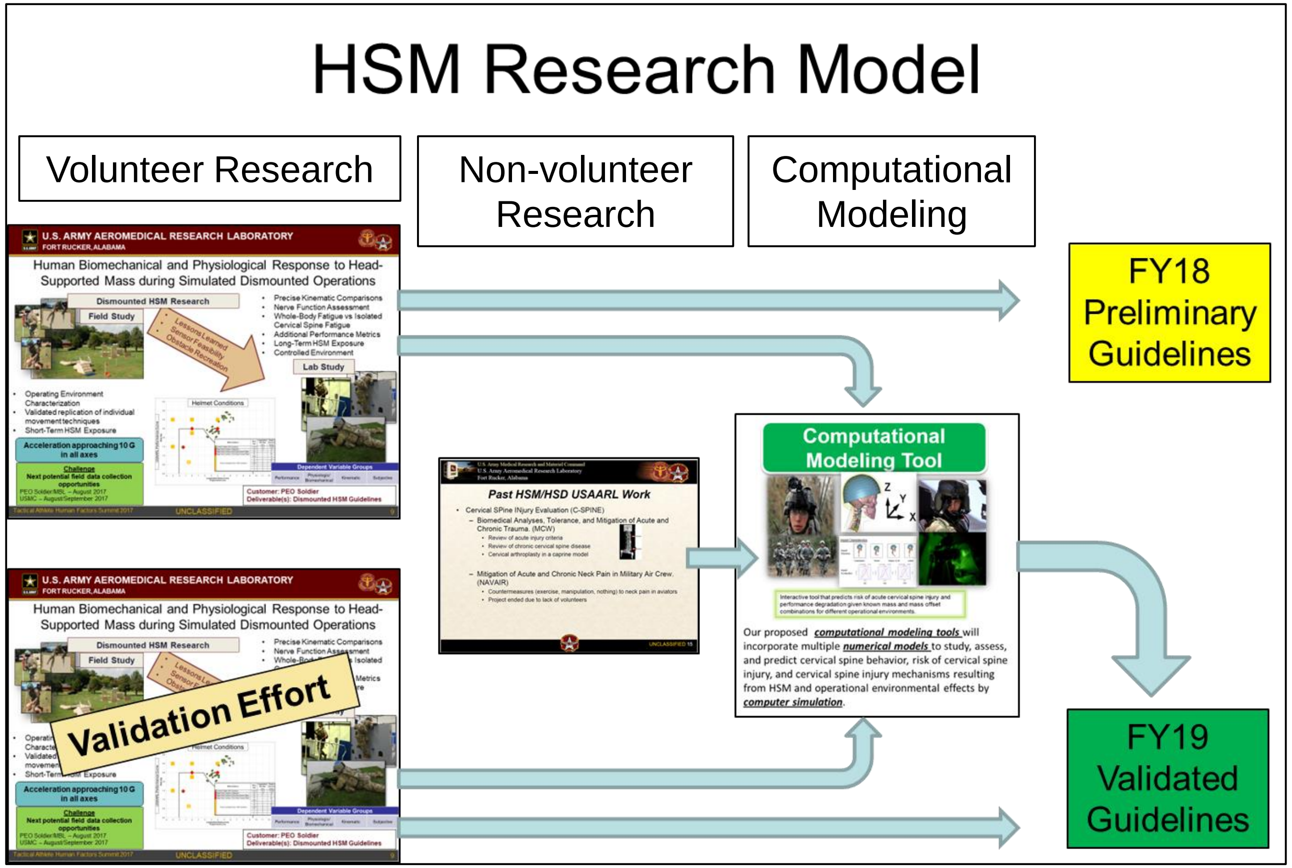
- High acceleration with short duration is an identified mechanism for acute injury. (Eiband, 1971; Gadd, 1971; and Yoganandan, 2014)
- Low to moderate acceleration with longer duration and/or greater frequency may contribute more to muscle fatigue and performance decrement.
- Designation of high, low, and moderate acceleration ranges is arbitrary and operating environment-dependent.
  - Aviation acceleration events (35 G crash) may result in AIS 3+ injuries:
    - Long-term loss of capability
    - Potentially career ending
  - Ground Soldier acceleration events (10 G landing off of a high wall) may result in AIS 2 injuries:
    - Short-term loss of capability
    - Unlikely to be career ending
- Repeated exposures to both types of ground Soldier acceleration patterns characterized may compound the effects and lead to increased risk of:
  - Acute musculoskeletal injury: sprains or strains (muscles, ligaments, tendons)
  - Performance decrement: muscle fatigue and/or muscle pain/soreness
  - Chronic injury: intervertebral disc degeneration, vertebral stress fracture

Neck pain and injury



Future Work

- Complete characterization of simulated operating environment
  - Remaining LEAP-A obstacles
  - Remaining metrics – kinematic, performance, physiologic/biomechanical, subjective
- Development of Dismounted HSM Guidelines
  - Mass/center of mass offset
  - Mass moment
  - Duration of wear
  - Operating environment or task specific



Questions?

Bethany L. Shivers, PhD

334-255-6894

bethany.l.shivers.civ@mail.mil

Carol Chancey, PhD

334-255-6952

valeta.c.chancey.civ@mail.mil

References

- Butler, B.P. (1992) Helmeted Head and Neck Dynamics Under Whole-Body Vibration (Doctoral Dissertation) retrieved from USAARL database.
- Eiband, A.M., (1971) Human Tolerance to Rapidly Applied Accelerations: A Summary of the Literature. NASA Memorandum 5-19-59E
- Gadd, C. W. "Tolerable severity index in whole-head, nonmechanical impact." Proceedings of the 15th Stapp Car Crash Conference. New York: Society of Automotive Engineers, 1971.
- McEntire, B.J., and Shanahan, D.F., (1998) Mass Requirements for Helicopter Aircrew Helmets. U.S. Army Aeromedical Research Laboratory technical report 98-14
- Yoganandan, Narayan, et al. Dynamic responses of intact post mortem human surrogates from inferior-to-superior loading at the pelvis. No. 2014-22-0005. SAE Technical Paper, 2014.