USAARL-TECH-AR--2025-04

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

Notice

Qualified Requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Fort Belvoir, Virginia 22060. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of Address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Human Subject Use

In the conduct of research involving human subjects, the investigator(s) adhered to the policies regarding the protection of human subjects as prescribed by Department of Defense Instruction 3216.02 (Protection of Human Subjects and Adherence to Ethical Standards in DoD-Supported Research) dated 8 November 2011.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
15-10-2024	Annual Report	08/01/2023 – 07/15/2024

4. TITLE AND SUBTITLE

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

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Brozoski, F. T.[1], & Madison, A. M.[1]

5d. PROJECT NUMBER

PR191552P1

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Aeromedical Research Laboratory
P.O. Box 620577
Fort Novosel, AL 36362

8. PERFORMING ORGANIZATION REPORT NUMBER

USAARL-TECH-AR--2025-04

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Medical Research and Development Command
Military Operational Medicine Research Program
504 Scott Street
Fort Detrick, MD 21702-5012

10. SPONSOR/MONITOR'S ACRONYM(S)

USAMRDC MOMRP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release: distribution is unlimited.

13. SUPPLEMENTARY NOTES

[1]U.S. Army Aeromedical Research Laboratory

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 2023 – July 2024.

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, cervical range of motion, CROM

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Loraine St. Onge, PhD
UNCLAS	UNCLAS	UNCLAS	SAR	10	19b. TELEPHONE NUMBER *(Include area code)* 334-255-6906

This page is intentionally blank.

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 2023 – July 2024

TYPE OF REPORT: Annual

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

This page is intentionally blank.

TABLE OF CONTENTS

1. INTRODUCTION:

An increase in cervical spine problems and musculoskeletal discomfort has been correlated with the increased weight that a Soldier is required to support on their head. This increased weight is primarily due to implementing novel technologies, such as night vision goggles and other helmet components that increase Soldier effectiveness and protect against mounting 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 injuries, 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.
- Obtain muscle activity and head and neck movement data in a laboratory setting while subjects complete relevant military tasks.
- Use the muscle activity and head and 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, 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 and cervical spine strength and flexibility testing of military and non-military personnel	USAARL	In Progress	70%	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 personnel begins	USAARL	In Progress	35%	Sixty (60) participants have been tested to date.
Data analysis and final report completed	USAARL	In Progress	40%	Data analysis is ongoing, and the final report draft is in progress.

Specific Aim 3	Site	Aim Status	% Task Complete	Notes
Prepare, package, and transfer kinematic and electromyography (EMG) data collected from field and/or lab based dismounted Soldier studies under varied HSM conditions in preparation for Duke University Human Neck Model (DUHNM) simulations	USAARL	Paused	10%	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, there was a 2 year pause in data collection. The data sets collected during Aim 2 by collaborating institutions were reviewed and determined sufficient to meet the computational model objectives in Aim 3. No additional work is planned in support of this aim since the PoP is ending for USAARL.

- **Project Schedule:** The no cost extension (NCE) request submitted in 2023 to extend the PoP through May 2024 was approved. A second NCE request was initially planned in alignment with Atrium Health to extend the PoP through September 2024; however, this request was abandoned.

- **Research Personnel:** Alexis Stewart was named the replacement Associate Investigator after Brian Novotny departed from USAARL.

- **Specific Aim 1:**

  (Data Collection Numbers): During this reporting period, testing was completed on fifty-four (54) subjects. Testing of twenty-seven (27) subjects was completed at USAARL; twenty-seven (27) subjects also completed testing at Natick, MA. Combined with the six (6) subjects tested during last reporting period, a total of sixty (60) subjects have completed testing.

  (Fort Novosel Recruitment and Data Collection): During this reporting period, recruitment and data collection efforts continued at Fort Novosel. Key events (e.g., new Soldier welcome gatherings) on Fort Novosel were leveraged to recruit prospective subjects. Twenty-seven (27) subjects completed testing at USAARL during this reporting period.

  (Group Testing Coordination and Kickoff): During this reporting period, the protocol amendment was approved to allow for group consent and testing. Recruitment and consenting briefings were held for the Development Command Soldier Center Human Research Volunteer (DEVCOM SC HRV) Program's cohorts at Natick, MA. Data collection at Natick, MA was scheduled. In preparation for group data collection, two dry runs were completed at USAARL to familiarize and train personnel on the group data collection methodology. Twenty-seven (27) subjects from the DEVCOM SC HRV cohort were consented and tested during a three-day data collection in Natick, MA (October 2023). This data collection was the first time the cohort participated in testing conducted external to DEVCOM SC. Coordination was initiated for a second data collection using the Spring 2023 DEVCOM SC HRV cohort; however, there was not enough funding remaining on this effort to cover the DEVCOM SC requested costs to leverage the population for a second time. Lastly, a letter of support (LoS) was received to support group

testing using the 10th Combat Aviation Brigade (CAB) Soldier population at Fort Drum, NY.

(Data Analysis and Final Report): During this reporting period, data analysis for the sixty (60) data sets and drafting of the final report were initiated.

- **Specific Aim 3:** During this reporting period, work also began to establish necessary data sharing agreements to share human subject data collected from other USAARL dismounted HSM focused-research efforts. Additionally, alternatives were explored to determine whether previously collected field-based kinematic and EMG data can be leveraged to meet Aim 3 objectives within this project's PoP.

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

  - This project has provided junior (military and contractor) personnel the opportunity to be involved in multiple aspects of the research process, most recently the planning and execution of group data collections. 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 currently. Results will be disseminated upon project completion.

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

  - **Specific Aim 1:** No additional data collections are planned due to the project reaching the end of the PoP. Data analysis and report writing is underway. The final report will be based on the data outcomes collected from the 60 participants tested to-date.

  - **Specific Aim 3:** The data sets collected during Aim 2 by collaborating institutions were reviewed and determined sufficient to meet the computational model objectives in Aim 3. No additional work is planned in support of this aim since the PoP is ending for USAARL.

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**
    - **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 was paused for 2 years until a funding source could be identified to complete the work. This 2-year delay has significantly affected the availability and transmission of laboratory-based kinematic and biomechanical/physiologic (EMG) data to Duke University. Funding for the key USAARL project was received in July 2023 and plans to resume data collection are underway. However, it is unlikely that these data would be available for transfer prior to the end of this project's PoP. As an alternative, we explored whether human subject kinematic and EMG data from completed USAARL field-based studies could be leveraged to meet this project aim. After discussions with Duke University, it was concluded that only the laboratory-based data collected from Aim 2 would be used in support of Aim 3.
- **Actual or anticipated problems or delays and actions or plans to resolve them**
    - **Specific Aim 1:** The exclusion criteria of Soldiers with significant exposure to vibration has limited the number of eligible participants on Fort Novosel. The military installation is largely comprised of rotary-wing aviators and aircrew with advanced experience. Current local recruitment efforts are largely focusing on incoming flight student populations, air traffic control populations, and aviators who have accumulated limited (less than 500) flight hours. Additionally, the ability to leverage recurring DEVCOM SC HRV cohorts previously assisted USAARL with increasing the number of eligible subjects was expected; however, there was not enough funding remaining on this effort to cover the costs to leverage the population for a second time. Therefore, we are still short of the target number of subjects (N = 170). Data analysis and final report outcomes will be based on the sixty participants tested to date.
- **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:	1.5
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 oversees data analyses and transfer, and serves 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:	1.5
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 oversees data analysis and transfer and serves 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:	Alexis Stewart
Project Role:	Associate Investigator
Percent (%) Effort	25
Nearest person month worked:	2
Contribution to Project:	Ms. Stewart 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, she assists with data analysis and transfer, as well as serving 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

- **Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**
  - Brian Novotny, the previous associate investigator, is no longer affiliated with USAARL or this project. Alexis Stewart was designated as his replacement. No other changes were made.
- **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:** Atrium Health is the location of the initiating PI of this research effort and their IRB was lead reviewer on the protocol. USAARL personnel has worked in collaboration with Atrium Health to complete tasks outlined in Specific Aims 1 and 3.
    - **Personnel exchanges** USAARL personnel has provided consultation or subject matter expert (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**: The Injury and Orthopedics Biomechanics Laboratory at Duke University is the location of the initiating Co-PI of this research effort. USAARL personnel will work in collaboration with Duke University personnel to complete tasks outlined in Specific Aim 3. These tasks include the sharing of helmet geometry data for inclusion in the computational model.

          Personnel exchanges USAARL personnel have provided consultation or SME support for data collection and/or modeling and simulations outlined in Specific Aims 2.

8. SPECIAL REPORTING REQUIREMENTS:

QUAD CHARTS: To be submitted with report.

9. APPENDICES: N/A

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

PR191552P1

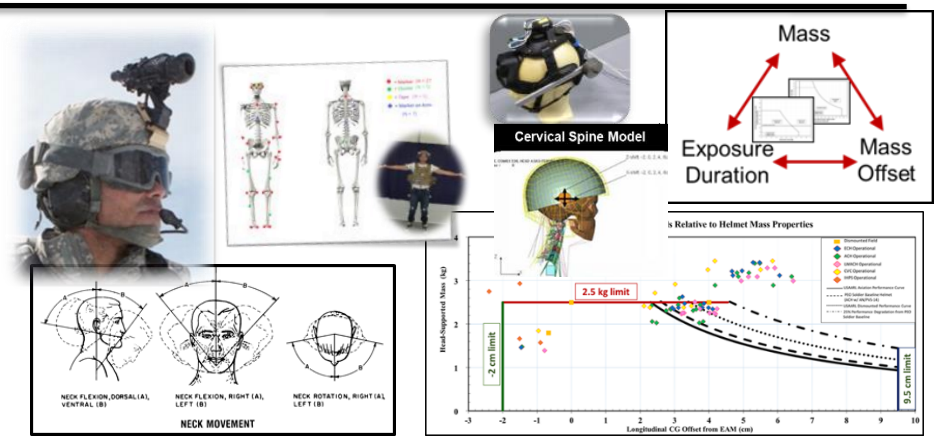
PI: Brozoski/Madison **Org:** USAARL **Award Amount:** $684K

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: Completed group data collection (N=27) leveraging DEVCOM SC Human Research Volunteer (HRV) Program (Natick, MA)

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

CY22 Goals Data Collection

☑ IRB Approval

☑ Recruitment, scheduling, and data collection for human subject studies

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

- Aim 1:Testing has been completed on 60 of 170 subjects; data analysis and final report will focus on the outcomes on the completed subjects.
- Aim 3: Transmission of human subject data significantly affected by Delays in separate data collections. Only data collected in Aim 2 will be used in model development

Budget Expenditure to Date

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

Actual Expenditure: Y1: $226K, Y2: $231K, Y3: $215K

This page is intentionally blank.

U.S. ARMY AEROMEDICAL RESEARCH LABORATORY

FORT NOVOSEL, ALABAMA

Optimizing

HUMAN PROTECTION AND PERFORMANCE

since 1962

All of USAARL's science and technical informational documents are available for download from the Defense Technical Information Center.
https://discover.dtic.mil/results/?q=USAARL

U.S. ARMY

FUTURES COMMAND

MRDC