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UNITED STATES ARMY AEROMEDICAL RESEARCH LABORATORY

Examining the Effects of Head Supported Mass on Cervical Spine Biomechanics and Injury Risk in Special Forces Operators

Frederick T. Brozoski & Adrienne M. Madison

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14. ABSTRACT

Cervical spine injuries and neck pain are particularly problematic. These injuries and complaints of pain have been linked to head supported mass (HSM) including helmet, communications, and night vision technology. The Congressionally Directed Medical Research Program (CDMRP) Peer Reviewed Medical Research Program (PRMRP) funded collaborative effort "Examining the Effects of Head Supported Mass on Cervical Spine Biomechanics and Injury Risk in Special Forces Operators" is one of several dismounted Soldier HSM-focused projects at the the U.S. Army Aeromedical Research Laboratory. This study, conducted in collaboration with Atrium Health and Duke University, aims to examine the effects of HSM on c-spine epidemiology, strength/flexibility, and health in Special Forces dismounted populations. This report summarizes the progress made to the aims from August 2022 – July 2023.

15. SUBJECT TERMS

ground Soldier, Special Forces Combat Soldier, SFCS, dismounted Soldier, head supported mass, HSM, injury criteria, design guidelines, cervical spine, helmets and helmet systems, range of motion, CROM

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AWARD NUMBER: PR191552P1

TITLE: Examining the Effects of Head Supported Mass on Cervical Spine Biomechanics and Injury Risk in Special Forces Operators

PRINCIPAL INVESTIGATOR: Frederick Brozoski

CONTRACTING ORGANIZATION: Not applicable (N/A)

REPORT DATE: August 2022-July 2023

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Development Command
Fort Detrick, Maryland 21702-5012

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1. INTRODUCTION:

An increase in cervical spine problems and musculoskeletal discomfort has been correlated with the increased weight that Soldiers are required to support on their head. This increased weight is primarily due to the implementation of novel Warfighter technologies, such as night vision goggles and helmet materials that increase Soldier effectiveness and protect against increasing threats. Previous studies looked at the role this head supported mass (HSM) plays in causing injury immediately following high impact events and the performance differences that occur due to muscle fatigue in high-vibration environments, such as helicopters. However, long-term cervical spine injuries that occur due to repetitive stress on the body are being seen in the military at ages younger than the civilian population. The primary goal of this study is to investigate the role HSM plays in causing these long-term consequences, which has not yet been addressed in the research community. This goal will be accomplished through three aims:

- Survey and compare injury history, neck strength and flexibility, and neck degeneration in three populations, Special Forces Combat Soldiers (SFCS), dismounted Army personnel, and physically active non-military civilians.
- In a laboratory setting, obtain muscle activity and head and neck movement while subjects complete relevant military tasks.
- Use the muscle activity and head/neck movement to inform accurate computer model simulations that will return internal neck stress values to develop long term repetitive loading neck injury criteria and design guidelines for HSM.

2. KEYWORDS:

ground Soldier, Special Forces Combat Soldier, SFCS, dismounted Soldier, head supported mass, HSM, injury criteria, design guidelines, cervical spine, helmets and helmet systems, range of motion, cervical range of motion, CROM

3. ACCOMPLISHMENTS:

- **What were the major goals of the project?**

Specific Aim 1	Site	Aim Status	% Task Complete	Notes
Major Task 1: Injury epidemiology, cervical spine strength and flexibility testing of military and non-military personnel	USAARL	In Progress	50%	Institutional Review Board (IRB) and Human Research Protection Office (HRPO) approvals were delayed. Each of these approvals took longer than originally anticipated due to complexities and varying requirements for non-Department of Defense (DoD) and DoD organizations' IRB approvals and human subject data collections. Despite these delays, the protocol has received approvals and data collection is underway.
University and Military IRB/HRPO Approval	USAARL	Completed	100%	IRB and HRPO approvals have been received.
Testing of military and non-military personnel begins	USAARL	In Progress	4%	Six (6) participants have been tested to-date.

Data analysis and final report completed	USAARL	Not Started	0	N/A

Specific Aim 3	Site	Aim Status	% Task Complete	Notes
Prepare, package, and transfer kinematic and electromyography (EMG) data collected from field and/or laboratory based dismounted Soldier studies under varied HSM conditions in preparation for Duke University Human Neck Model (DUHNM) simulations	USAARL	Ongoing	5%	The period of performance (PoP) for the separate research effort that was the source of kinematic and EMG data for this study aim ended due to lack of funding. As a result, data collection under that effort has been paused until a funding source can be identified. This pause in data collection will significantly affect the availability and transmission of laboratory-based kinematic and biomechanical/physiologic EMG data to Duke University.

Note. USAARL supports Aims 1 and 3 of this effort.

- **What was accomplished under these goals?**
  - **Project Schedule:** A no-cost extension (NCE) request was submitted to align with the lead institution's (Atrium Health) request to extend the project period of performance to May 2024.

  - **USAARL HSM Subject Matter Expert Support:** Conducted 126 mass property assessments of U.S. Special Operation Force Command (SOCOM) helmet systems to gather mass and center of mass (CM) offset data for use in developing helmet mass simulation devices (HMSDs) for laboratory-based testing at Duke University (Specific Aim 2).

  - **Specific Aim 1:**
    (Data Collection Kickoff and Project Schedule): During this reporting period, data collection efforts at the U.S. Army Aeromedical Research Laboratory (USAARL) site location kicked off. In preparation for data collection, USAARL personnel developed standard operating procedures (SOPs) for data collection and trained four new personnel on test equipment and methodology, as well as conducted final dry runs. Human subject recruitment in the local Fort Novosel area was conducted. Following recruitment, subjects were scheduled, consented, and enrolled. Six subjects have completed testing.

    (Group Testing Coordination): Coordination efforts were conducted to develop the ability to conduct group testing. The first coordination approach was to leverage the Development Command Soldier Center Human Research Volunteer (DEVCOM SC HRV) Program (Natick, MA) recurring cohorts to supplement USAARL site data collections. As part of these coordination efforts, planning meetings were held with DEVCOM SC HRV program management. Meetings to recruit and consent members of the cohort were also scheduled. Next, coordination efforts focused on the ability to conduct group testing in the local Fort Novosel area. A meeting was held with the Fort Novosel Advanced Individual Training (AIT) unit to establish a

relationship for access to group testing capabilities. Lastly, a protocol amendment has been drafted to allow for group testing and consent of the HRV cohorts at Natick, MA as well as local Fort Novosel AIT School groups.

- **Specific Aim 3:** Work began to determine if data sharing agreements and additional human subject regulatory approvals are required for USAARL to share previously collected human subject data with Duke University in support of computational model simulation development.

- **What opportunities for training and professional development has the project provided?**

  - The project has resulted in the development of SOPs to ensure that Atrium Health and USAARL personnel use identical methodologies to collect accurate and precise cervical spine range of motion (CROM) and neck strength data at each testing location.

  - All research personnel have been trained on these procedures in order to ensure inter- and intra-testing reliability.

  - This project has provided junior personnel the opportunity to be involved in multiple aspects of the research process including protocol development, final testing preparations, recruitment, and data collection. In addition, this project has also granted the junior personnel the experience of conducting collaborative research with external academic partners.

- **How were the results disseminated to communities of interest?**

  - Nothing to report.

- **What do you plan to do during the next reporting period to accomplish the goals?**

  - **Specific Aim 1:** During the next reporting period, we plan to continue to recruit and test subjects at the USAARL site, finalize coordination efforts for group testing for the DEVCOM SC HRV cohorts as well as Fort Novosel AIT groups, and initiate group testing at Natick, MA and Fort Novosel.

  - **Specific Aim 3:** During the next reporting period, we plan to obtain additional human subject regulatory approvals that are required and begin discussions on anticipated or expected data types, formatting, etc.

4. IMPACT:

- **What was the impact on the development of the principal discipline(s) of the project?**

  - Nothing to report.

- **What was the impact on other disciplines?**

  - Nothing to report.

- **What was the impact on technology transfer?**
    - USAARL has implemented the Atrium Health methodology for neck strength assessments into other HSM-related human subject data collections.
- **What was the impact on society beyond science and technology?**
    - Nothing to report.

5. CHANGES/PROBLEMS:

- **Changes in approach and reasons for change**
    - Nothing to report.
- **Actual or anticipated problems or delays and actions or plans to resolve them**
    - The departure of key study personnel (Brian Novotny) may contribute to delays in data collection. Efforts are ongoing to ensure that new personnel will be trained on test procedures and methodology as soon as possible to minimize potential ongoing delays.
    - **Specific Aim 1:** The exclusion criteria of Soldiers with significant exposure to vibration will likely limit the number of eligible participants on Fort Novosel. The military installation is largely comprised of rotary-wing aviators and aircrew with advanced experience. Future local recruitment efforts will focus largely on incoming flight student populations, air traffic control populations, and aviators that have accumulated limited flight hours. Additionally, the ability to leverage recurring DEVCOM SC HRV cohorts will assist with achieving the desired number of subjects.
    - **Specific Aim 3:** This project aim was written to leverage data from other ongoing or recently completed laboratory based USAARL dismounted HSM research studies. Direct and indirect effects of the COVID-19 pandemic led to a funding lapse in the key project that was to be leveraged to provide data for this aim. Data collection for that project has been paused until a funding source could be identified to complete the work. This pause will significantly affect the availability and transmission of laboratory-based kinematic and biomechanical/physiologic (EMG) data to Duke University. Efforts are ongoing to identify alternative data sources to meet aim objectives.
- **Changes that had a significant impact on expenditures**
    - Nothing to report.
- **Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**
    - Nothing to report.
- **Significant changes in use or care of human subjects**
    - Nothing to report.

- **Significant changes in use or care of vertebrate animals.**
  - N/A
- **Significant changes in use of biohazards and/or select agents**
  - N/A

6. PRODUCTS:

- **Publications, conference papers, and presentations**
  - **Journal publications.**

    Nothing to report.
  - **Books or other non-periodical, one-time publications.**

    Nothing to report.
  - **Other publications, conference papers, and presentations.**

    Nothing to report.
- **Website(s) or other Internet site(s)**

  Nothing to report.
- **Technologies or techniques**

  Nothing to report.
- **Inventions, patent applications, and/or licenses**

  Nothing to report.
- **Other Products**

  Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

- **What individuals have worked on the project?**

Name:	Frederick Brozoski
Project Role:	Partnering and USAARL Site Principal Investigator
Percent (%) Effort	10

Nearest person month worked:	1
Contribution to Project:	Mr. Brozoski is responsible for the conduct of the study in accordance with the protocol and maintenance of a list of appropriately qualified persons to whom significant study-related responsibilities have been delegated. Additionally, he will oversee data analyses, and transfer and serve as a consultant in human subject volunteer instrumentation, testing, and data analysis.
Funding Support:	N/A

Name:	Adrienne M. Madison, PhD
Project Role:	Partnering and USAARL Site Co-Principal Investigator
Percent (%) Effort	15
Nearest person month worked:	1
Contribution to Project:	Dr. Madison is responsible for protocol development, study preparation, volunteer recruitment, volunteer consent, participant instrumentation, data collection, analysis, and report generation. Additionally, she will oversee data analyses, and transfer and serve as a consultant in human subject volunteer instrumentation, testing, and data analysis.
Funding Support:	N/A

Name:	Valeta Carol Chancey, PhD
Project Role:	Consultant
Percent (%) Effort	5
Nearest person month worked:	1
Contribution to Project:	Dr. Chancey serves as a consultant for human subject volunteer instrumentation, testing, and data analysis.
Funding Support:	N/A

Name:	Kimberly V. Vasquez
Project Role:	Administrative Research Facilitator
Percent (%) Effort	5

Nearest person month worked:	1
Contribution to Project:	Mrs. Vasquez serves as an administrative research facilitator. She manages financial and logistical (equipment purchasing, information technology coordination, data shipping/transfer) operations.
Funding Support:	N/A

Name:	Brian Novotny
Project Role:	Associate Investigator
Percent (%) Effort	25
Nearest person month worked:	3
Contribution to Project:	Mr. Novotny assists the USAARL PI and Co-PI with protocol development, study preparation, volunteer recruitment, volunteer consent, participant instrumentation, data collection, analysis, and report generation. Additionally, he will assist with data analyses and transfer and serve as a consultant in human subject volunteer instrumentation, testing, and data analysis.
Funding Support:	USAARL Contract Support Personnel (Katmai)

- **Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**
  - Nothing to report.
- **What other organizations were involved as partners?**
  - **Initiating PI Organization Information**
    - **Organization Name:** The Charlotte-Mecklenburg Hospital Authority d/b/a Atrium Health (Timothy Sell, PT PhD)
    - **Location of Organization:** Charlotte, NC
    - **Partner's contribution to the project:**
      - **Financial support:** No
      - **In-kind support**: No
      - **Facilities:** Atrium Health serves as the coordinating center for research that includes personnel at Atrium Health, Duke University, and USAARL. USAARL will not use these facilities for testing.

- **Collaboration** Yes. Atrium Health is the location of the initiating PI of this research effort and their IRB was the lead reviewer on the protocol. USAARL personnel has worked in collaboration with Atrium Health to complete tasks outlined in Specific Aims 1 and 3. Additionally, USAARL has provided subject matter expertise in support of Aim 2 by conducting mass property assessments of helmet conditions as well as sharing design concepts of HMSD to be replicated during Aim 2 testing.

- **Personnel exchanges** USAARL personnel may visit for final training data collection preparations for Specific Aim 1 as well as to provide consultation or SME support for Atrium Health data collection outlined in Specific Aims 2 and 3.

- **Initiating Co-PI Organization Information**

  - **Organization Name:** Injury and Orthopedics Biomechanics Laboratory, Duke University

  - **Location of Organization:** Durham, NC

  - **Partner's contribution to the project**

    - **Financial support:** No

    - **In-kind support:** No

    - **Facilities:** The kinematic and EMG data provided by USAARL will be used in the modeling and simulation conducted as outlined in Specific Aim 3. USAARL personnel will not use Duke University facilities for testing.

    - **Collaboration** Yes. The Injury and Orthopedics Biomechanics Laboratory at Duke University is the location of Initiating Co-PI of this research effort. USAARL personnel has worked in collaboration with Duke University personnel to complete tasks outlined in Specific Aim 3. These tasks included the sharing of geometry of helmet data for inclusion in the computational model.

    - **Personnel exchanges** USAARL personnel may visit to provide consultation or subject matter expert (SME) support for data collection and/or modeling and simulations outlined in Specific Aims 2 and 3**.**

8. SPECIAL REPORTING REQUIREMENTS:

QUAD CHARTS: To be submitted with report.

9. APPENDICES: N/A

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Examining the Effects of Head Supported Mass on Cervical Spine Biomechanics and Injury Risk in Special Forces Operators

PR191552P1

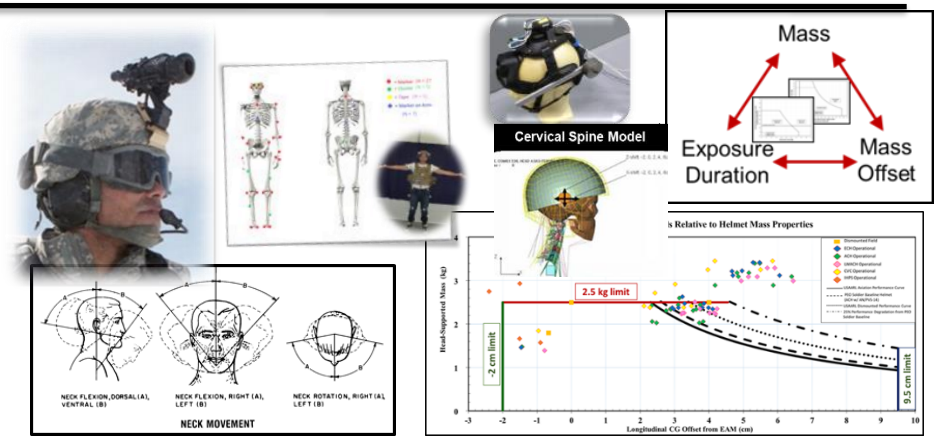
PI: Brozoski/Madison **Org:** USAARL **Award Amount:** $684K

Study/Product Aim(s)

- Survey the injury epidemiology, cervical spine (c-spine) strength and flexibility, and current cervical spine radiology of SFCS (special forces combat Soldiers) and physically active non-military personnel
- Obtain head/neck kinematics and flexion/extension electromyography data of a cohort of SFCS personnel during a number of relevant simulated military scenarios
- Implement the experimental kinematic and EMG data into a validated hybrid finite element – multibody head/neck model to determine intervertebral stiffnesses during these simulated military scenarios with varying levels and positions of head supported mass.

Approach

A descriptive cross-section study using three groups of subjects will be used to examine the effects of head supported mass on c-spine epidemiology, strength/flexibility, neck disability (survey), and health (MRI). Additionally, experimental kinematic and EMG data will be incorporated into a hybrid multibody and finite element human next model to determine the maximum cervical intervertebral stresses to model HSM effects on chronic c-spine injury risk.



Cervical spine injuries and neck pain are particularly problematic. These injuries and complaints of pain have been linked to head supported mass (HSM) including helmet, communications, and night vision technology.

Accomplishment: Protocol development was completed and has received IRB and HRPO approval.

Timeline and Cost

Activities CY	20	21	22	23	24
Protocol Development/Approval					
Data Collection: Specific Aim 1					
Data Collection: Specific Aim 2					
Data Collection: Specific Aim 3					
Data Analysis					
Reporting/Publishing of Results					
Estimated Budget ($K)		**$226**	**$231**	**$227**	**NCE**

Updated: 18 September 2024

Goals/Milestones (Example)

CY22 Goals Data Collection

☑ IRB Approval

☑ Recruitment, scheduling, and data collection for human subject studies (Aim 1 and Aim 2)

CY23 Goal – Data Analysis

☑ Submit Request for NCE through May 2024

☑ IRB Protocol Amendment for group consent and testing (Aim 1)

☐ Continue individual and group testing (Aim 1)

CY24 Goal – Reporting/Publishing

☐ Complete all data analysis and publish final reports

Comments/Challenges/Issues/Concerns

- Protocol Approval process took longer than originally anticipated
- Protocol amendment underway to incorporate group testing in Natick, MA and Fort Novosel to get desired number of subjects

Budget Expenditure to Date

Projected Expenditure: Y1: $226K, Y2: $231K, Y3: $227K

Actual Expenditure: Y1: $226K, Y2: $231K; Y3: $200K

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