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14. ABSTRACT This report covers the third year of a five year award that encompasses multiple projects. This group of projects is designed to look at various aspects of transport, immobilization, optimal physical space, ergonomics, and enhancement of medical awareness. Outcomes of the project will provide information and tools that can be used toward increasing a patient's safety, providing more effective patient care, reducing patient and medic discomfort, and the development of vibration mitigation systems. This report covers year three of the award.					
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Table of Contents

	Page
1. INTRODUCTION	3
Project 1	3
Project 2	3
Project 3	3
Project 4	3
Project 5	4
2. KEYWORDS	4
3. ACCOMPLISHMENTS	4
Project 1 Goals	4
Project 2 Goals	4
Project 3 Goals	5
Project 4 Goals	5
Project 5 Goals	5
Project 1 Accomplishments	5
Project 2 Accomplishments	11
Project 3 Accomplishments	15
Project 4 Accomplishments	15
Project 5 Accomplishments	15
Project 1 Year 4 Goals	16
Project 2 Year 4 Goals	16
Project 3 Year 4 Goals	16

Project 4 Year 4 Goals	16
Project 5 Year 4 Goals	16
4. IMPACT	16
5. CHANGES/PROBLEMS	17
6. PRODUCTS.....	18
7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS	19
8. SPECIAL REPORTING REQUIREMENTS	20
9. APPENDICES	20

1. INTRODUCTION:

This study promises to yield valuable information about (1) the effects of patient size, handling, securing and enroute care practices on supine human vibration exposure during patient handling and ground and air transport, (2) the postures associated with the confined space of common MEDEVAC platforms and their effect on care provider health and efficiency, and (3) enhanced medical awareness and patient data documentation for medical providers in the military medical evacuation environment. Findings from the proposed research will contribute to the transport of Wounded Warriors from the point of injury to the next level of care.

This award contains a series of five projects:

Project 1

Evaluate patient weight with patient immobilization system verses no immobilization system.

The proposed project was designed to investigate various factors that may affect biodynamic response of the supine human under whole body vibration and repeated shock. The findings will contribute to the development of mathematical models that can be used to study vibration response of the supine human.

Project 2

Administer survey to en route care providers regarding posture and health.

This project was developed to present a survey to medical providers regarding postures assumed during administration of en route critical care tasks, routine medical transport scenarios, and patient loading.

Project 3

Incorporation of medical device alarms into ICS.

A need exists for improvement of medical awareness of patient condition in the noisy and distraction-rich environments of medical evacuation platforms with improved documentation of patient condition and patient hand-off procedures. This improvement should include use of wireless carry-on medical equipment integrated with an access point and transmissions to an end user device including SATCOM communications, VHF data exchange system, audio integration with ICS, radio compatibility, AHLTA integration, and cybersecurity. This project is designed to explore the feasibility of incorporating medical alarms into the ICS.

Project 4

Forces transmitted to patients during patient handling and litter loading.

As part of the re-scoped award, subprojects 1.2 and 2.2 have been combined into the new Project 4. The existing patient handling research protocol will be revised and combined with the litter loading protocol. A biofidelic manikin will be used as a human surrogate under conditions that involve patient loading/unloading and litter dropping conditions. Forces transmitted to the manikin's body and the resulting body motion will be measured using force and motion sensors. The posture of the Flight Medics receiving the litter in the aircraft will be recorded and analyzed.

Project 5

Effects of strapping configuration on transmitted forces and pressure points.

This study will evaluate the effect of strapping tensions applied by expert Medics on the patients' biodynamic response. Relative motion of body segments will be recorded. The team will evaluate whether different strapping methods using current strapping protocol and the amount of tension applied on various straps will affect the biodynamic response of patients during medical transport. Distribution of pressure points between the human body and supporting surfaces will be characterized.

2. KEYWORDS:

Medical evacuation, paramedic, vibration, ergonomics, en route care, transport, immobilization, space, posture, awareness, medical equipment, litter loading, Integrated Communication System

3. ACCOMPLISHMENTS:

What were the major goals of the project?

The FY 2019 goals were set for each project as listed:

Project 1 Goals

1. Final determination by Grants Officer Representative (GOR) and funding agency of proposed re-scoping of projects. (Completed)
2. Protocol 1.1 (now Project 1 protocol) approval by the Internal Review Board (IRB). (Completed)
3. Data collection for Project 1 protocol. (Completed)
4. Completion of data analysis and reporting for Project 1. (In progress – 95% complete)

Project 2 Goals

1. Final determination by GOR and funding agency of proposed re-scoping of projects. (Completed)
2. Protocol 2.1 (now Project 2 protocol) will be approved by the USAARL RCO, Science Review Committee (SRC), and the IRB. (Completed)

3. Project 2 survey will be disseminated. (Completed)
4. Data from at least the minimum number of surveys needed, 41, will be collected. (Completed)
5. Completion of data analysis and reporting for Project 2. (Completed)

Project 3 Goals

1. Final determination by GOR and funding agency of proposed re-scoping of projects. (Completed)
2. Protocol 3.1 will be approved by the USAARL RCO, Science Review Committee (SRC), and the IRB. Project 3 protocol is written and in review. (In progress – 75% complete)
3. Data collection will begin. (Not started yet – pending protocol approval)
4. The PI will work with the GOR regarding the concern for duplication of effort for Project 3 sub-projects. Alternative projects may be proposed for the same general topic area as the current sub-project 3.1. (Completed)

Project 4 Goals

1. Protocol 1.2 will be combined with 2.2 and approved by the IRB. (In progress – 80% complete)
2. Data collection in progress on 1.2/2.2 protocol. (Not started yet – pending protocol approval)

Project 5 Goals

No goals were set in 2018 for this project. Project 5 will begin in 2020.

During the first quarter, all projects were reduced, combined, or adjusted from three major projects (with 14 individual sub-projects within) to a total of five major projects according to the re-scoping plan (refer to Section 5). The USAARL and ActiBioMotion (ABM) teams met during Quarter 1 to discuss the new plan and ABM's role on Projects 1, 4 and 5.

What was accomplished under these goals?

Project 1 Accomplishments

The patient weight research protocol was approved as a minimal risk study with stipulations. A project progress meeting took place with the extramural partner ABM to discuss activities and scheduling and the protocol was executed.

Over 60 persons responded to the recruitment efforts. Of these persons, 26 were eligible for and completed all testing. This number exceeded the minimum enrollment target of 24 total. A total of 13 subjects in each weight category were tested (Table 1). Due to data corruption, two of the subjects in the low weight category had to be excluded from the analyses. The transmitted vibration of human subjects with different body weights under the conditions of immobilization system (SB) verses no immobilization system (NB) were tested using a man-rated shaker table

(Figure 1). The participants were subjected to different vibration profiles that include vibration of different magnitudes and directions as well as repeated shock. Two groups of human subjects with either low weight (LW) in the range 110 to 150 lb. or high weight (HW) in the range 190 to 240 lb. were tested under the two different support conditions.

Table 1. Subject List

Subject ID	Gender	Weight (lb.)	Group
01	Male	143.7	Low Weight Group
02	Male	238.9	High Weight Group
03	Female	190.3	High Weight Group
04	Female	227.0	High Weight Group
05	Female	129.1	Low Weight Group
06	Female	146.1	Low Weight Group
07	Female	201.3	High Weight Group
08	Female	120.6	Low Weight Group
09	Male	209.7	High Weight Group
10	Female	128.9	Low Weight Group
11	Male	210.1	High Weight Group
12	Female	114.2	Low Weight Group
13	Female	138.4	Low Weight Group
14	Female	194.7	High Weight Group
15	Male	240.9	High Weight Group
16	Male	204.4	High Weight Group
17	Female	132.2	Low Weight Group
18	Male	194.3	High Weight Group
19	Female	111.5	Low Weight Group
20	Female	145.0	Low Weight Group
21	Male	133.8	Low Weight Group
22	Female	147.2	Low Weight Group
23	Female	130.7	Low Weight Group
24	Male	234.3	High Weight Group
25	Male	229.0	High Weight Group
26	Male	204.4	High Weight Group

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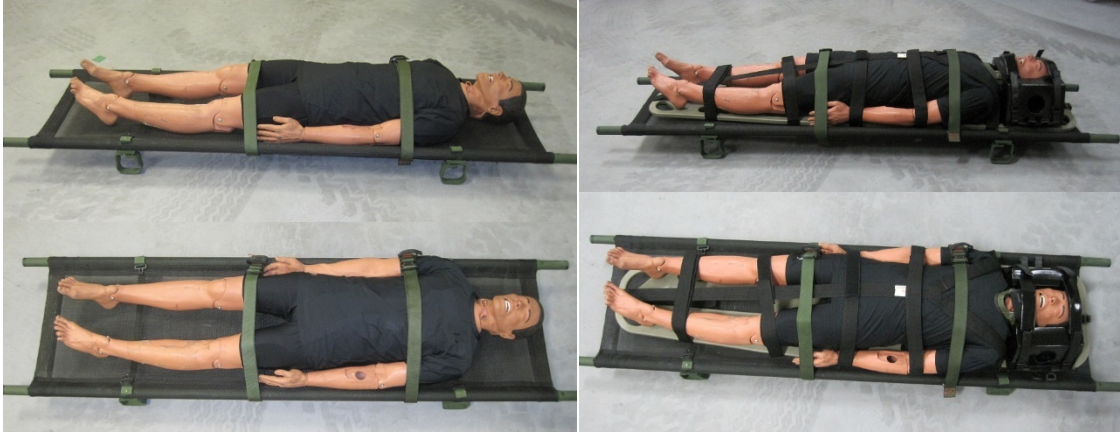


Figure 1: Examples of litter only and backboard immobilization system configurations.

The research team generated the vibration exposure profiles using the Multi-Axis Ride Simulator (MARS) platform. Three vibration profiles (MRAP ground ambulance, HH-60M Black Hawk MEDEVAC helicopter, and broadband Gaussian white noise with vibration and repeated shock in three directions) ran on the MARS table during the study for each participant. Each subject completed all three ride profiles in each of the two configurations. Sensors on the MARS platform, litter, backboard, and body segments of the subjects recorded acceleration and rotational velocity data. Multiple analyses were performed on the collected acceleration and rotational data.

The root mean square acceleration (RMS) was used to quantify how much acceleration and rotation each subject received, on average, over the course of the entire ride profile. The acceleration and rotation that each subject received, in each direction over the course of the entire ride was converted to one RMS value per degree of freedom using Equation 1. All subjects' RMS values were averaged per each degree of freedom.

$$\text{Equation 1: } \mathbf{X}_{RMS} = \sqrt{\frac{(x_1^2 + x_2^2 + x_3^2 + \dots + x_n^2)}{n}}$$

The concept of resonance was referenced and mentioned often when analyzing data in this investigation. An object will resonate, or store energy and increase the amplitude of its motion, when the driving frequency matches the natural frequency of the object. When referenced in simple harmonic motion, resonant frequency is determined by only two parameters (1) the stiffness of the system k , and (2) the mass of the system m . Equation 2 was used frequently when identifying key differences between the LW and HW groups.

$$\text{Equation 2: } \omega_n = \sqrt{\frac{k}{m}}$$

Transmissibility represents the ratio of output motion to input motion. When the transmissibility is above unity, the output is moving more than the input; consequently, amplification occurs. When the driving frequency matches the natural frequency of the system, the output

amplification is maximized. Likewise, when the transmissibility is below unity, the output is moving less than the input, and attenuation occurs. In this study, transmissibility was calculated in three dimensional (3D) space (3 input / 3 output). Transmissibility response is a type of transfer function. Figure 2 shows an example of transmissibility functions.

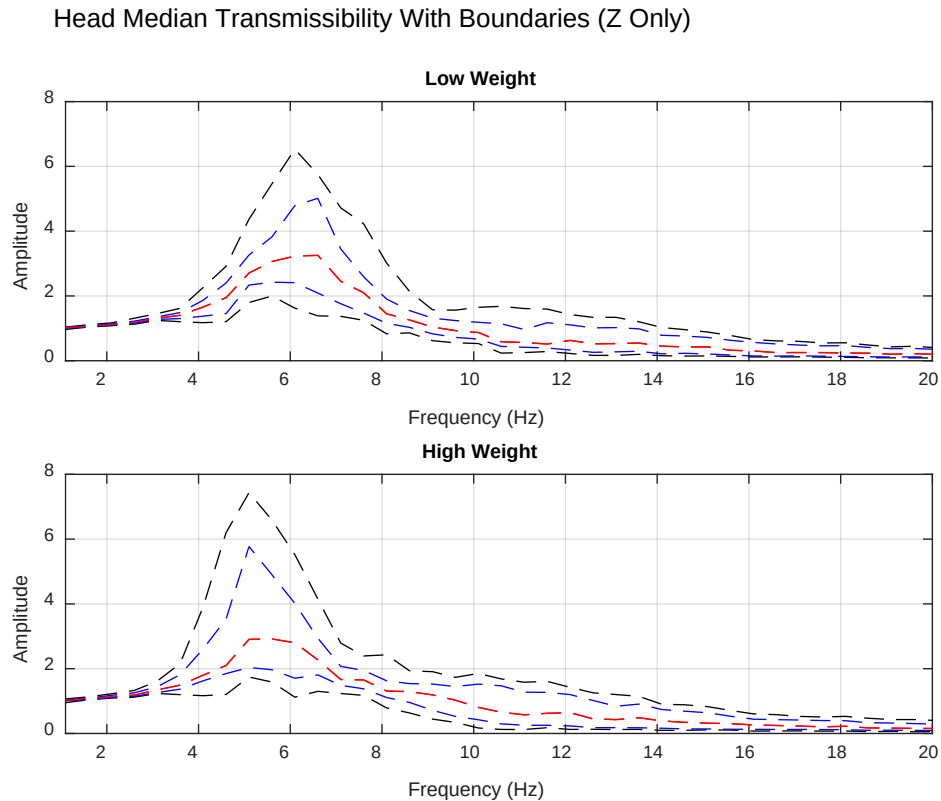


Figure 2. An overlaid transmissibility plot for the head comparing the LW and HW groups. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile.

The median transmissibility for each weight group at the head was analyzed (Tables 2 and 3). Only transmissibility along the z-axis was analyzed. When looking to the median line, the magnitude of transmissibility is nearly identical between the LW and HW subjects. However, the HW group's resonance has been shifted back by approximately 1.5 Hz. The HW subjects' 95th percentile was also higher than the LW group and featured the same shift in frequency as the median line. The areas under the transmissibility curves are calculated measures that can be compared to determine differences between the study variables.

Table 2. The effect of immobilization condition on various analysis quantities for low weight subjects.

Ride Profile	Segment	Low Weight									
		Z Transmissibility (Peak)		Area under Z Transmissibility		Z Transmissibility Wn (Hz)		RMS Z Acc (g)		RMS Gyro (deg/s)	
		SB	NB	SB	NB	SB	NB	SB	NB	SB	NB
ALL	Head	2.74±0.45*^	5.49±1.06*^	1.12±0.06*	1.19±0.08*^	5.83±0.62*	6.39±0.41*^	0.16±0.04	0.20±0.08	10.04±5.77*	25.91±15.61*
	Chest	3.56±0.55^	3.72±0.54^	1.04±0.09*^	1.12±0.11*^	5.73±0.50^	5.81±0.54^	0.14±0.05	0.15±0.05	9.10±5.06*	12.39±5.86*
	Pelvis	4.24±0.77*	3.72±0.71*	1.15±0.11*^	1.02±0.09*^	5.75±0.45*^	5.22±0.45*^	0.15±0.06	0.14±0.05	14.25±8.03^	17.76±9.78
Ground	Head	2.80±0.44*^	5.75±1.15*	1.17±0.05	1.22±0.08	5.88±0.40*^	6.26±0.23*^	0.18±0.01*	0.22±0.01*	7.32±1.61*	17.73±2.41*
	Chest	3.46±0.53	3.75±0.38^	1.07±0.08	1.14±0.08^	5.84±0.37^	5.82±0.48^	0.17±0.01^	0.17±0.01^	7.24±2.80*	10.17±2.45*^
	Pelvis	3.95±0.68	3.45±0.63	1.13±0.11*	1.00±0.07*	5.82±0.37*^	5.15±0.45*^	0.18±0.01*	0.17±0.01*^	11.84±4.16^	13.64±4.38
Air	Head	2.82±0.51*^	5.52±1.19*	1.08±0.06*	1.17±0.10*	6.30±0.68	6.72±0.41^	0.11±0.01^	0.09±0.05	5.39±1.87*	13.35±3.64*
	Chest	3.81±0.63	4.05±0.61^	1.07±0.10*	1.17±0.12*^	6.09±0.46^	6.06±0.65^	0.08±0.02	0.09±0.02	5.48±1.99*	8.15±2.46*
	Pelvis	4.73±0.89	4.24±0.68	1.20±0.12*	1.07±0.10*^	6.09±0.34*^	5.42±0.51*^	0.07±0.01	0.08±0.01^	7.33±2.29*^	9.79±1.61*^
3D Vibration	Head	2.60±0.41*^	5.20±0.84*	1.11±0.04*	1.17±0.06*^	5.30±0.26*	6.18±0.36*^	0.20±0.01*	0.28±0.02*	17.41±2.97*^	46.65±6.36*
	Chest	3.41±0.45^	3.35±0.37	1.00±0.08^	1.05±0.09^	5.27±0.23^	5.54±0.36^	0.17±0.01^	0.18±0.01^	14.59±4.34*	18.85±5.17*
	Pelvis	4.03±0.49*	3.48±0.58*	1.11±0.10*	1.01±0.07*^	5.35±0.28^	5.09±0.35^	0.20±0.02	0.18±0.02	23.59±5.36*^	29.85±5.91*^

*A statistically significant difference between the immobilization conditions exists.

^A statistically significant difference ($p < .05$) between weight groups exists.

Table 3. The effect of immobilization condition on heavy weight subjects, reflected by various analysis quantities.

Ride Profile	Segment	High Weight									
		Z Transmissibility (Peak)		Area under Z Transmissibility		Z Transmissibility Wn (Hz)		RMS Z Acc (g)		RMS Gyro (deg/s)	
		SB	NB	SB	NB	SB	NB	SB	NB	SB	NB
ALL	Head	2.31±0.27*^	6.25±1.60*^	1.11±0.07	1.13±0.09^	5.92±1.49*	5.41±0.43*^	0.16±0.04*	0.19±0.08*	9.11±4.41*	25.87±15.98*
	Chest	3.22±0.44*^	4.33±0.76*^	0.98±0.08*^	0.93±0.06*^	5.38±0.50*^	4.99±0.27*^	0.13±0.04	0.14±0.04	9.71±5.57	10.82±5.76
	Pelvis	4.28±0.77	4.00±0.92	1.05±0.16*^	0.93±0.10*^	5.36±0.43*^	4.82±0.24*^	0.15±0.05	0.14±0.04	20.76±11.66^	22.45±11.79
Ground	Head	2.42±0.29*^	6.43±1.42*	1.17±0.04	1.19±0.09	5.38±0.61^	5.35±0.40^	0.18±0.01*	0.21±0.01*	6.89±1.23*	17.85±2.74*
	Chest	3.23±0.42*	4.30±0.38*^	1.00±0.08	0.96±0.04^	5.45±0.40*^	4.97±0.33*^	0.16±0.01^	0.16±0.00^	7.39±1.96	8.11±1.82^
	Pelvis	4.13±0.71	3.73±0.62	1.04±0.16*	0.93±0.10*	5.38±0.33*^	4.82±0.22*^	0.17±0.01*	0.16±0.01*^	16.37±4.88^	16.62±3.29
Air	Head	2.26±0.28*^	6.50±2.22*	1.06±0.06	1.11±0.10	6.96±1.58*	5.63±0.54*^	0.10±0.01*^	0.09±0.01*	5.52±1.32*	12.54±1.55*
	Chest	3.40±0.49*	5.03±0.73*^	1.00±0.07	0.97±0.04^	5.65±0.56*^	5.12±0.24*^	0.08±0.01	0.08±0.01	5.82±1.84	6.41±1.83
	Pelvis	4.81±0.67	4.80±0.94	1.10±0.18*	0.97±0.10*^	5.65±0.42*^	5.01±0.18*^	0.08±0.02	0.09±0.01^	12.05±3.50^	13.88±3.74^
3D Vibration	Head	2.24±0.21*^	5.83±0.91*	1.10±0.04	1.10±0.06^	5.42±1.56	5.24±0.22^	0.20±0.01*	0.28±0.02*	14.91±1.66*^	47.22±6.52*
	Chest	3.04±0.36*^	3.65±0.35*	0.93±0.07*^	0.87±0.03*^	5.03±0.30^	4.88±0.20^	0.16±0.01^	0.16±0.01^	15.90±5.22	17.92±3.82
	Pelvis	3.89±0.66	3.48±0.57	1.01±0.16*	0.89±0.10*^	5.05±0.31*^	4.63±0.14*^	0.20±0.02*	0.17±0.01*	33.86±10.27^	36.83±8.64^

*A statistically significant difference between the immobilization conditions exists.

^A statistically significant difference ($p < .05$) between weight groups exists.

In order to provide a more comprehensive analysis of the gathered data, the results were subdivided based on three factors, as shown in Tables 2 and 3: weight (high or low), immobilization (immobilization system or no immobilization system), and ride profile (all profiles [ground vehicle, aircraft, and 3D vibration]). For each subdivided set of results, a set of metrics were calculated, specifically the peak of the z-axis transmissibility, the area under the z-axis transmissibility curve (calculated via the integral from 2 Hertz [Hz] to 10 Hz), the resonant frequency (in the z-axis), the RMS z-axis acceleration, and the RMS of the gyroscope magnitude (the norm of the x-, y-, and z-axis components). The gyroscope metric contains all three axes (rather than just the z-axis) because acceleration in the z-axis can cause rotational velocity about all three axes. The metrics were further analyzed for statistical significance using one-way analysis of variance (ANOVA). Results were deemed significant if $p < 0.05$.

Initial examination of the results reveals the use of the immobilization system has a significant impact on the movement of the head. There are marked reductions in the peak transmissibility. The use of the head block constraints and stiffness of the spine board do demonstrate a reduction of the relative motion of the head with respect to the board (which is the purpose of the immobilization system). The implications of the motion of the other body segments, such as the chest, versus the relatively-immobile head are less clear. The head segment is connected to the chest segment via the neck, and the pelvis is connected to the chest via the trunk. Greater peak transmissibility and rotational RMS values suggest that this independent movement of segments takes place at those connecting points. These disparities could be cause for concern in patients with injuries in those intersegmental regions (e.g., spinal injury).

The ANOVA analyses also show the resonant frequency is significantly impacted by the weight factor. Shifts in resonance frequency are important because if the driving energy from the vehicle aligns with the resonance frequency of the human, this leads to exacerbation of the vehicle vibration through the human. The existence of a range of resonance frequencies also has implications for vibration mitigation technologies that might be used to reduce vibration dose for patients. Reduction at the resonance frequencies of the human-litter-immobilization system combined package would be key to effective vibration mitigation to prevent injury exacerbation.

A USAARL Technical Report describing the complete study results and conclusions is forthcoming. The full data analysis report by ABM may be found in Appendix A.

Project 2 Accomplishments

This project involved designing a survey to investigate awkward postures associated with delivering patient care in the confined space of common medical evacuation (MEDEVAC) platforms. The survey also related care provider health and efficiency with these postures and resulting injuries. The goal of this work was to provide recommendations for countermeasures to reduce the impact of awkward postures. The survey was presented via email and social media to U.S. Army Active Duty, Reserve, and National Guard en route care medical providers. Valid data were collected from 60 respondents. Statistical analyses were used to define trends in the data. Results will contribute to the long-term health of care providers and to en route care task administration efficiency. An abstract for this study was submitted to the Military Health System Research Symposium and results were presented in a poster at the symposium. Survey intake

was closed on 31 May 2019. The following information outlines the data and responses collected during the study.

The survey was created and distributed online using ClassApps LLC SelectSurvey.NET v4 .154.010. Survey questions inquired about the data in Table 4.

Table 4. Survey Question Content

Data Classifications
Gender
Height
Weight
Position title
Platform or position location
Length of time in position
Aircraft/vehicle/gear design characteristics that impacted mission performance
Items in the current aeromedical or ground evacuation Medical Equipment Set (MES) which caused awkward or painful postures
If number of patients affects postures
Number of patients typically cared for
Frequency of awkward postures during tasks
Occupational injuries / discomfort associated with postures during patient loading and care
Reasons for not reporting injuries
Specific postures or tasks that cause primary source of pain
Other injuries that were not previously mentioned

ANOVA was performed using an Excel filter table to compare the numbers of a single continuous variable between two groups. The two-number lists were examined using the ANOVA single factor feature of Excel's Analysis ToolPak Add-In. Power analyses were performed on the ANOVA results in R 3.6.1 using the `pwr.t2n.test` function from the PWR package. Fisher's exact analyses were performed in RStudio 0.99.903 using the `fisher.test` function on two-by-two tables created in Excel with the alternative hypothesis set to "two.sided." Open-ended data were read and categorized according to the content of each comment. Categories were created as comments were sorted, and the comments were broken down into components since most comments cited multiple issues and sources. The data were then tallied and illustrated as bar graphs.

A total of 60 valid surveys, 46 complete and 14 incomplete surveys, were collected. Respondents included Critical Care Flight Paramedics, Ground Medics, Standardization Instructors, Flight Instructors, Flight Surgeons, a MEDEVAC Crew Chief, and a Flight Medic. All respondents had 68W Military Occupational Specialty (MOS) experience except the MEDEVAC Crew Chief. Compartment Configurability, the Litter System, Cabin Ergonomics, Compartment Size, Patient Loading Capability, and Personal Protective Gear were all found to negatively affect the mission by over 60% of respondents (Figure 3). Almost half (49%) of respondents reported that they usually care for one patient at a time and 94% of respondents agreed that an increasing number

of patients increases the amount of painful postures that must be employed by care providers. Figure 4 illustrates the care providers' primary pain sources. Loading and unloading littered patients was among the top causes of awkward postures such as bending, overextending, kneeling, and squatting. Every type of injury had more counts of being unreported than reported. Lower back, knee, neck, shoulder, and upper back injuries were prevalent among respondents (Figure 5). Lower back injuries were the most common among respondents, suffered by 87% of respondents. Awkward positions, flight gear, and body armor were the leading causes of lower back injuries among respondents. The leading cause of knee injuries was kneeling/crawling. The leading causes of neck injuries were NVGs and helmets, and many comments cited the combination to be particularly painful. Statistically significant relationships were found between groups based on height.

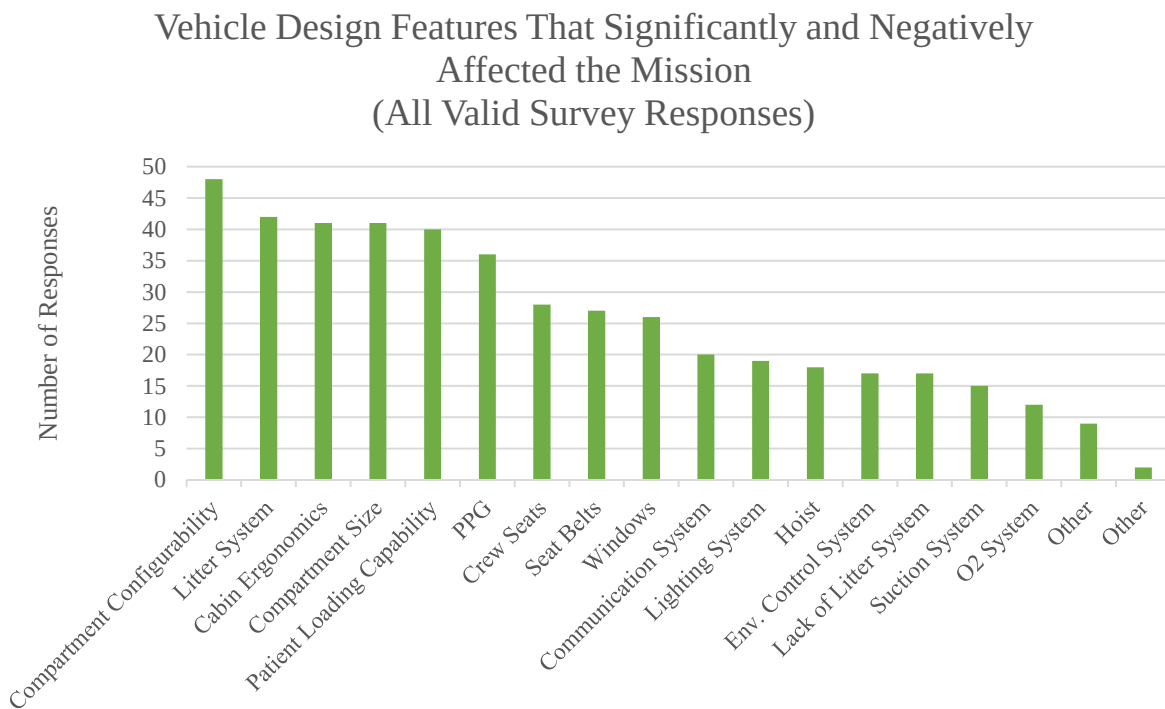


Figure 3. Vehicle design features with negative impact.

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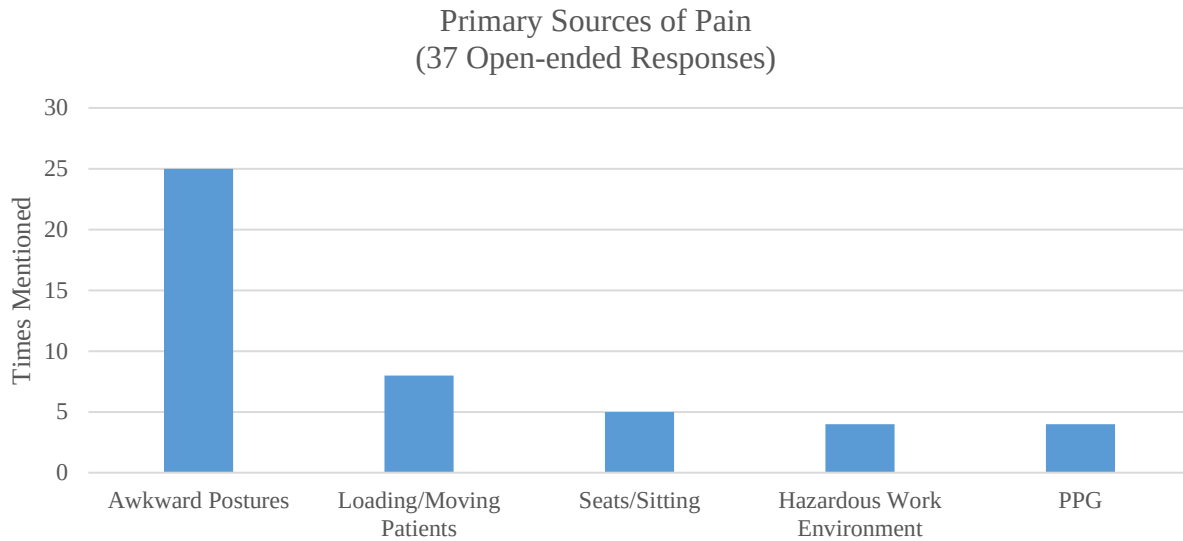


Figure 4. Primary sources of pain.

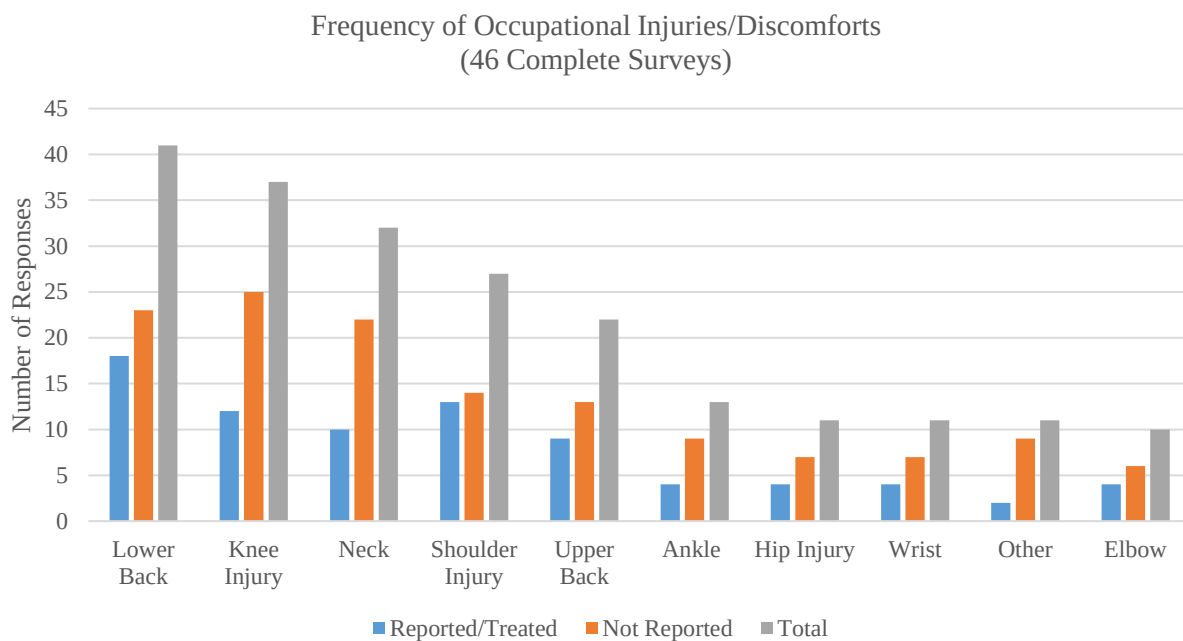


Figure 5. Frequency of occupational injuries.

The Fischer's exact analysis identified that taller care providers at least 69.09 in. tall were 73% less likely to find the crew sets to significantly and negatively affect the mission than care providers of average height or below, 84% less likely to find the environmental control system to be a negative feature, 81% less likely to find the O₂ system to be a negative feature, and 86% less likely to find patient loading capability to be a negative feature that significantly and negatively

affected the mission. No statistically significant differences were found when comparing male to female groups in the study.

Since this study is in agreement with previous civilian studies that back injuries are the most prevalent among en route care providers, it would be prudent to focus on solving issues that cause back problems. According to survey results, finding a way to minimize the stress placed on the care providers while lifting and loading patients would contribute significantly to reducing the amount of back injuries. Also, the current cabin area necessitates that care providers bend and kneel frequently to care for patients. Designing cabin areas and litter pan systems with the intention of minimizing these awkward postures would significantly reduce the amount of back and knee injuries suffered by care providers.

A USAARL Technical Report describing the complete data analysis, study results, and conclusions has been published and is presented in Appendix B.

Project 3 Accomplishments

An extensive literature review for Project 3 (formerly sub-project 3.1) was conducted and the protocol is in the final revision stages. The literature review focused on the efficacy of medical device alarms, alarm usefulness in high-noise environments, and alarm fatigue/attentional deafness that occurs when an excessive number of non-significant alerts are present.

Project 4 Accomplishments

As part of the re-scoped award, sub-projects 1.2 and 2.2 have been combined into Project 4. The existing patient handling research protocol was revised and combined with the drafted litter loading protocol. A project progress meeting took place between USAARL and ABM during this reporting period, and the re-scoped focus of this projects was discussed. The combined protocol is awaiting review by the extramural partner ABM to verify the instrumentation identified to collect appropriate measures discussed during the project progress meeting.

Project 5 Accomplishments

Nothing to report. This project is scheduled to begin in 2020.

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

Nothing to report.

How were the results disseminated to communities of interest?

USAARL technical reports were written to communicate the results of Projects 1 and 2. The Project 1 report is currently in the approval process. The report for Project 2 was delivered to the U.S. Army Medical Evacuation Proponency Division and the U.S. Army Medical Materiel Development Activity as interested stakeholders for military medical evacuation topics. A poster for the results from Project 2 was presented at the 2019 Military Health System Research Symposium.

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

Project 1 Year 4 Goals

The final USAARL Technical Report will be delivered to the sponsor and interested stakeholders in FY20Q1.

Project 2 Year 4 Goals

None, this project was completed in YR3Q4.

Project 3 Year 4 Goals

The protocol will be submitted to the USAARL Research Compliance Office for approval. Data collection will begin. The PI will continue to engage with medical evacuation SMEs to determine research gaps of interest in this area of research (alert mechanisms associated with medical devices). Relevant ideas will be presented to the GOR and sponsoring agency for study consideration.

Project 4 Year 4 Goals

After review of the combined and revised protocol by the extramural partners, the protocol will be submitted for institutional approval during Year 4. Data collection and analysis will take place. The project will be completed in Year 4.

Project 5 Year 4 Goals

A project kick-off meeting will take place with the extramural partner, ABM. The protocol will be written and submitted for institutional approval during Year 4.

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?

Nothing to report.

What was the impact on society beyond science and technology?

Nothing to report.

Military Relevance

USAARL, with the above proposed projects, will impact military health care by (1) developing guidelines that can reduce secondary damages to the patients during transport; (2) creating assessment tools to develop better patient vibration mitigation technologies and more effective patient transport systems; (3) providing recommendations for countermeasures to reduce the impact of awkward postures and loading procedures assumed by care providers; and (4) communicating critical patient data in the medical evacuation environment without compromising medical provider administration of critical care tasks. These goals complement on-going Department of Defense areas of research into the effects of the transport environment on patients and care providers, telemedicine, and enhanced medical monitoring.

5. CHANGES/PROBLEMS:

Changes in approach and reasons for change.

The Defense Health Program grant “En Route Care in Confined Spaces: Impact of Transport, Immobilization Practices, Space Constraints, and Medical Awareness Enhancements (DM167047)” was awarded to USAARL in FY17. This grant is a multi-project undertaking, initially structured as three major projects, each of which was compromised of multiple sub-projects. Major Project 1 included a partnership with ABM under contract W81XWH17P0315.

A total of 14 “sub-projects” were originally proposed. While classified as sub-projects, the majority of these studies are full-scale projects, several needing more than one year and more substantial budgets to feasibly execute. Also, it took nearly a year to get extramural partner for Project 1 under contract. Two of the three project PIs left USAARL, because of a permanent change in station or leaving government service. The site PI was functioning as the project PI as well. It became clear to the research team that accomplishing all of the sub-projects in the five year period of performance within the limits of the award funding would not be possible.

The overall grant PI reached out to the GOR because it was clear that the grant as originally structured was unachievable. A get well plan was agreed to by the sponsoring agency, GOR and PI. This plan included a restructuring of the three major projects, with all sub-projects, into five main projects with revised timelines. A revised statement of work, budget, and budget justification were submitted and accepted.

Actual or anticipated problems or delays and actions or plans to resolve them.

Nothing to report.

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.

6. PRODUCTS:

Publications, conference papers, and presentations

Conti, S., Kroening, L., Kinsler, R., Lloyd, A., Molles, J. (2019). "Optimal Physical Space for En Route Care: Medic Posture and Injury Survey Results," *USAARL Technical Report No. 2019-18*,

Kroening, L., Conti, S., Kinsler, R., Lloyd, A., Molles, J. (2019). "Optimal Physical Space for En Route Care: Medic Posture and Injury Survey, 2019," poster presentation at *Military Health System Research Symposium*, Kissimmee, Florida, August 2019.

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.

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7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

Name:	Rachel Kinsler
Project Role:	Site Principal Investigator (PI), Project PI
Nearest person month worked:	8
Contribution to Project:	Ms. Kinsler has performed protocol drafting and revision, worked on the review process for the research protocols, worked on the contracting actions, directed data collection and analysis, and wrote reports.
Funding Support:	Department of Army Civilian
Name:	Sandra Conti
Project Role:	Associate Investigator
Nearest person month worked:	4
Contribution to Project:	Dr. Conti has drafted protocol documents, written the survey, assisted with the review process, performed data collection and analysis, and wrote reports.
Funding Support:	Goldbelt, Inc. (funded partially by award)
Name:	Amy Lloyd
Project Role:	Research Engineer
Nearest person month worked:	3
Contribution to Project:	Ms. Lloyd has assisted with the preparation and review of test/protocol documents, performed data collection and analysis, and wrote reports. (Ms. Lloyd started at USAARL in September 2018).
Funding Support:	Goldbelt, Inc. (funded partially by award)
Name:	Laura Kroening
Project Role:	Research Engineer
Nearest person month worked:	3
Contribution to Project:	Ms. Kroening has assisted with the preparation and review of test/protocol documents, performed data collection and analysis, and wrote reports. (Ms. Lloyd began employment September 2018).
Funding Support:	Oak Ridge Institute of Science and Education (funded partially by award)

Name:	Jeffrey Molles
Project Role:	Research Technician (retired Flight Medic)
Nearest person month worked:	2
Contribution to Project:	Mr. Molles has performed data collection and analysis, and provided subject matter expertise pertinent to medical evacuation..
Funding Support:	Goldbelt, Inc. (funded partially by award)

Partner organization name: ActiBioMotion

Location of organization: 2500 Cross Park Road, E156Q, Coralville, IA 52241

Partner's contribution to the project: Extramural partner on Projects 1, 4 and 5. Primarily responsible for analysis of data and modeling efforts.

Financial support:

In-kind support: N/A

Facilities collaboration: N/A

Personnel exchanges: N/A

8. SPECIAL REPORTING REQUIREMENTS:

The project Quad Chart is attached in Appendix C.

9. APPENDICES:

Appendix A:

Harris, C., Frick, E. "Data Analysis for: Effect of Patient Weight as a Factor during Use of an Immobilization System Versus No Immobilization System," *ActiBioMotion, LLC Technical Report* for contract number W81XWH-17-P-0315, 2019.

Appendix B:

Conti, S., Kroening, L., Kinsler, R., Lloyd, A., Molles, J. "Optimal Physical Space for En Route Care: Medic Posture and Injury Survey Results," *USAARL Technical Report No. 2019-18*, 2019.

Appendix C:

Quad Chart.

Appendix A. ActiBioMotion, LLC Technical Report.

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This work was performed under Contract No. W81XWH-17-P-0315.

Data Analysis for:
Effect of Patient Weight as a Factor During Use of an Immobilization System Versus No Immobilization System

By

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25 September 2019

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 documentation.

Contents

Introduction.....3

Methods.....3

Results.....11

Statistical analysis 47

Discussion 50

References 52

List of Abbreviations 53

INTRODUCTION

Recent surveys on health care providers in the field have reported severe discomfort and pain experienced by casualties during military ground and air transport and attributed the pain to vibration and repeated shock associated with the transport (Kinsler, Barazanji, Lee, Fulton, and Hatzfeld, 2015). The transmitted forces and vibrations to the patient's body through the transport system can have severe consequences, especially for those neurotrauma patients sensitive to increased intracranial pressure (ICP) (Ratanalert, 2004; Reno, 2010). Litters and immobilization systems can also cause exacerbation of vibration stresses (Kinsler et al, 2018). Prior to transport, casualties with serious injuries such as head and back injuries are required to be immobilized to prevent movement that may lead to further complications. In other circumstances, patients may get transported using only litters with no backboard.

Besides the transmitted forces to the human body, patients may also suffer from discomfort/pain resulting from the formation of pressure sores at the contact points between the patient's body and the transport system. Previous studies have indicated association between the formation of the pressure sores and immobilization during transport (Linares et al, 1987). Strapping the patient and the degree of strapping tension varies dependent on patient condition and injuries, and that may play an effective role in the formation of pressure sores. It may also affect the severity of the motion transmitted to the patient's neck and lower back areas. Due to the inertial effect, it is expected that the severity of the resulting motion will be proportional to the patient's body mass.

The objective of this work was to investigate the effect of immobilization systems and body weight on the biodynamics response of supine humans during medical transport.

METHODS

This study was performed to investigate the interaction of patient weight with immobilization condition on relative body segment motion and magnitude of transmitted motion of supine humans. The hypothesis that the human weight has significant effect on the characteristics of the transfer functions was tested using 26 human subjects with different body weights. Two groups were selected based on weight: (1) 13 subjects with low weight (110 to 150 lbs.) (LW group), and (2) 13 subjects with high weight (185 to 245 lbs.) (HW group), were tested under the two different support conditions. Due to data corruption, however, data from two LW subjects could not be used in the analysis. As a result, only 24 subjects were tested, with 11 subjects in the LW group and 13 subjects in the HW group. This group selection allowed comparison of vibration transmissibility due to weight. The goal of the study is to determine whether different body weights produce different biodynamical responses with and without the immobilization system. The transmitted vibration of LW and HW human subject groups under the conditions of board verses no-board was measured using a man-rated shaking table. The subjects were secured to the litter and/or immobilization system on the Multi-axis Ride Simulator (MARS) at the U.S. Army Aeromedical Research Laboratory (USAARL) and subjected to different vibration profiles that included vibration of different magnitudes and directions as well as repeated shocks. The effect of the interactions between the body's weight and two immobilization conditions on the magnitude of the transmitted motion to the different body segments were evaluated. Appropriate transfer functions were calculated between the input/output motions to identify the critical

frequencies where the transfer functions have large magnitudes, i.e., where the input motion is magnified as it reaches the human body.

For the litter with no immobilization board (NB), the subjects were restrained on the litter using two straps across the body as shown in Figure 1. For the litter with full immobilization set-up, where the spinal-board is used (SB) a full immobilization system complete with a head brace, spine board, and spider straps is shown in Figure 2. The coordinate system showing the direction of the translational and rotational accelerations is illustrated in Figures 1 and 2.

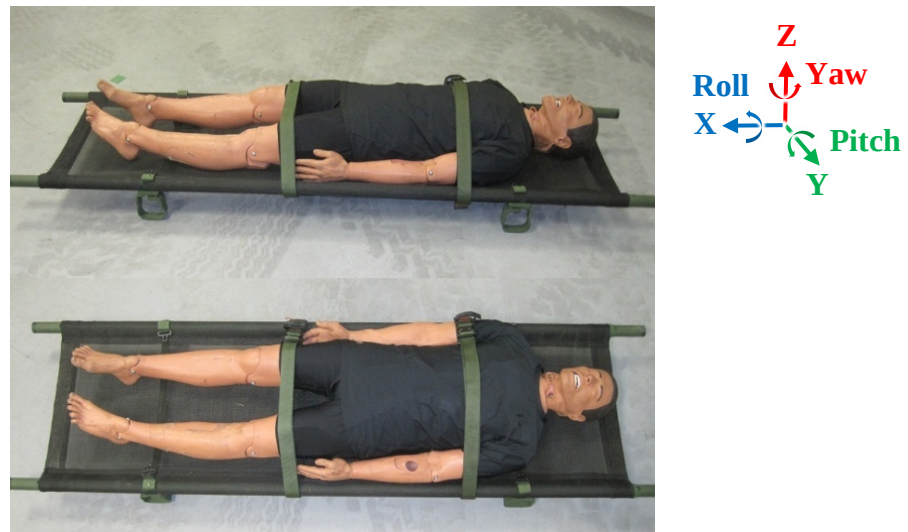


Figure 1: Litter with no immobilization system.



Figure 2: Litter with full immobilization set up.

While secured in the testing configuration, each subject was exposed to three ride profiles: (1) ground vehicle (~60 seconds), (2) air vehicle (~60 seconds), and (3) white noise shocks/vibration random vibration (~60 seconds). The ground vehicle profile is a recorded ride signature from a ground ambulance that was driven over a rough road with bumps. This profile contains a predominant low frequency vibration of 2 Hz associated with the vehicle suspension and some higher frequencies elements associated with the engine operation, along with some jolts from the bumps in the road. The air vehicle profile is a compilation of recorded signatures from an H-60 series MEDEVAC helicopter that was performing standard flight maneuvers. This profile contains energy associated with a predominant frequency of approximately 17 Hz that is associated with the operation of the main rotor. There are also some minor jolts in the profile from landing maneuvers. The shocks/random vibration profile is a Gaussian white noise signal with mixed frequencies at multiple amplitudes. The maximum amplitudes in each ride profile fall within the safety standards described in the ISO 2631 series (USAARL, 2019).

Motion sensors were placed on the head, chest, pelvis, and leg to gather data at each major body segment. The motion sensors used, except for the leg, were 6DOF to allow for the recording of both acceleration and rotational data. Another 6DOF sensor was mounted to the litter and was moved onto the spine board when the subject was immobilized. A 3DOF sensor was placed on the MARS platform. By placing sensors on both the litter and the MARS platform (both considered as input vibration), the biodynamic response of each subject could be measured relative to either input.

Before testing, each subject had their anthropometric data collected. Properties such as weight, height, and certain anthropometric measurements were measured. The subjects rated the comfort/discomfort of the system on a scale of 1 to 10 on the Borg CR-10 scale with higher numbers representing more discomfort, after each ride profile (Borg, 1982). They were also asked to report any pain being experienced. No subject reported a discomfort level of 7 or higher, or a pain level of 3 or higher. Those levels were the maximum allowed before the experiment was discontinued until the study physician examined the subject.

Transmissibility represents the ratio of output motion to input motion. When the transmissibility is above unity, the output is moving more than the input, and amplification occurs. When the driving frequency matches the natural frequency of the system, the output amplification is maximized. Likewise, when the transmissibility is below unity, the output is moving less than the input, and attenuation occurs. A more thorough way to calculate transmissibility is to use the *spa* function in MATLAB, which estimates frequency response using the Blackman-Tukey spectral analysis method. This method computes the covariances and cross-covariance from the input and output signals and computes the Fourier transforms of these values. The frequency-response function is calculated next by taking the ratio of the transformed cross-covariance to the transformed input covariance. In this study, transmissibility was calculated in 3D space (3 input/ 3 output).

The root mean square acceleration (RMS) was used in this analysis to quantify how much acceleration and rotation each subject received, on average, over the course of the entire ride profile. The acceleration and rotation that each subject received, in each direction over the course of the entire ride was converted to one RMS value per degree of freedom using Equation 1. All subjects' RMS values were averaged per each degree of freedom.

$$\text{Equation 1: } X_{RMS} = \sqrt{\frac{(x_1^2 + x_2^2 + x_3^2 + \dots + x_n^2)}{n}}$$

The concept of resonance was referenced and mentioned often when analyzing data in this investigation. An object will resonate, or store energy and increase the amplitude of its motion, when the driving frequency matches the natural frequency of the object. When referenced in simple harmonic motion, resonant frequency is determined by only two parameters. These parameters are the stiffness of the system k , and the mass of the system m . Equation 2 was used frequently when identifying key differences between the LW and HW groups.

$$\text{Equation 2: } \omega_n = \sqrt{\frac{k}{m}}$$

Many of the data collected between testing conditions were converted to ratios comparing the differences between each testing condition. When considering the effect of immobilization condition, the output at the spine board (SB) test was divided by the output at the litter only (NB) test for each subject, then averaged among the LW and HW groups (i.e., SB/NB). When analyzing the effect of subject weight, the output metric of the LW subject was divided by the output metric of the HW subject. Ratios allow intra-subject comparison and a comparison between testing conditions that is easily visualized.

The two conditions being tested, immobilization and weight, are different in nature. For the immobilization factor, there is data on every subject from both conditions (spine board and no board). This allows for an intra-subject comparison to be applied to all subjects. Specifically, spine board metrics could be normalized against the no board metrics (through division), yielding a normalized ratio that could be fairly compared between subjects. For the weight factor, however, no subject could be both high and low weight. Therefore, no intra-subject comparison can be done; it must be inter-subject. Therefore, the output metrics for the high and low weight subjects were compared directly, without any normalization.

To reduce unwanted noise within each subject's data, a bidirectional, 4th order lowpass Butterworth filter was utilized to cut off unwanted data above 30Hz.

The power spectral density was also analyzed for each body segment, immobilization condition, and ride profile. A power spectral density, or PSD, describes the distribution of power inside a signal by decomposing the signal into discrete frequencies over a continuous range (Stoica & Moses, 2004). The mean of all subjects' PSDs was used to identify where the most power was being transmitted to the subject. In addition, the PSD was generated at the MARS platform and at the litter in order to analyze the frequency content of each ride profile.

The coherence of each subject was used to determine the degree of causality between the input vibration and the subject. A higher coherence implies direct causality between the input vibration and the output.

Boxplots were used to further investigate the distribution of data for each testing condition, since the data followed a non-gaussian distribution. The boxed region represents data points contained inside 25 to 75 percent of the data range, and the plot whiskers expand out to include data points within 5 to 95 percent of the data range. The median and mean of the data is also provided. In some cases, outliers are also represented on the plot as circular regions outside of the 5th to 95th percentile. A sample plot can be found in Figure 3.

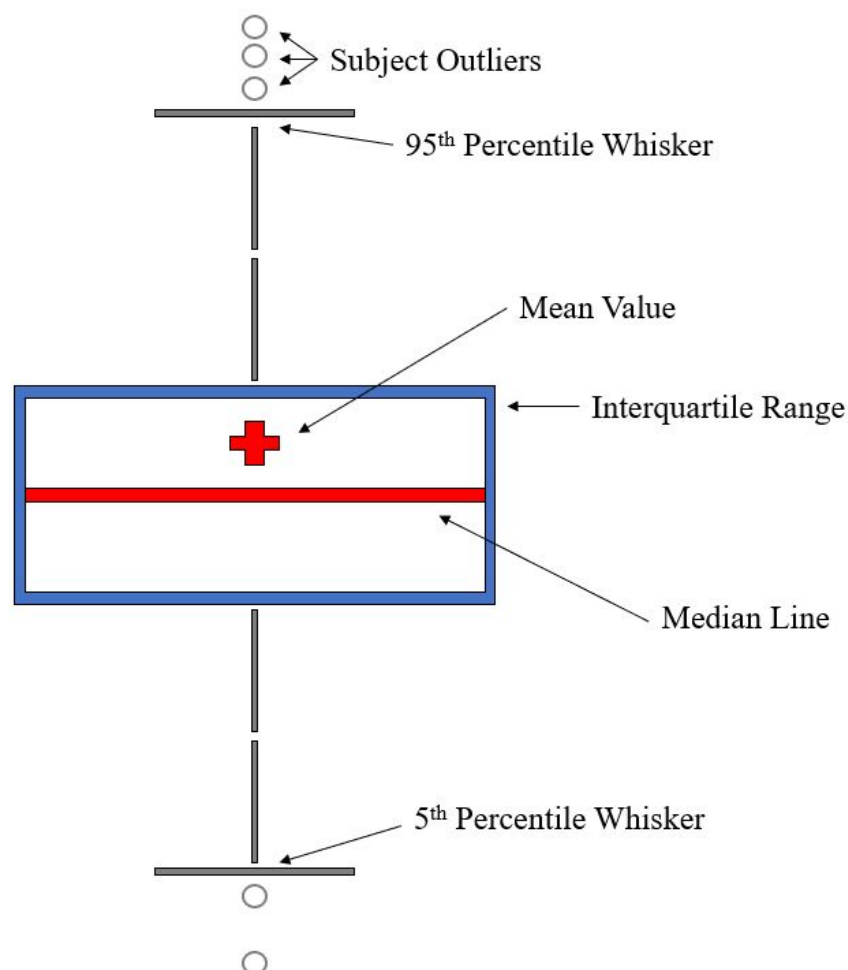


Figure 3: A sample box plot. The interquartile range is represented by the blue box, while the whiskers represent all data points within 5 to 95 percent of the data range. The red line represents the median of the data, while the red plus represents the mean. Outliers are located outside of the 5th to 95th percentile range and are indicated by hollow circles. Each circle represents one outlier.

The input power to the system was analyzed for all three axes. Data was broken out into each axis of motion, which can be found in Figure 4-Figure 6.

Figure 4 describes the input power for all ride profiles, analyzed at the X axis. Profile 1 shows a steady increase in power as frequency increases. Profile 2 features a smaller peak centered around 5 Hz, with lower power until 15 Hz. After this, power rises quickly to a large peak at 17 Hz. Power is centered around 12 Hz in Profile 3 but decreases more slowly after the resonance.

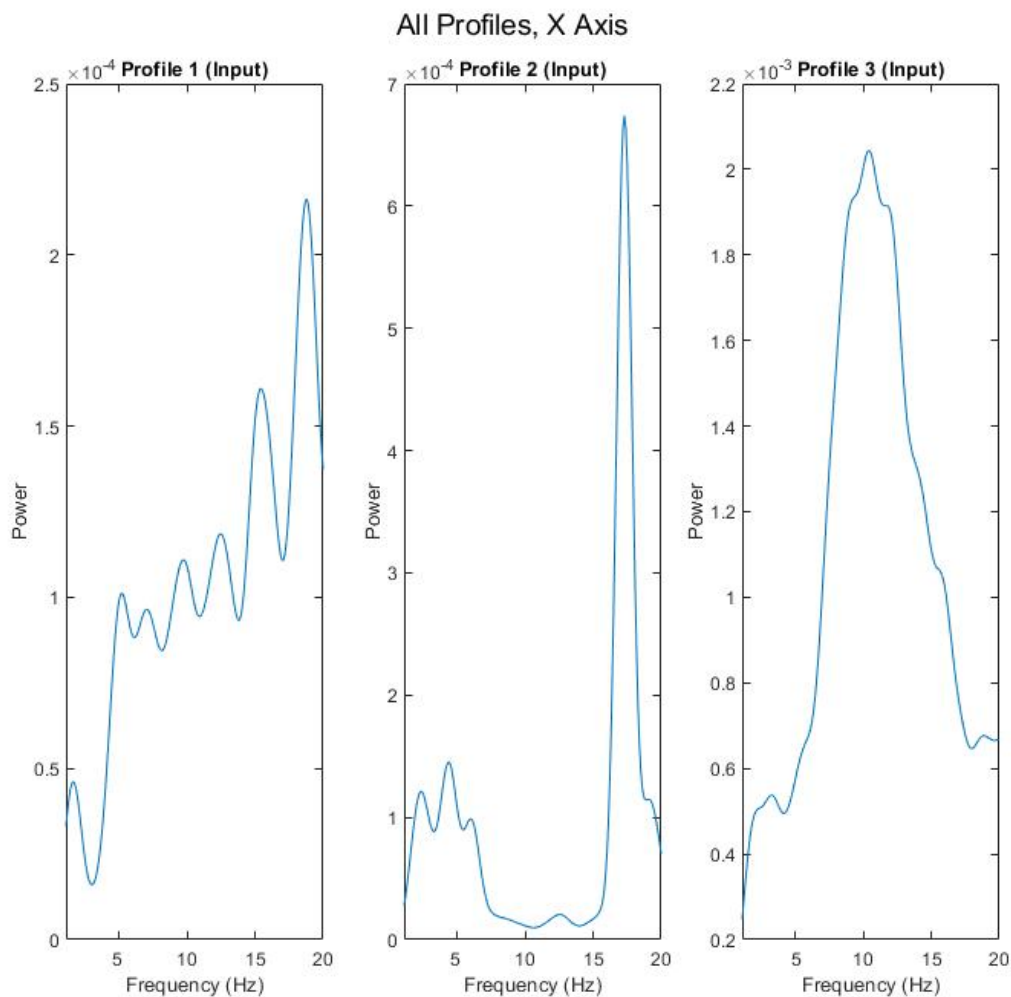


Figure 4: The input PSD power from the ground vehicle (Profile 1), helicopter ride (Profile 2) and the random 3D motion (Profile 3). Each PSD contains data from the X axis.

The input power analyzed at the Y axis can be described in Figure 5. All ride profiles exhibit one large peak. Profile 1 shows a large peak at 8 Hz, while Profile 2 features a large peak near 17 Hz. Profile 1 contains some power after its resonance, but at only 35% of the peak value. Profile 2 contains power almost exclusively at its resonance. 3 contains most of its power around 9 Hz, but still has power roughly 40% that of the peak across all frequencies.

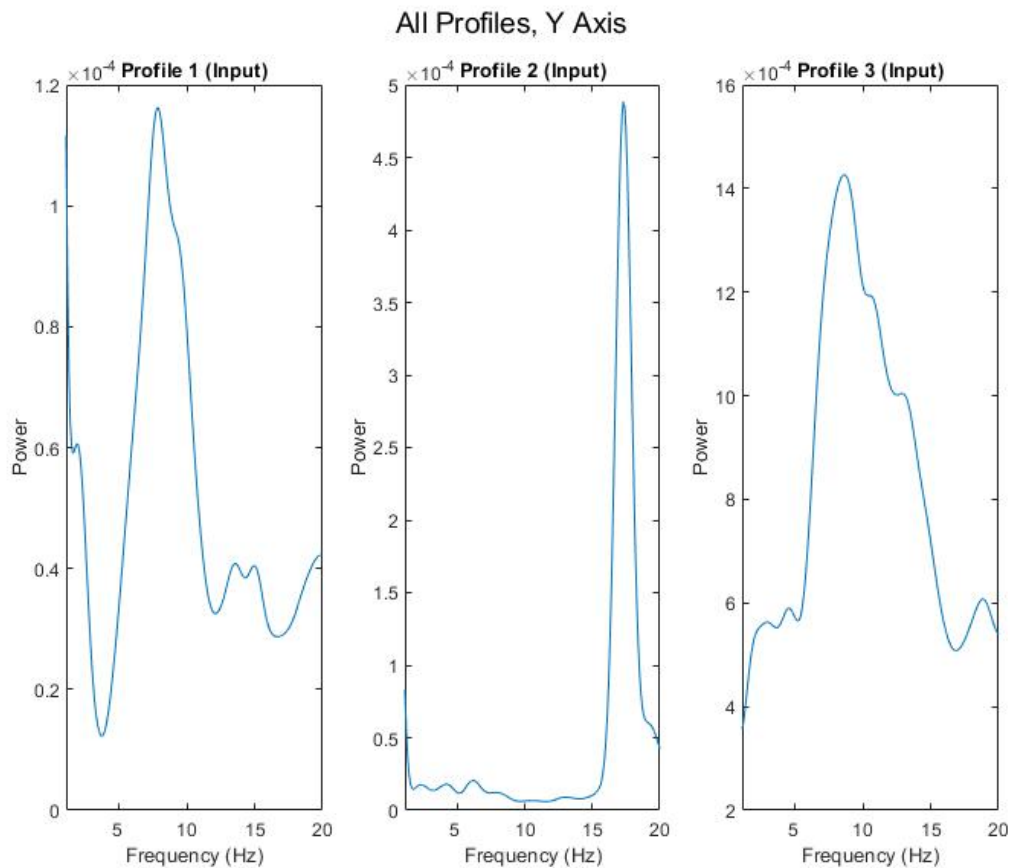


Figure 5: The input PSD power from the ground vehicle (Profile 1), helicopter ride (Profile 2), and the random 3D motion (Profile 3). Data pertains to the Y axis.

The input power analyzed at the Z axis can be described in Figure 6. Both Profiles 1 and 2 contain nearly all their power at their peaks. Profile 1 exhibits maximum power near 2 Hz, and Profile 2 reaches full power at 17 Hz. Profile 3 contains power throughout all frequencies but exhibits its maximum power near 2 Hz. A second, smaller peak is present near 16 Hz, at approximately 80% the power of the larger peak.

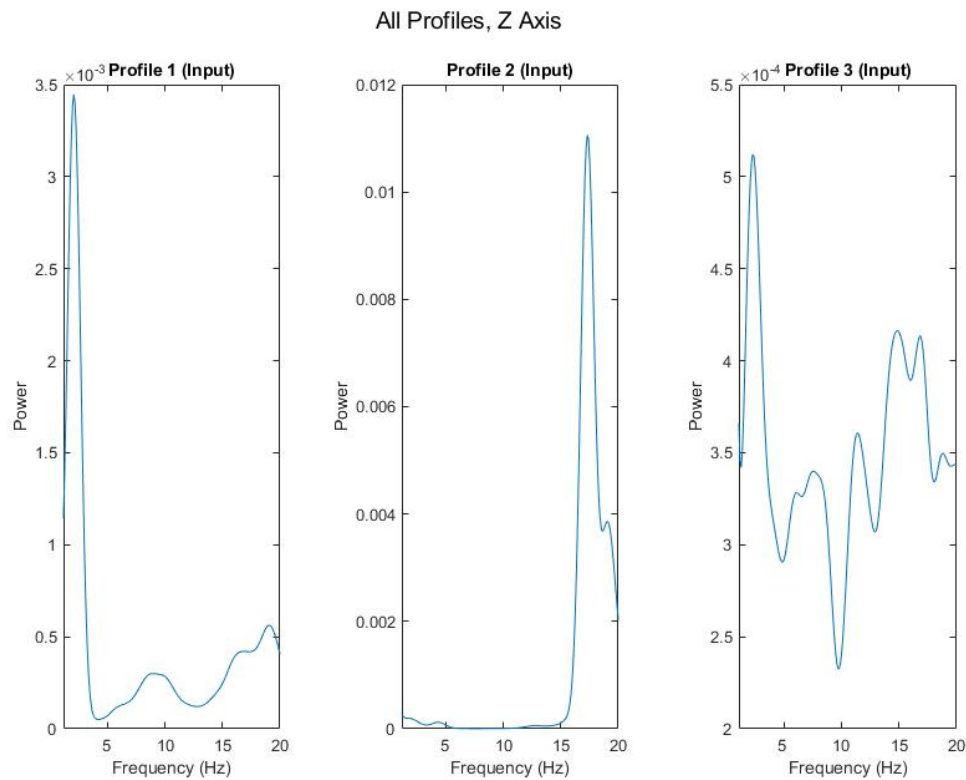


Figure 6: The input PSD power from the ground vehicle (Profile 1), helicopter ride (Profile 2), and the random 3D motion (Profile 3). Data pertains to the Z axis.

RESULTS

RMS Acceleration Ratio

The ratio of the RMS acceleration at the head when immobilized to when not immobilized (SB/NB) can be found in Figure 7. Along the Z axis, median acceleration was reduced by nearly 20 percent for both LW and HW subjects. The mean RMS acceleration for the LW group is slightly higher than that for the HW group. The interquartile range for the LW group was larger than that for the HW group. The 5th percentile was nearly the same for both groups, but the 95th percentile was larger for LW group.

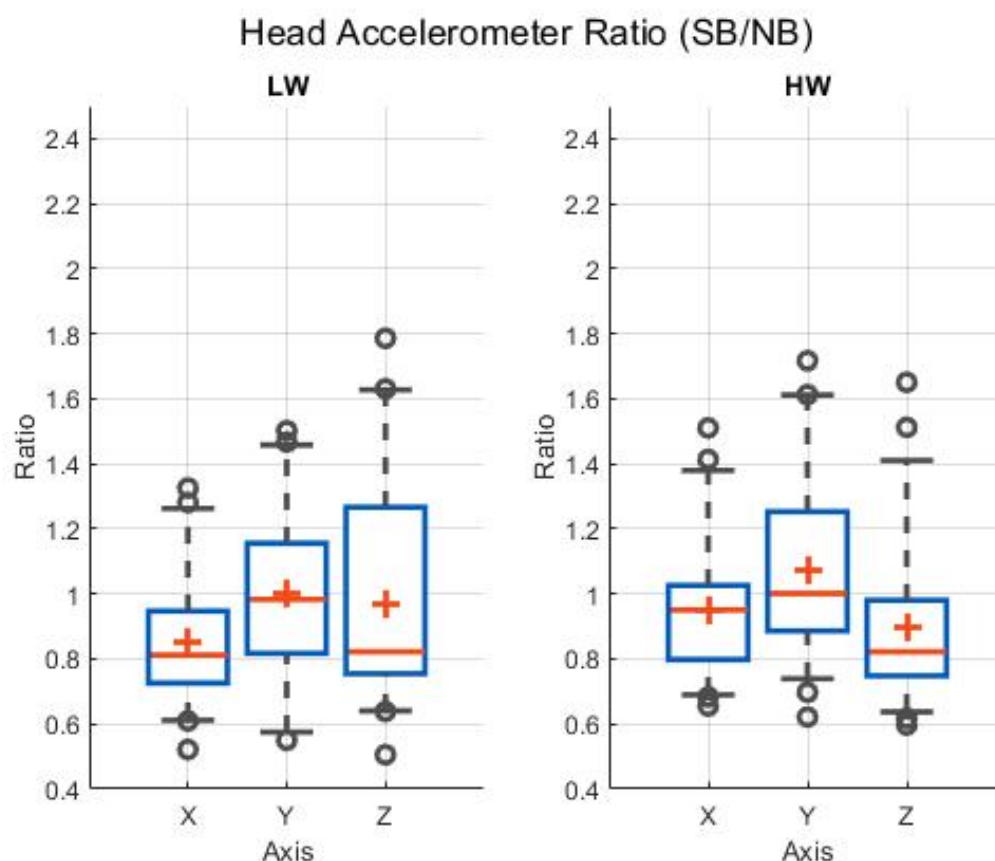


Figure 7: The ratio of the RMS acceleration experienced while immobilized to when not immobilized, measured at the head.

The ratio of the RMS acceleration at the chest when immobilized to when not immobilized (SB/NB) can be found in Figure 8. When looking to the Z axis, the median acceleration was largely unchanged when implementing a spine board versus when no spine board was used. The interquartile for the LW group, and both the interquartile range and the 5th to 95th percentile on the HW subjects are tightly grouped. The mean RMS acceleration remains close to the median in both weight groups.

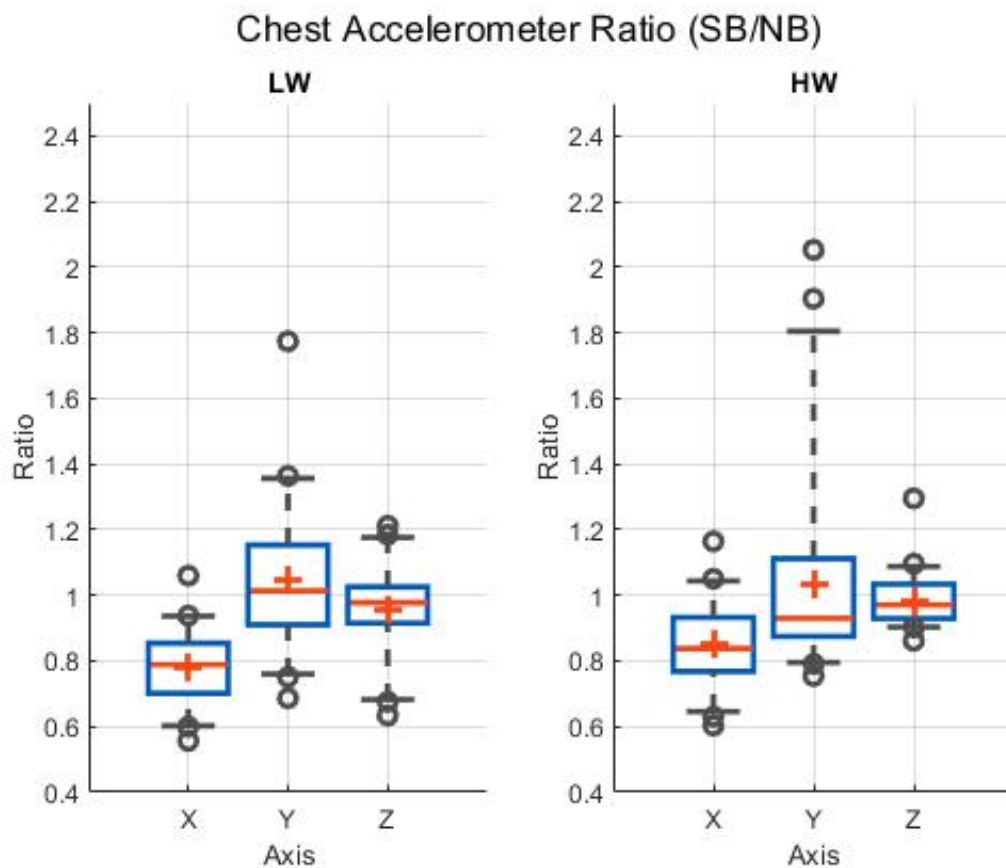


Figure 8: The ratio of the RMS acceleration experienced while immobilized to when not immobilized, measured at the chest.

The RMS acceleration ratio at the hip when immobilized to when not immobilized can be found in Figure 9. Both the median and mean acceleration along the Z axis increased when implementing a spine board. The interquartile range for both weight groups were closely grouped. The 5th percentile for both weight groups were similar, although the 95th percentile for the LW subjects was slightly higher than the HW subjects.

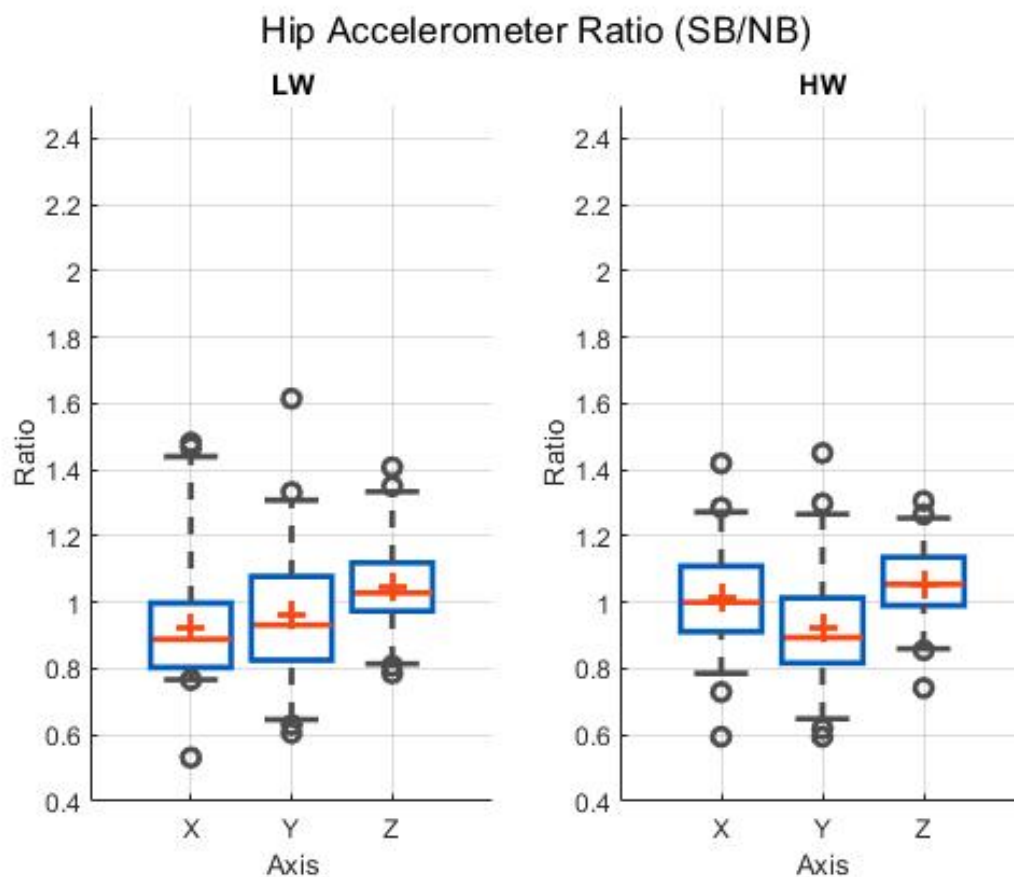


Figure 9: The ratio of the RMS acceleration experienced while immobilized to when not immobilized, measured at the hip.

RMS Angular Velocity Ratio

Figure 10 describes the ratio between the gyroscope measurements when using a spine board to when no spine board was used. These measurements were taken at the subject's head. A reduction in median and mean RMS rotational velocity was observed when rotating around the Z axis. Both the LW and HW groups saw an ~50 percent reduction in the median RMS rotation at the head. The interquartile range for the HW subjects was lower than that of the LW subjects. The 5th percentile was similar between the two weight groups, but the 95th percentile was higher for the LW group.

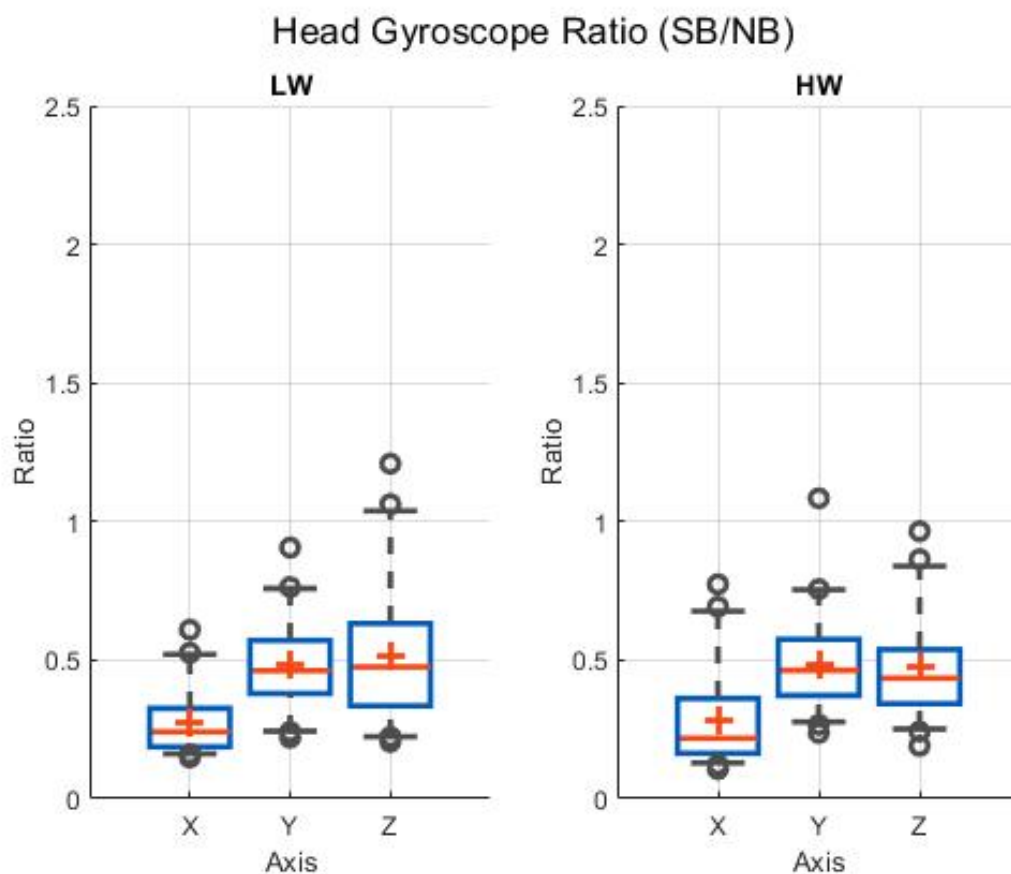


Figure 10: The ratio of the RMS rotation experienced while immobilized to when not immobilized, measured at the head.

The ratio of RMS rotational velocity experienced by each subject at the chest while using a spine board to without using a spine board can be found in Figure 11. For rotation around the Z axis, the median and mean RMS rotation was reduced by more than 25 percent when using a spine board (as compared to no spine board). The interquartile range for the LW subjects was lower than the HW subjects, and the 5th to 95th percentile ranges for both weight groups were similar.

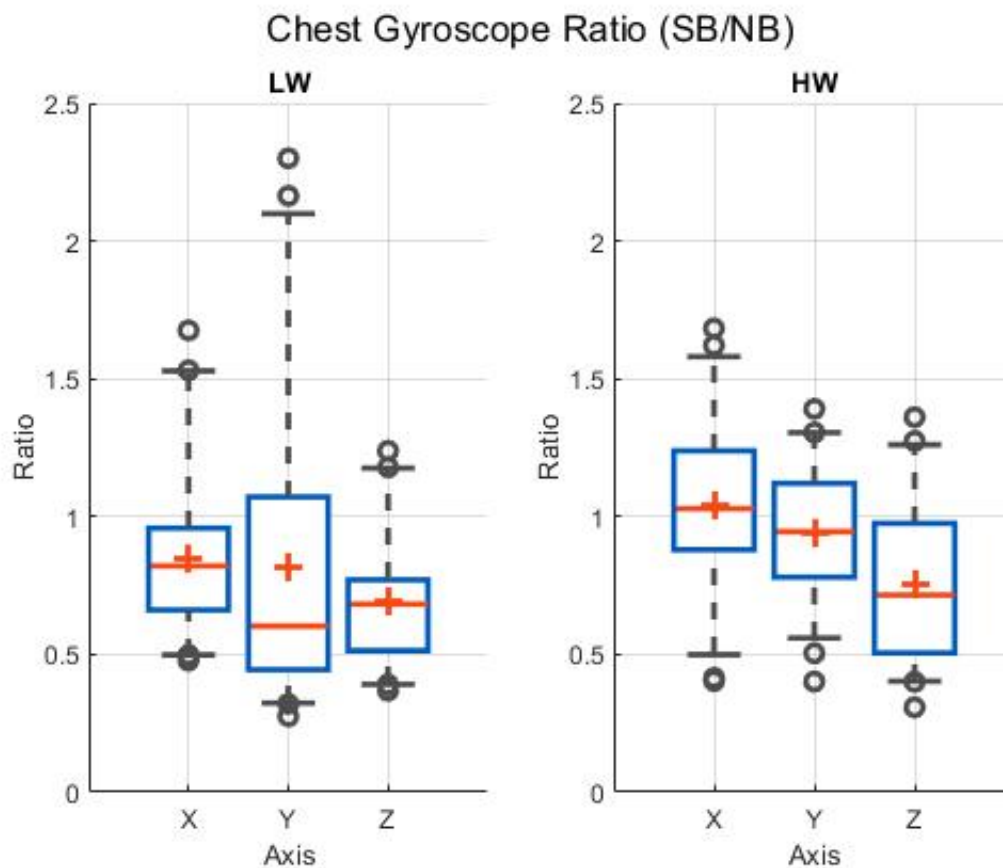


Figure 11: The ratio of the RMS rotation experienced while immobilized to when not immobilized, measured at the chest.

The ratio of the gyroscope measurements at the hip when using a spine board to when not using a spine board can be found in Figure 12. The median acceleration for the HW subjects was lower than the LW subjects; however, the mean acceleration was similar between the two weight groups. The interquartile ranges were similar between the two weight groups. The 5th and 95th percentiles for the HW subjects were higher than LW subjects.

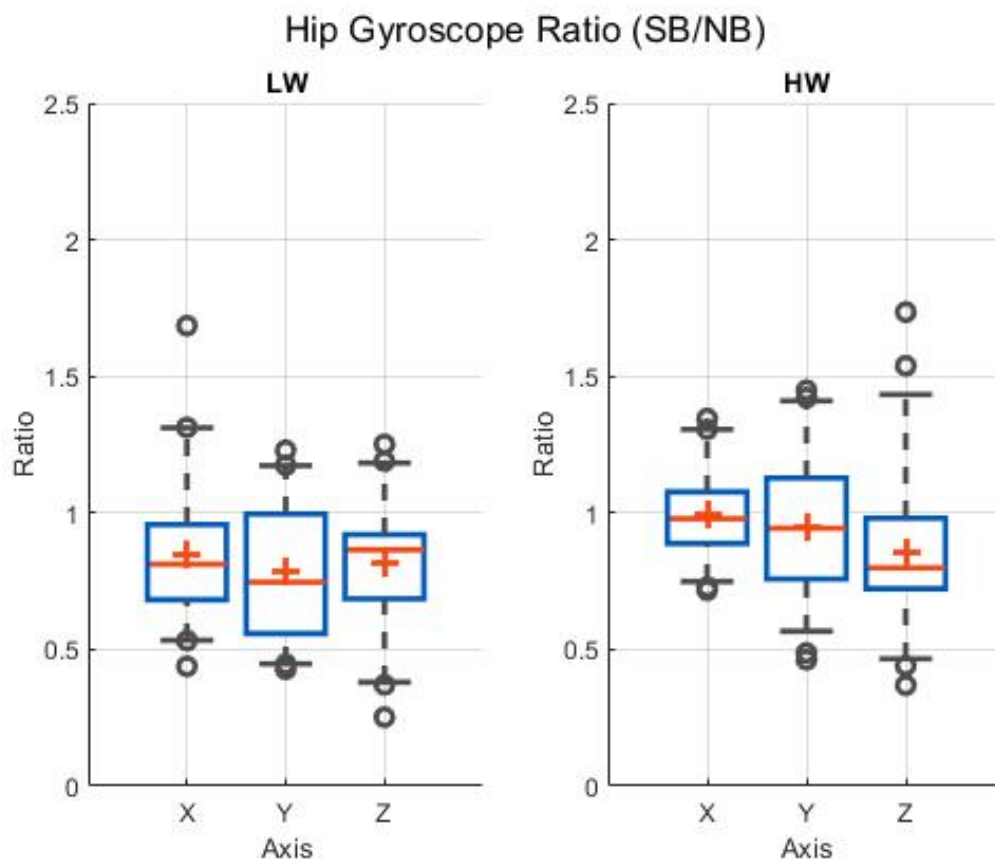


Figure 12: The ratio of the RMS rotation experienced while immobilized to when not immobilized, measured at the hip.

RMS Acceleration Ratio of All Subjects

Effect of Weight

For Figure 13-Figure 18, boxplots were used to describe the median, mean, interquartile range, and 5th to 95th percentile range of RMS acceleration experienced by all subjects. Figure 13-Figure 15 represent statistical data pertaining to the two weight groups, while Figure 16-Figure 18 represent statistical data pertaining to the two immobilization conditions.

The RMS acceleration experienced by each weight group can be found in Figure 13. Each weight group represents both immobilized and non-immobilized subjects. When analyzing RMS acceleration along the Z axis, both the median and mean accelerations were similar between the LW subjects and HW subjects. The interquartile ranges were also similar, with the HW group having an interquartile range shifted lower than the LW group. The 5th percentile acceleration was higher in the HW group subjects, and the 95th percentile was very similar between the two weight groups.

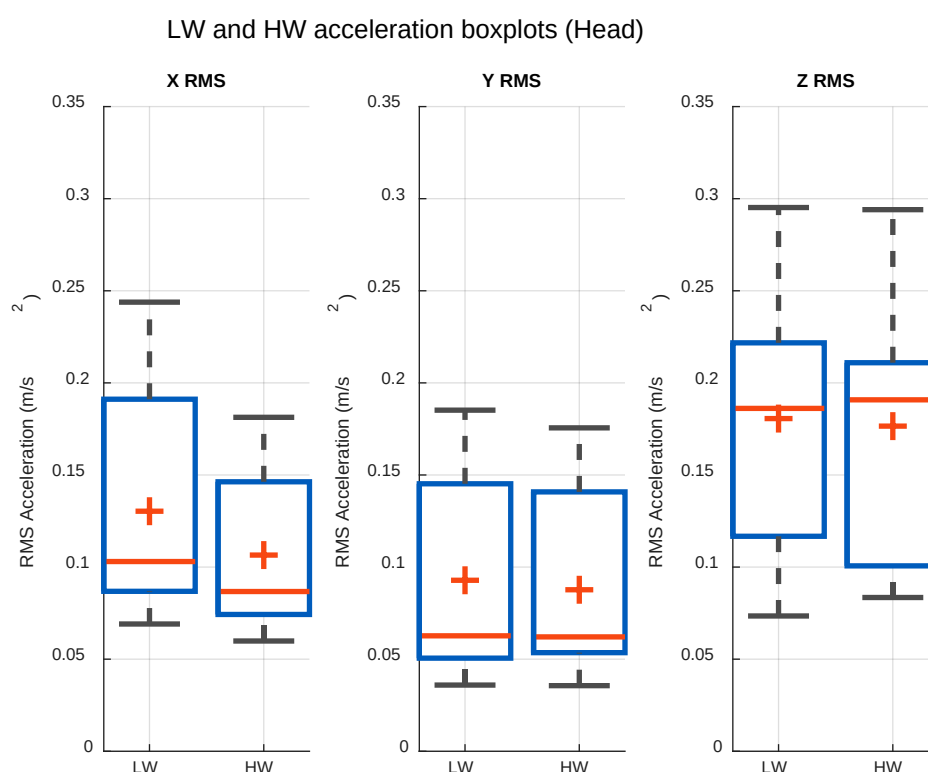


Figure 13: The RMS acceleration experienced at the head for each weight group.

A comparison of the RMS acceleration at the chest between LW and HW groups can be found in Figure 14. Both non-immobilized and immobilized conditions are represented by the boxplots. The median and mean RMS acceleration of the HW subjects along the Z axis is lower than the LW subjects, and also has a smaller 5th to 95th percentile. The interquartile range between the two weight groups is similar, although the range is shifted lower for the HW group.

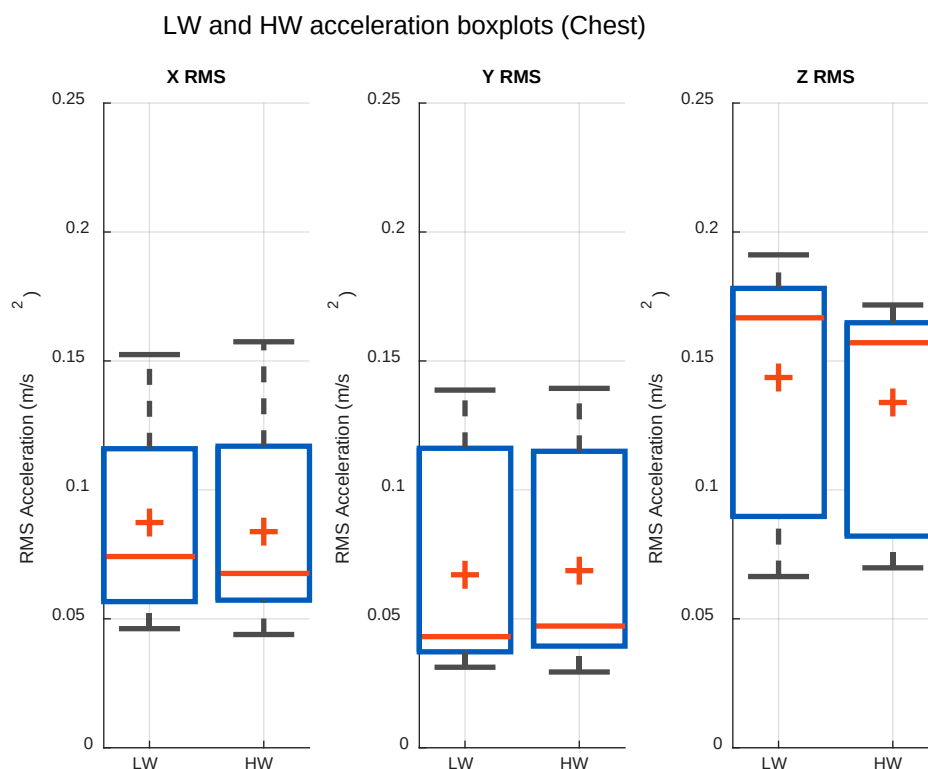


Figure 14: The RMS acceleration experienced at the chest for each weight group.

Figure 15 compares the RMS acceleration of the LW subjects to the HW subjects, with both immobilization conditions represented. The mean RMS acceleration along the Z axis was very similar between the two weight groups, but the median acceleration was higher in the LW group. The HW subjects also featured a smaller interquartile range, as well as a smaller 5th to 95th percentile range.

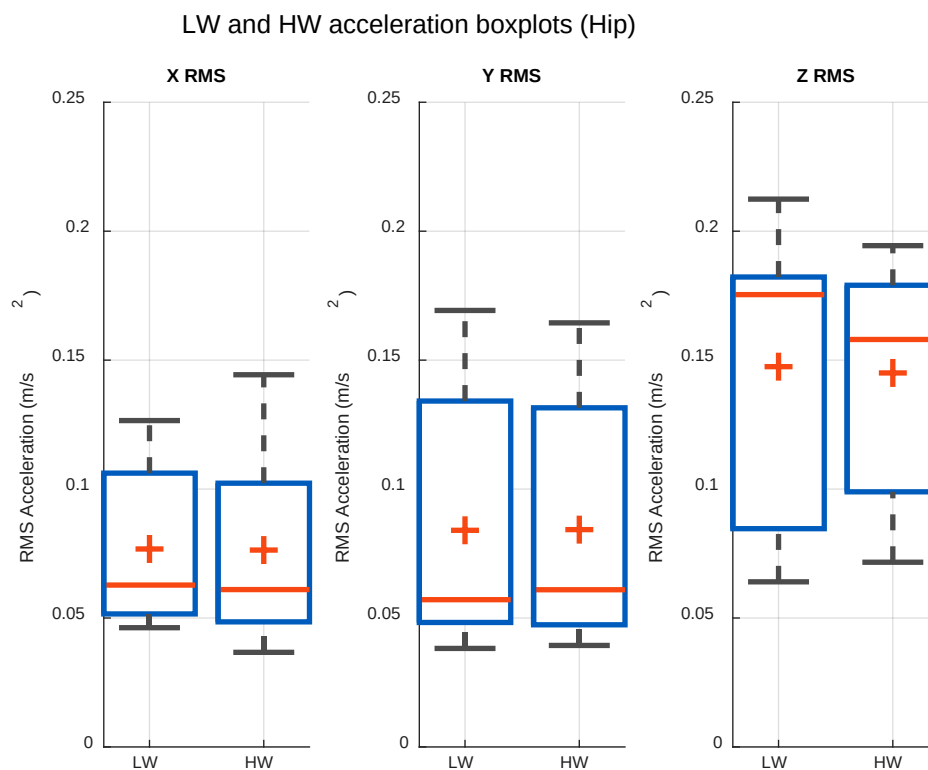


Figure 15: The RMS acceleration experienced at the hip for each weight group.

Effect of Immobilization

The RMS acceleration at the head is shown in Figure 16. Figure 16 compares the RMS acceleration when no immobilization system was used versus when a full immobilization system was used. Both weight groups were represented. Along the Z axis, the immobilized subjects had a lower median and mean RMS acceleration. The immobilized subjects also had a smaller interquartile range, as well as a smaller 5th to 95th percentile range.

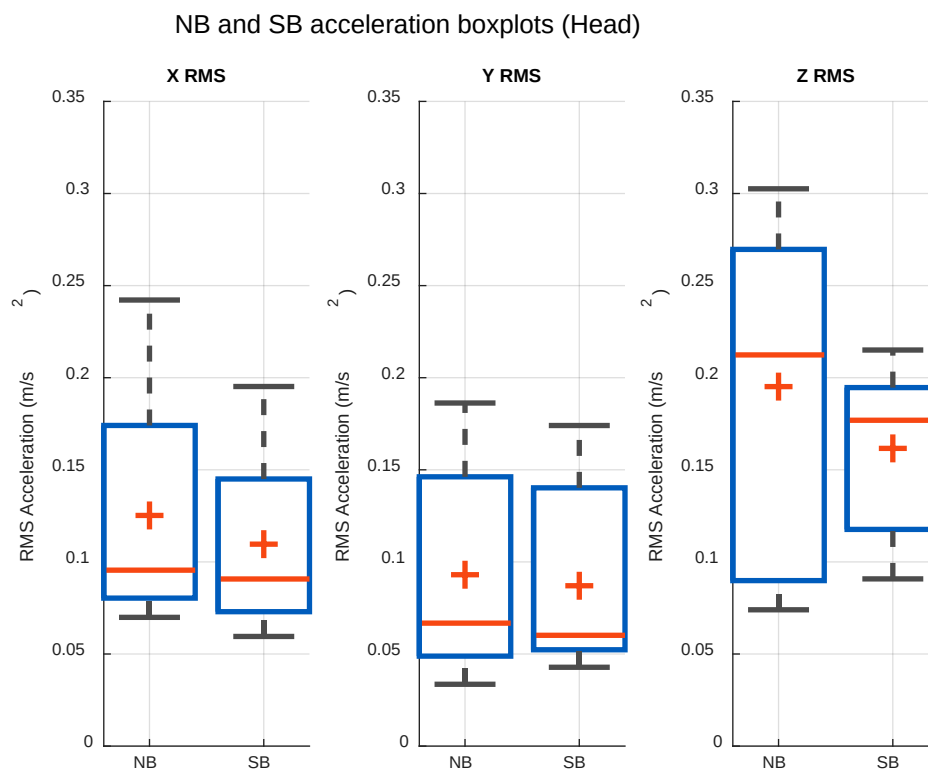


Figure 16: The RMS acceleration experienced for each immobilization condition, measured at the head.

A comparison between the RMS acceleration when immobilized and when not immobilized can be found in Figure 17. These accelerations were measured at the chest and analyzed along the Z axis. The mean and median acceleration of the immobilized subjects was slightly lower than the non-immobilized subjects. Both immobilization conditions had very similar interquartile ranges and 5th to 95th percentile ranges.

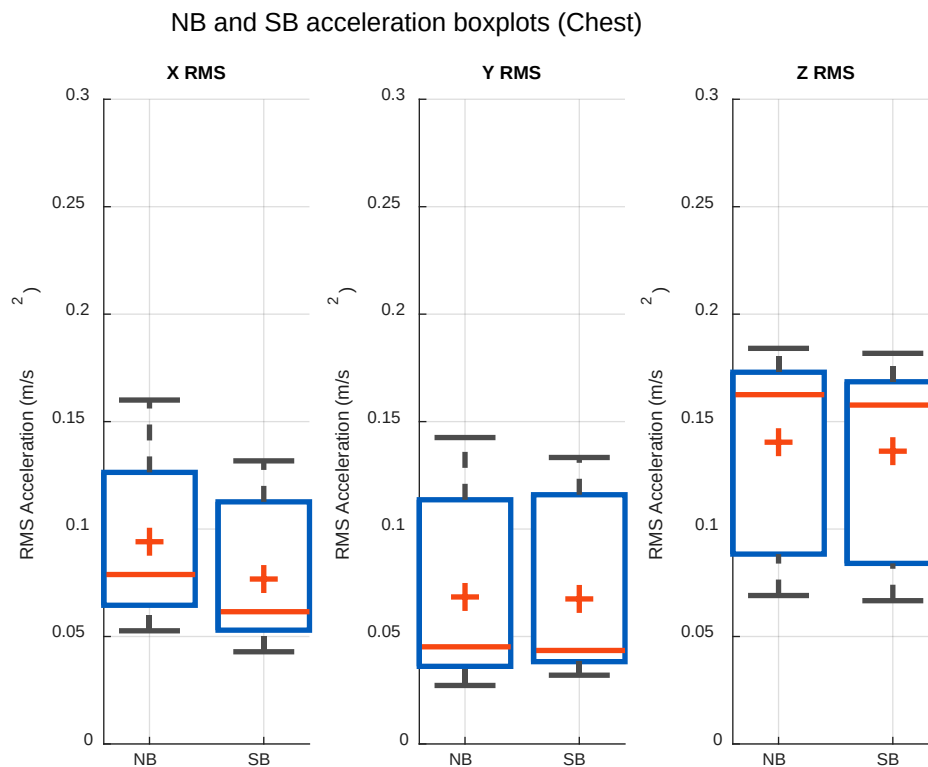


Figure 17: The RMS acceleration experienced for each immobilization condition, measured at the chest.

Figure 18 describes the RMS acceleration at the hip for each immobilization condition. Both weight groups were represented in each immobilization condition. Along the Z axis, the mean and median RMS acceleration for the immobilized subjects were higher than the non-immobilized subjects. The immobilized subjects had a wider 5th to 95th percentile, as well as a wider interquartile range.

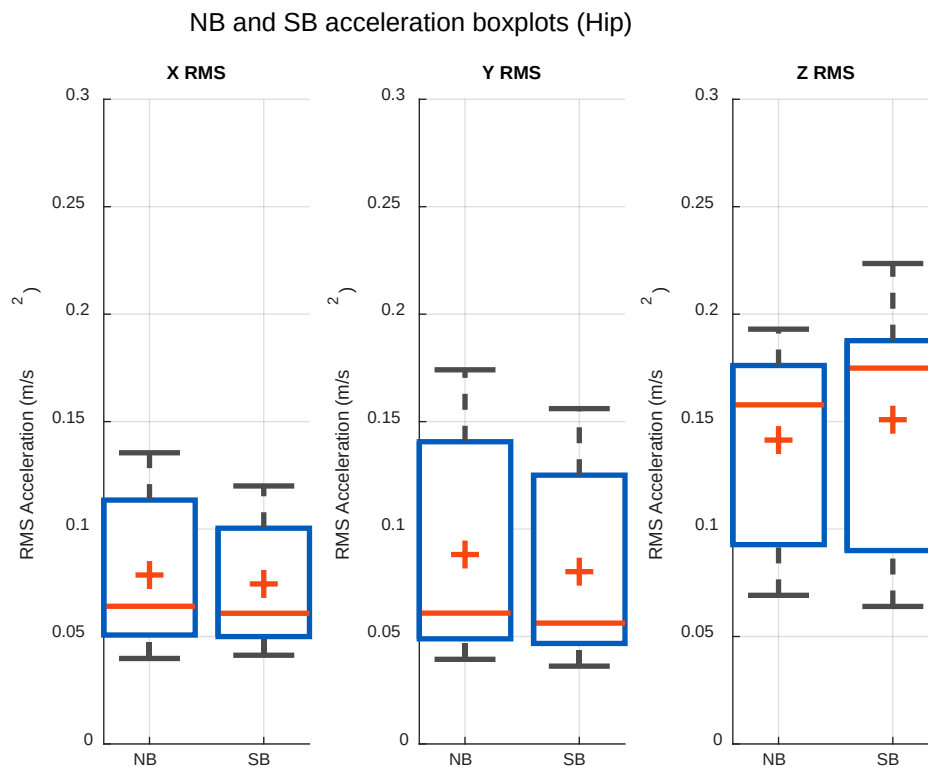


Figure 18: The RMS acceleration experienced for each immobilization condition, measured at the hip.

RMS Rotation

Effect of Weight

The RMS rotation experienced by each subject is described in Figure 19-Figure 24. Boxplots were used to display the median, mean, interquartile range, and the 5th to 95th percentile of RMS rotation. Figure 19-Figure 21 compare the effect of subject weight on RMS rotation. Figure 22-Figure 24 compare the effect of immobilization condition on RMS rotation.

The RMS rotation by each subject at the head can be described in Figure 19. Each weight group also represented both immobilization conditions. The median and mean RMS rotation around the Z axis was higher in the HW subjects than in the LW group. The HW group also had a slightly higher interquartile range, and a higher 95th percentile.

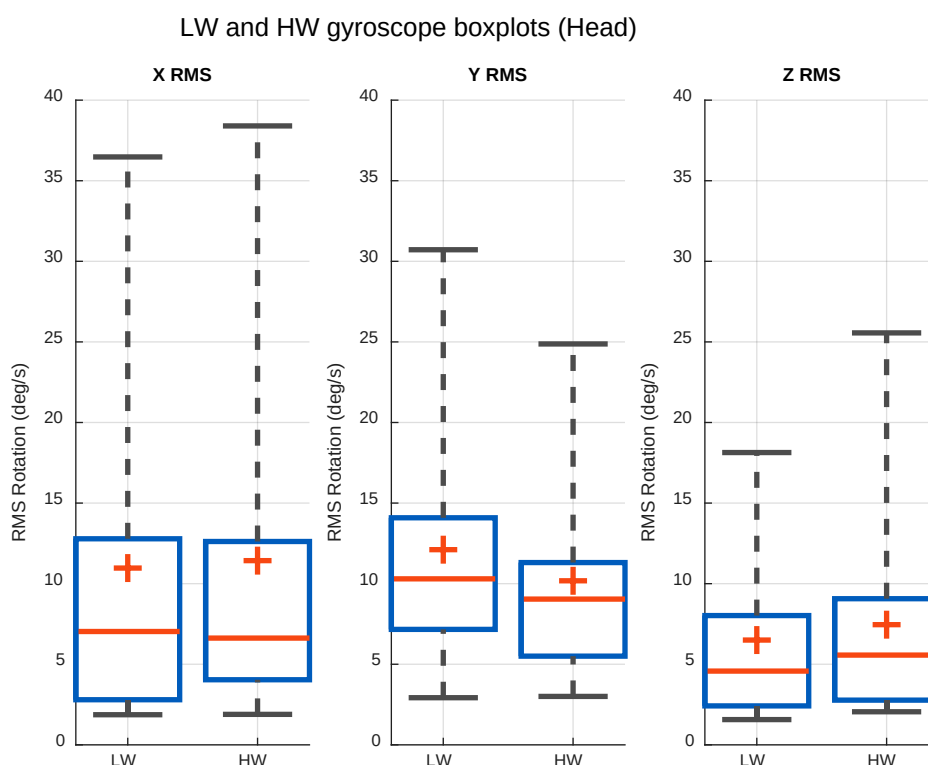


Figure 19: The RMS rotation for each weight group, measured at the head.

Figure 20 compares the effect of subject weight on RMS rotation, analyzed at the chest. For rotation around the Z axis, the HW subjects had a lower median and mean RMS rotation. Both weight groups had a very similar 5th to 95th percentile, but the HW subjects had a smaller interquartile range.

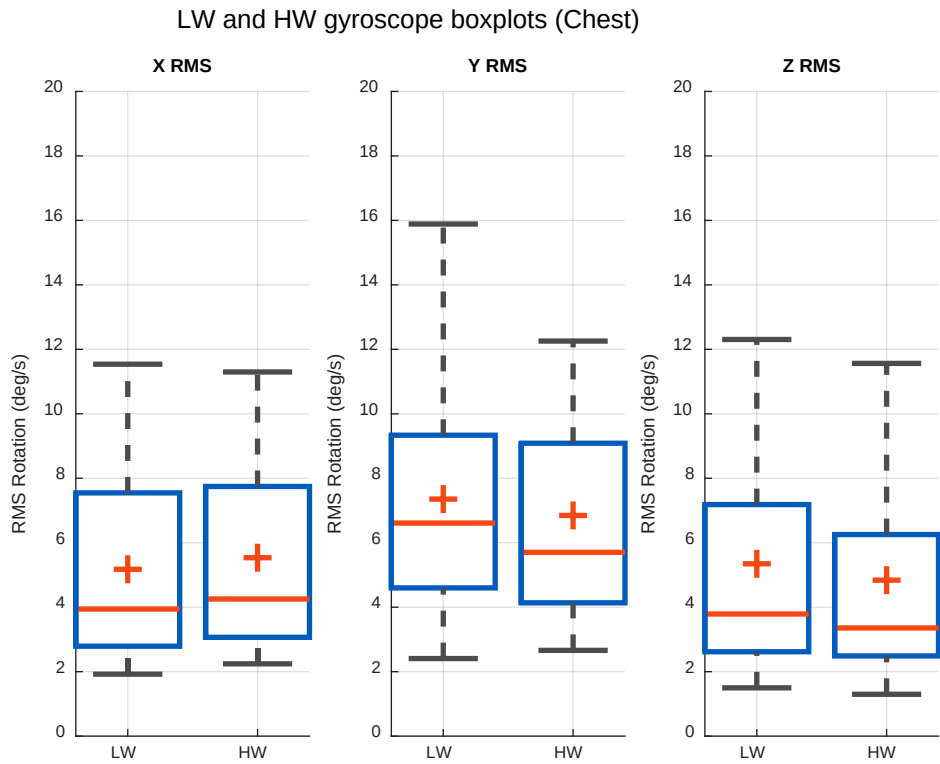


Figure 20: The RMS rotation for each weight group, measured at the chest.

An analysis was performed on the RMS rotation experienced at the hip for all subjects and compared the results between both weight groups. Figure 21 describes this analysis. The HW subjects experienced a higher mean and median RMS rotation around the Z axis than the LW subjects. The interquartile range was similar between the two weight groups, with the HW group having a slightly larger range but shifted higher than the LW group. The HW group also has a wider 5th to 95th percentile.

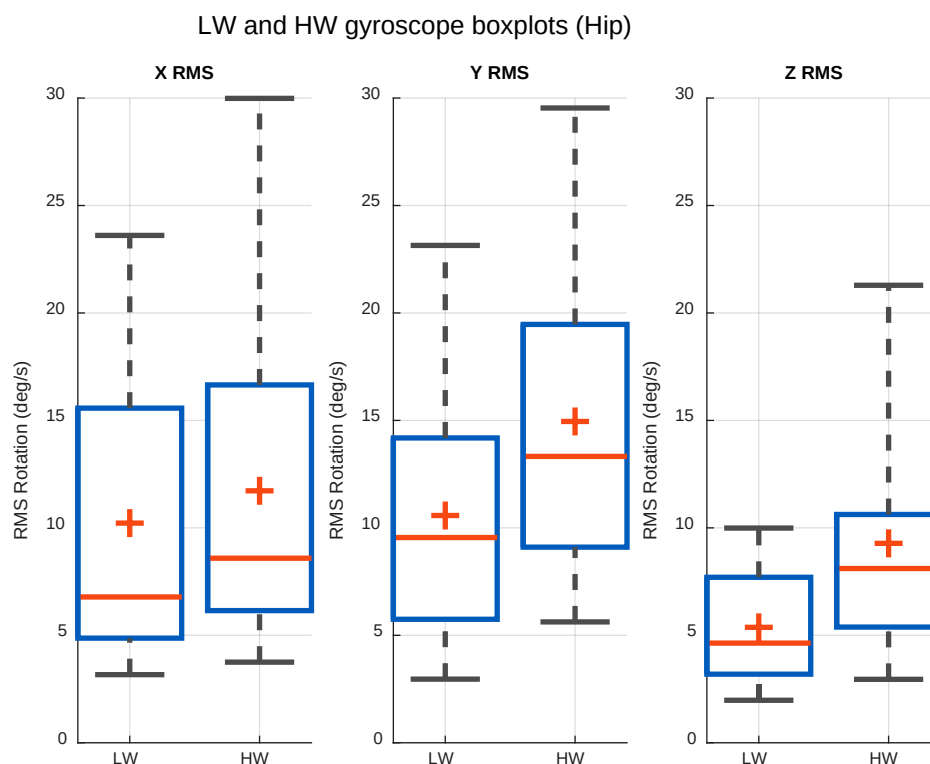


Figure 21: The RMS rotation for each weight group, measured at the hip.

Effect of Immobilization

Figure 22 compares the effect of immobilization condition on RMS rotation experienced by each subject at the head. Both weight groups were represented in each immobilization condition. The immobilized subjects had a lower median and mean RMS rotation, as well as a smaller interquartile range. This interquartile range is also shifted downwards in the immobilized subjects. The immobilized subjects also had a smaller 5th to 95th percentile than the non-immobilized subjects.

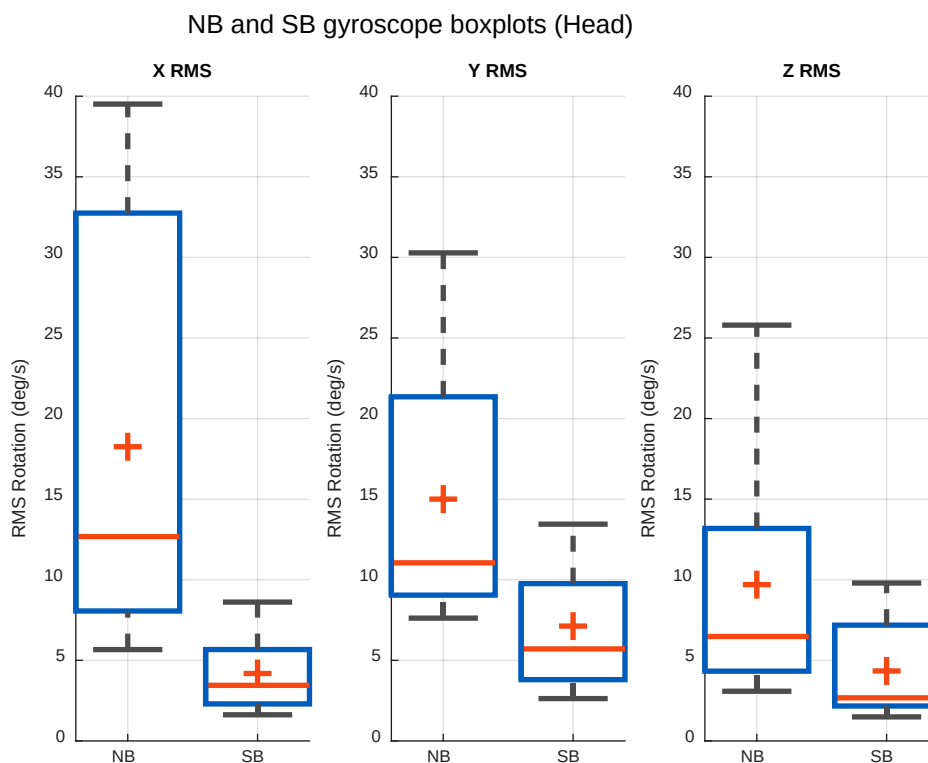


Figure 22: The RMS rotation experienced for each immobilization condition, measured at the head.

An analysis was performed on the RMS rotation experienced by each subject at the chest and compared between each immobilization condition. Both weight groups were represented in each immobilization condition. Figure 23 displays this analysis. The immobilized subjects had a lower mean and median RMS rotation, and had a smaller interquartile range. The 5th percentile was lower in the immobilized subjects, but the 95th percentile was similar between the two weight groups.

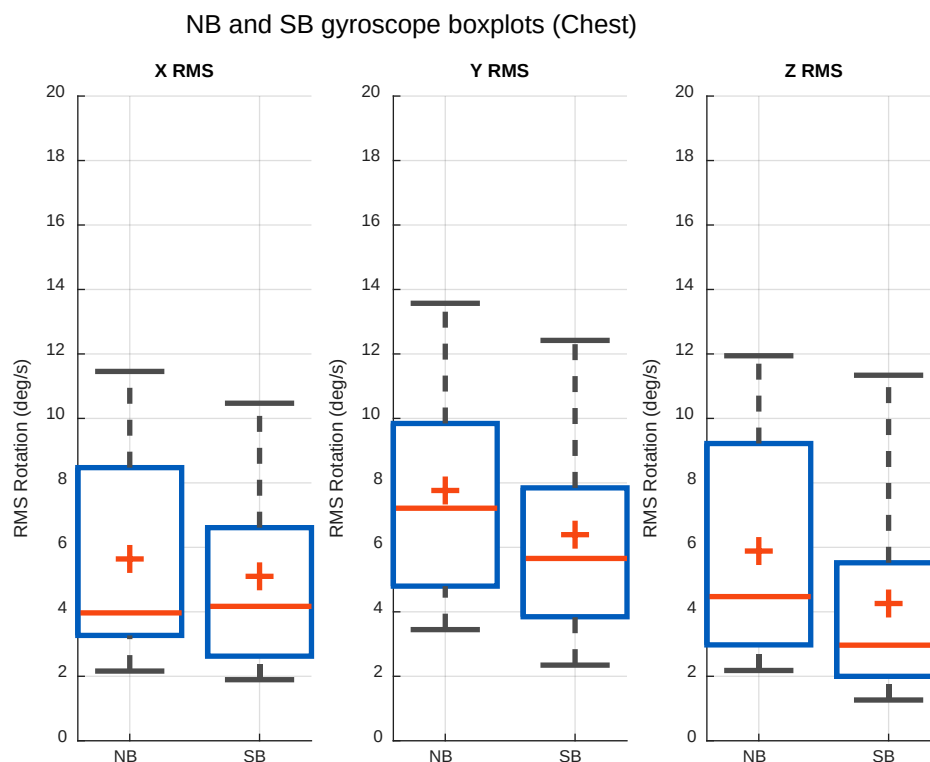


Figure 23: The RMS rotation experienced for each immobilization condition, measured at the chest.

Figure 24 depicts a comparison of the RMS rotation each subject experienced at the hip when immobilized versus not immobilized. The median and mean RMS rotation was lower for the immobilized subjects, and the interquartile range was shifted lower for the immobilized subjects. In addition, the 5th to 95th percentile was smaller in the immobilized subjects.

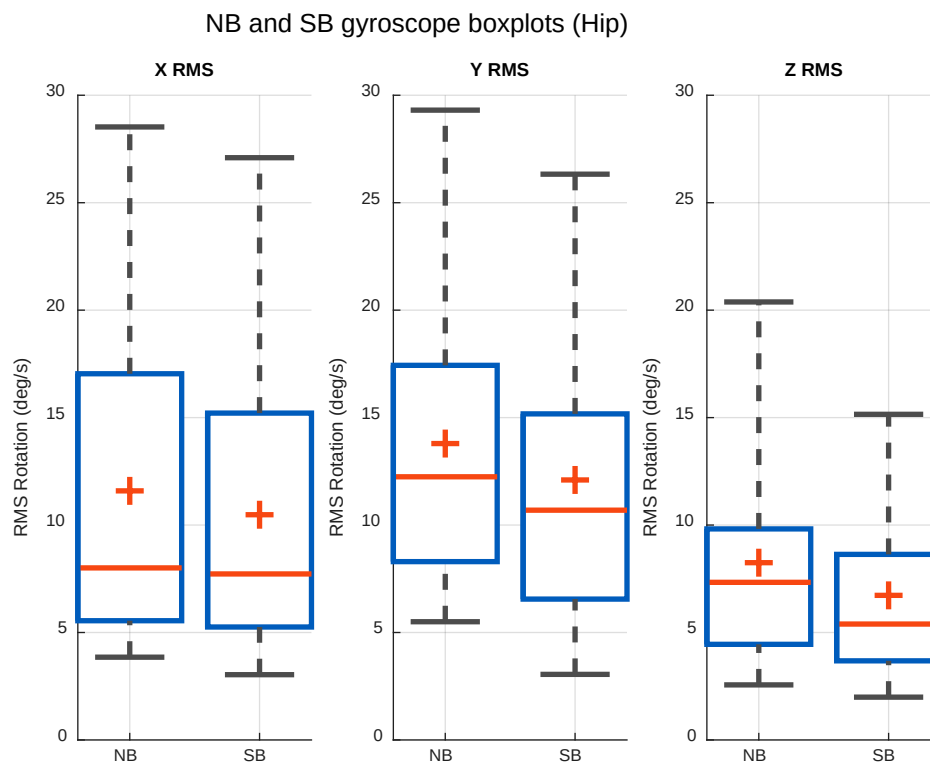


Figure 24: The RMS rotation experienced for each immobilization condition, measured at the hip.

Transmissibility

In Figure 25-Figure 30, the median transmissibility plot is plotted against the 25th to 75th percentile, and the 5th to 95th percentile. The fifth point of each data set was plotted so that the plots were easier to analyze. Figure 25, Figure 26, and Figure 27 separate the data into LW and HW categories, while Figure 28, Figure 29, and Figure 30 separate the data into non-immobilized and immobilized categories.

The median transmissibility for each weight group at the head was analyzed in Figure 25. Only transmissibility along the Z axis was analyzed. When looking to the median line, the magnitude of transmissibility is nearly identical between the LW and HW subjects. The HW group's resonance has been shifted back by approximately 1.5 Hz, however. The HW subjects' 95th percentile was also higher than the LW group, and also featured the same shift in frequency as the median line.

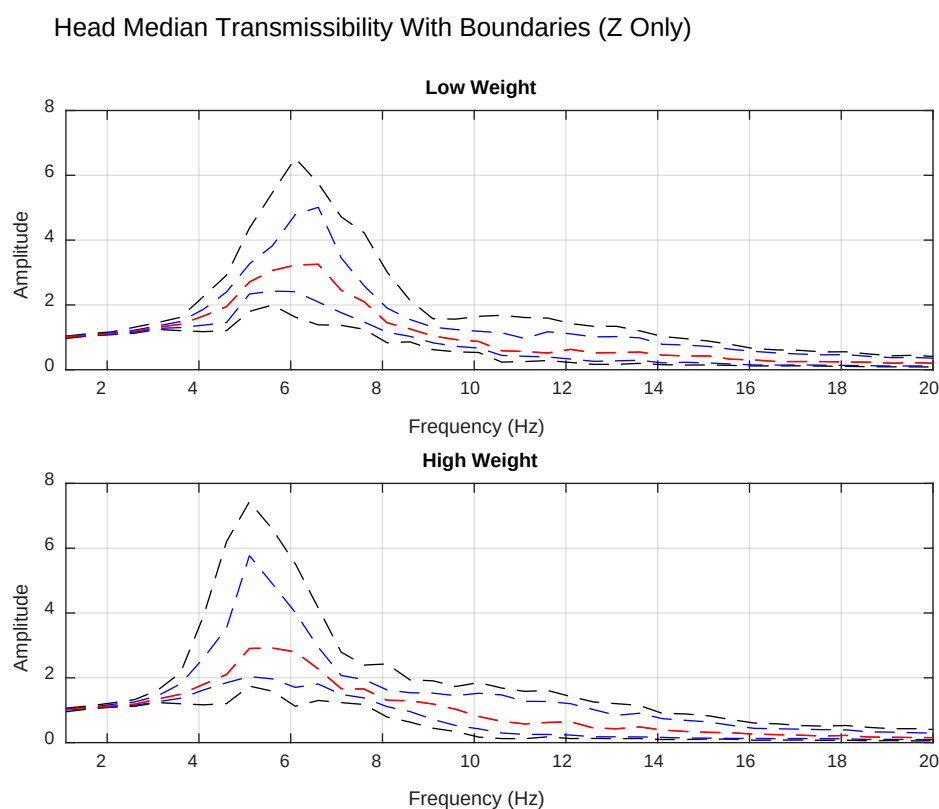


Figure 25: An overlaid transmissibility plot for the head comparing the LW and HW groups. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile

The median transmissibility for each weight group at the chest was analyzed in Figure 26. Only transmissibility along the Z axis was analyzed. The LW group had a transmissibility magnitude slightly higher than that of the HW subjects. In addition, the HW group resonated approximately 1 Hz earlier than the LW group. The HW group's 95th percentile was higher than the LW group's 95th percentile, and resonated nearly 2 Hz earlier than the LW group.

Chest Median Transmissibility With Boundaries (Z Only)

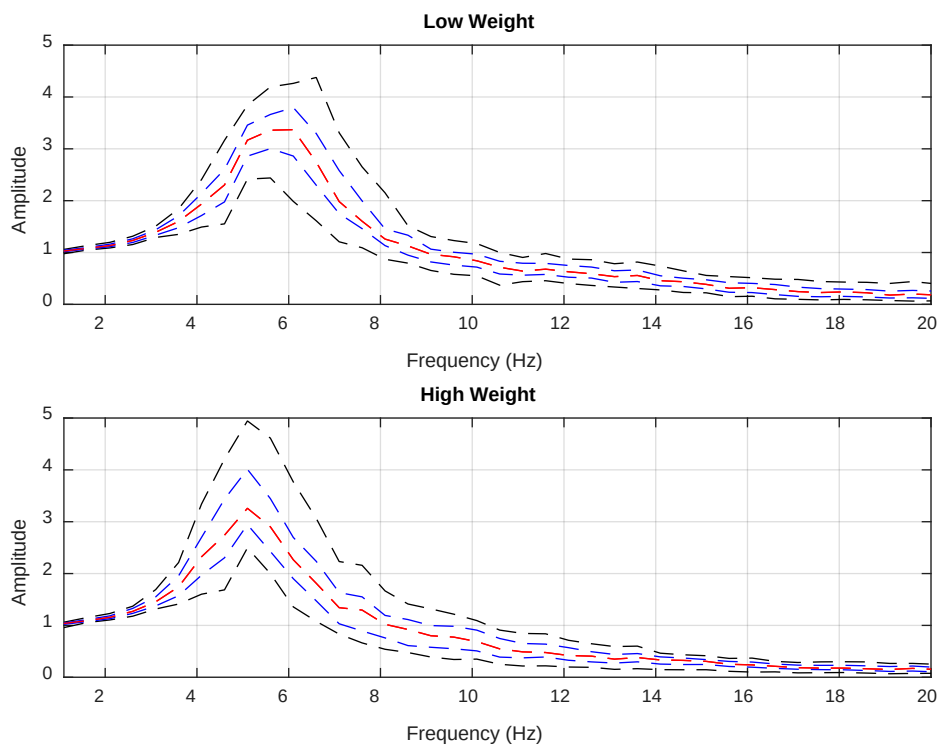


Figure 26: An overlaid transmissibility plot for the chest comparing the LW and HW groups. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile.

The median transmissibility along the Z axis for each weight group was analyzed in Figure 27. Only the hip was observed in this case. The median transmissibility magnitude was nearly the same between the two weight groups; in addition, both weight groups appeared to resonate at the same frequency. The 95th percentile was nearly identical in magnitude for both weight groups, but the HW group resonated approximately .5 Hz earlier than the LW subjects.

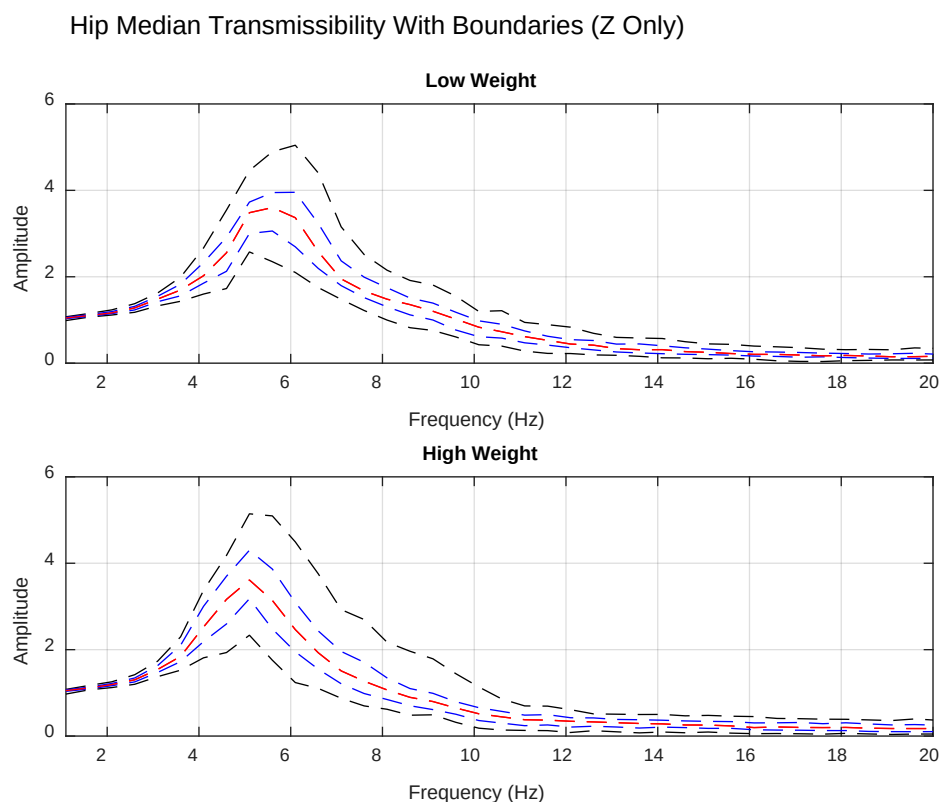


Figure 27: An overlaid transmissibility plot for the hip comparing the LW and HW groups. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile.

The median transmissibility along the Z axis for either immobilization condition was analyzed in Figure 28. Only the head was analyzed in this case. The median transmissibility magnitude was higher when no board was used, compared to when a spine board was used. The magnitude of the peak transmissibility was reduced by nearly 50 percent when a spine board was implemented. The spine board condition also saw its peak transmissibility shift back by approximately .5 Hz when compared to the no board condition; however, the spine board 95th percentile experienced its resonance around 1 Hz after the no board condition. After 10 Hz, the transmissibility magnitude continued towards 0 for the non-immobilized condition but remained at above 1 for much of the frequency content after 10 Hz for the immobilized condition.

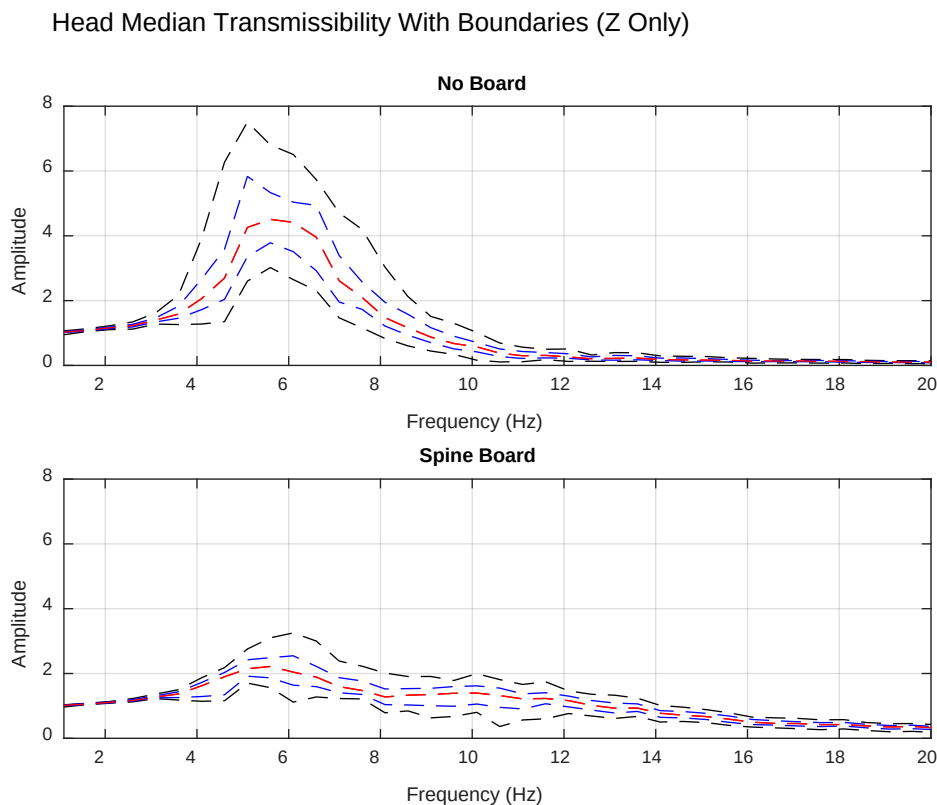


Figure 28: An overlaid transmissibility plot for the head comparing the immobilized and non-immobilized conditions. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile.

The median transmissibility for the chest with respect to each immobilization condition was analyzed in Figure 29. Only the Z axis was observed in this case. The spine board saw only a slight decrease in magnitude at its median, and the 95th percentile saw a drop when compared to the non-immobilized condition. Both immobilization conditions had a resonance that occurred at the same frequency at their medians; however, the immobilized 95th percentile had a resonance occur almost 2 Hz after the non-immobilized condition. Both immobilization conditions tended towards 0 magnitude after the resonance.

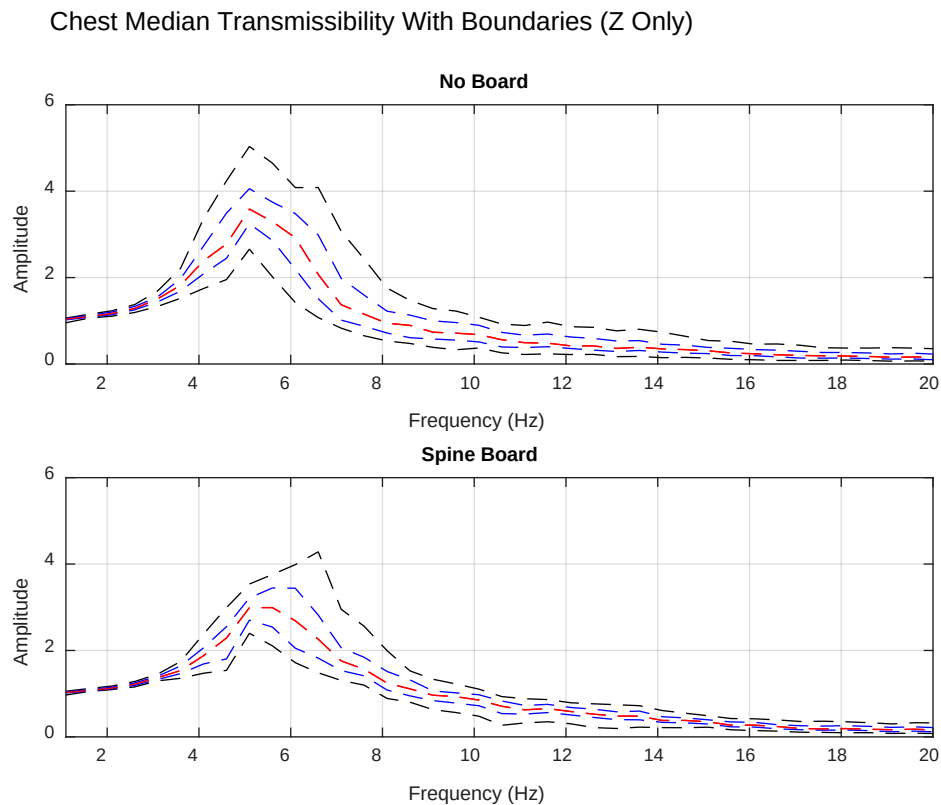


Figure 29: An overlaid transmissibility plot for the chest comparing the immobilized and non-immobilized conditions. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile.

The median transmissibility for the hip with respect to each immobilization condition was analyzed in Figure 30. Only the Z axis was observed in this case. The immobilized condition saw a slightly higher peak transmissibility magnitude at both its median and 95th percentile, when compared to the non-immobilized condition. The immobilized condition appeared to resonate less than .5 Hz after the non-immobilized condition at the 95th percentile. The non-immobilized condition tended towards 0 magnitude sooner than the immobilized condition.

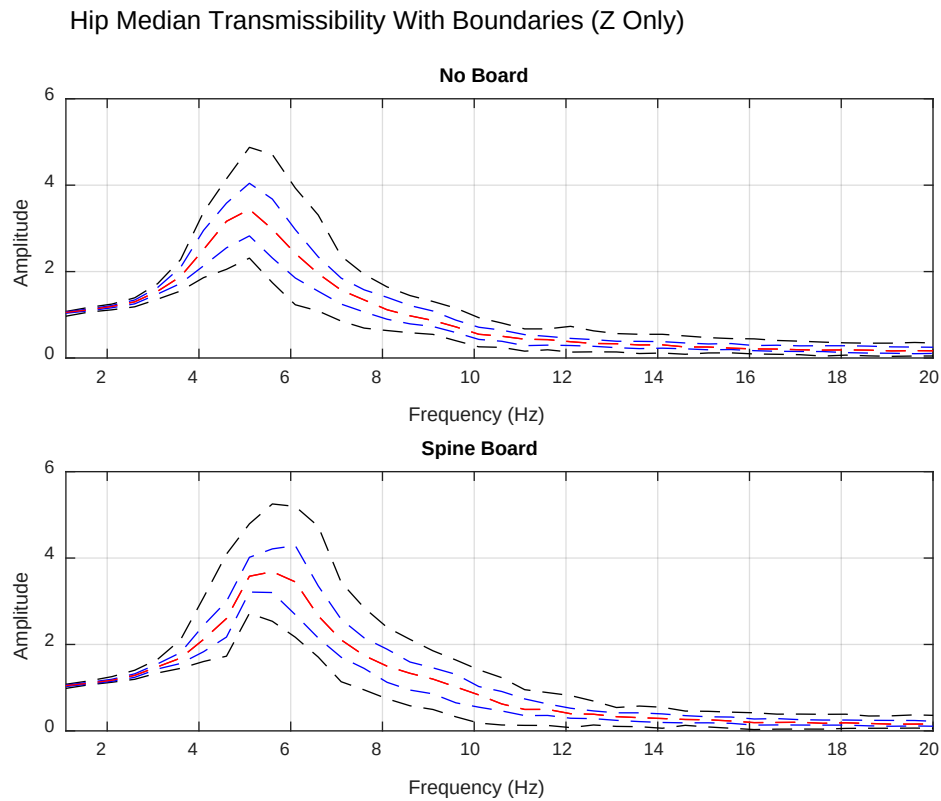


Figure 30: An overlaid transmissibility plot for the hip comparing the immobilized and non-immobilized conditions. The red line represents the subject median transmissibility, the blue line represents the 25th to 75th percentile, and the black line represents the 5th to 95th percentile.

Boxplots were used to describe the transmissibility data; an explanation of the boxplot can be found in Figure 3. Data was broken out into LW and HW groups and separated into non-immobilized and immobilized conditions (Figure 31-Figure 36).

An analysis of the peak transmissibilities for both weight groups at the head can be found in Figure 31. Along the Z axis, the peak median and mean transmissibility was higher for the HW group when compared to the LW group. The interquartile range and 5th to 95th percentile of the HW subjects was more widespread than the LW subjects.

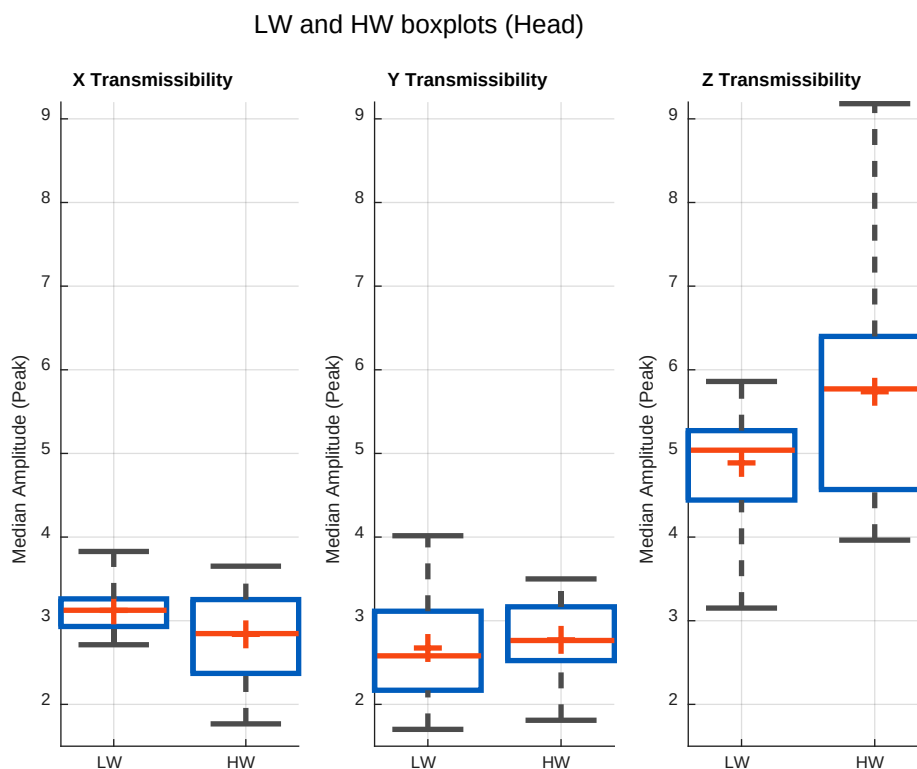


Figure 31: A plot comparing the peak median transmissibility of the LW subjects with the HW subjects. Transmissibilities are measured at the head.

The peak median transmissibilities for both weight groups measured at the chest can be found in Figure 32. Along the Z axis, the peak median transmissibility for the HW group is higher than the LW group. The interquartile range for the HW group is also larger than the LW group. The 5th to 95th percentile span is very similar between the two weight groups.

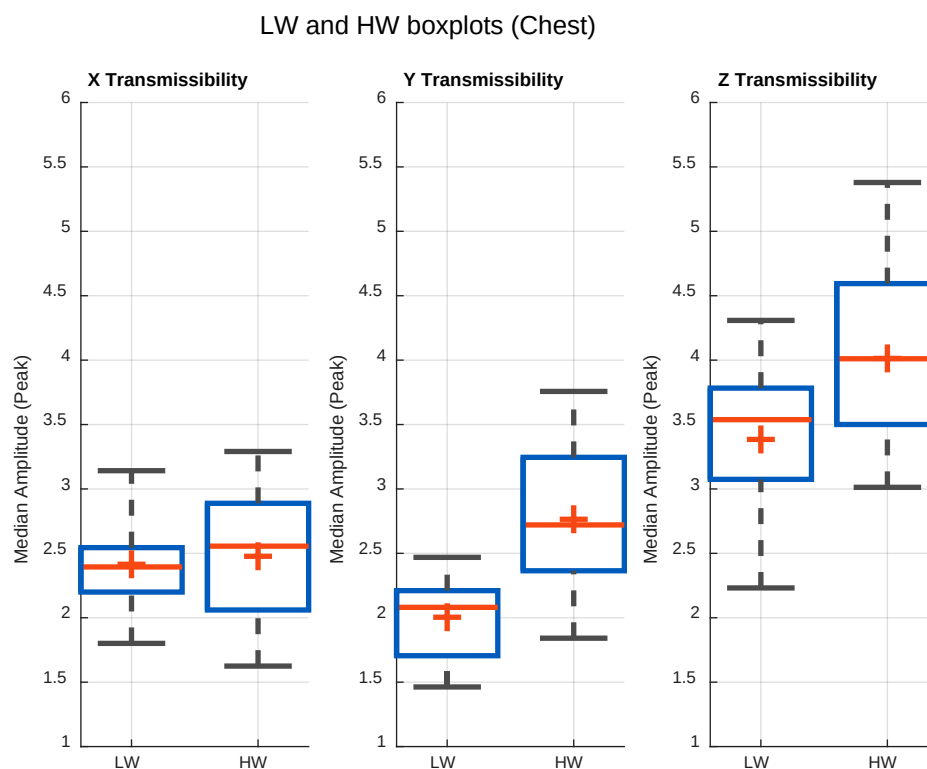


Figure 32: A plot comparing the peak median transmissibility of the LW subjects with the HW subjects. Transmissibilities are measured at the chest.

The peak median transmissibilities for both weight groups measured at the chest can be found in Figure 33. Along the Z axis, the peak median transmissibility is nearly the same between the two weight groups. The peak mean transmissibility is slightly higher in the HW group when compared to the LW group. The HW subjects' interquartile range and 5th to 95th percentile span is larger than the LW subjects.

LW and HW boxplots (Hip)

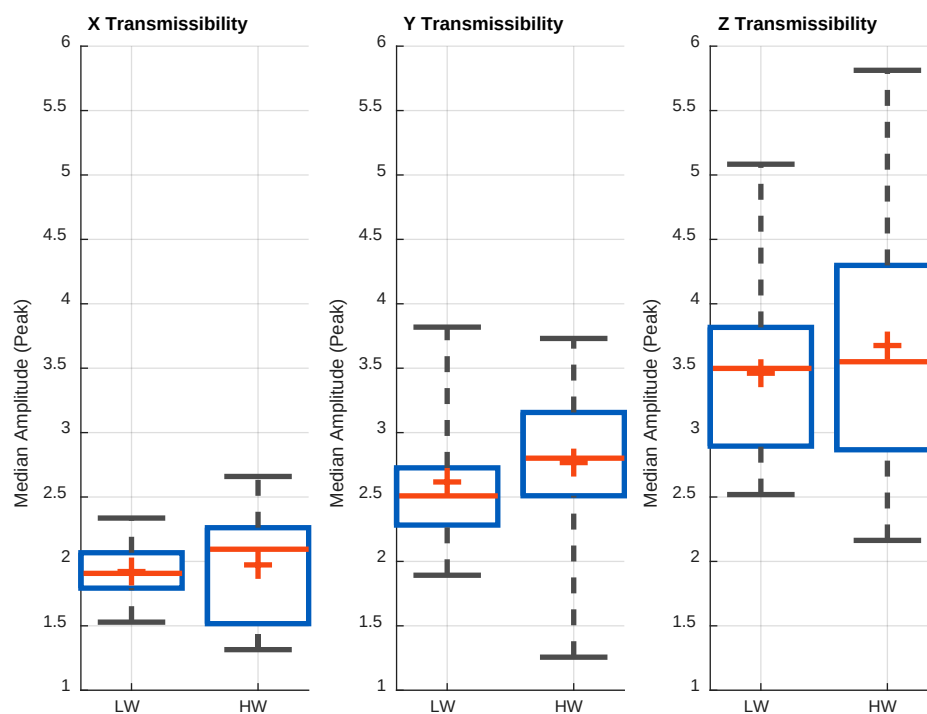


Figure 33: A plot comparing the peak median transmissibility of the LW subjects with the HW subjects. Transmissibilities are measured at the hip.

The peak transmissibilities for both weight groups at the head can be found in Figure 34. Along the Z axis, the immobilized condition had lower peak median and mean transmissibilities than the non-immobilized condition. The interquartile range and 5th to 95th percentile range is larger in the non-immobilized condition than the immobilized condition.

NB and SB boxplots (Head)

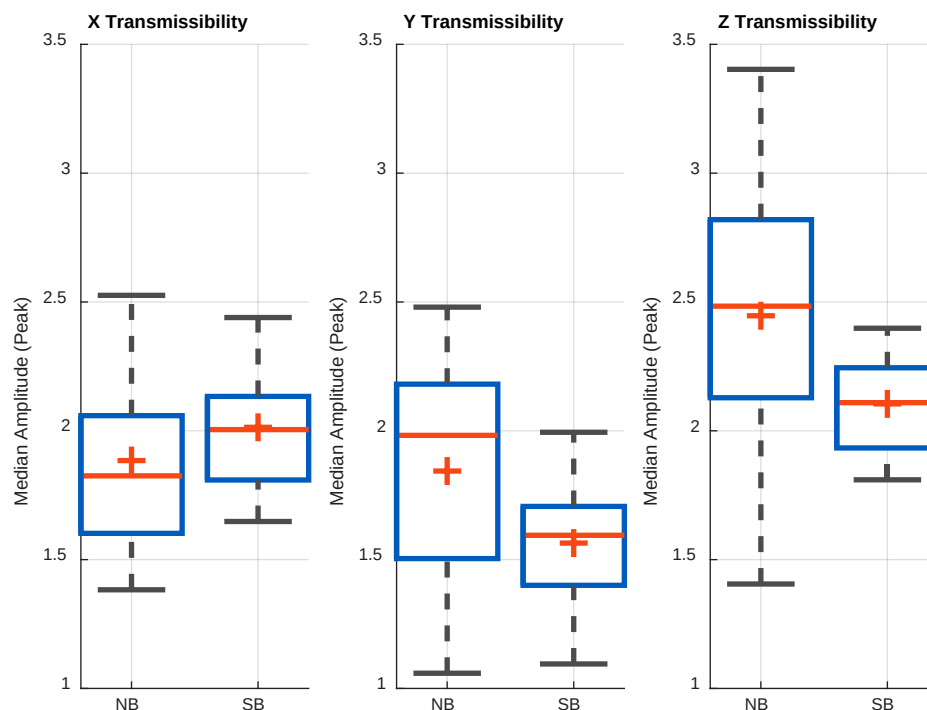


Figure 34: A plot comparing the peak median transmissibility of the non-immobilized and immobilized conditions. Transmissibilities are measured at the head.

The peak transmissibilities for both weight groups at the chest can be found in Figure 35. When analyzing the Z axis, the non-immobilized condition had higher peak median and mean transmissibilities than the immobilized condition. The non-immobilized 5th to 95th percentile range is larger than the immobilized condition, and as well as the interquartile range.

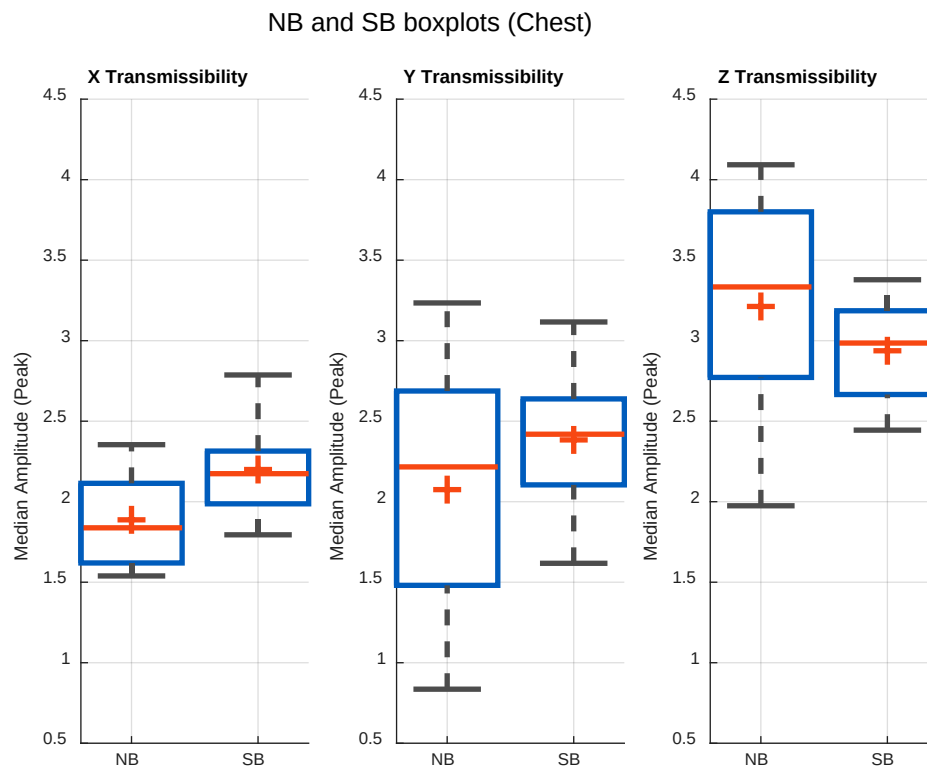


Figure 35: A plot comparing the peak median transmissibility of the non-immobilized and immobilized conditions. Transmissibilities are measured at the chest.

The peak median transmissibilities for both weight groups measured at the chest can be found in Figure 36. The peak mean and median transmissibilities of the immobilized condition were slightly lower than the non-immobilized condition. The interquartile range of the non-immobilized condition was larger than the immobilized condition. The 5th to 95th percentile range was nearly identical between the two immobilization conditions.

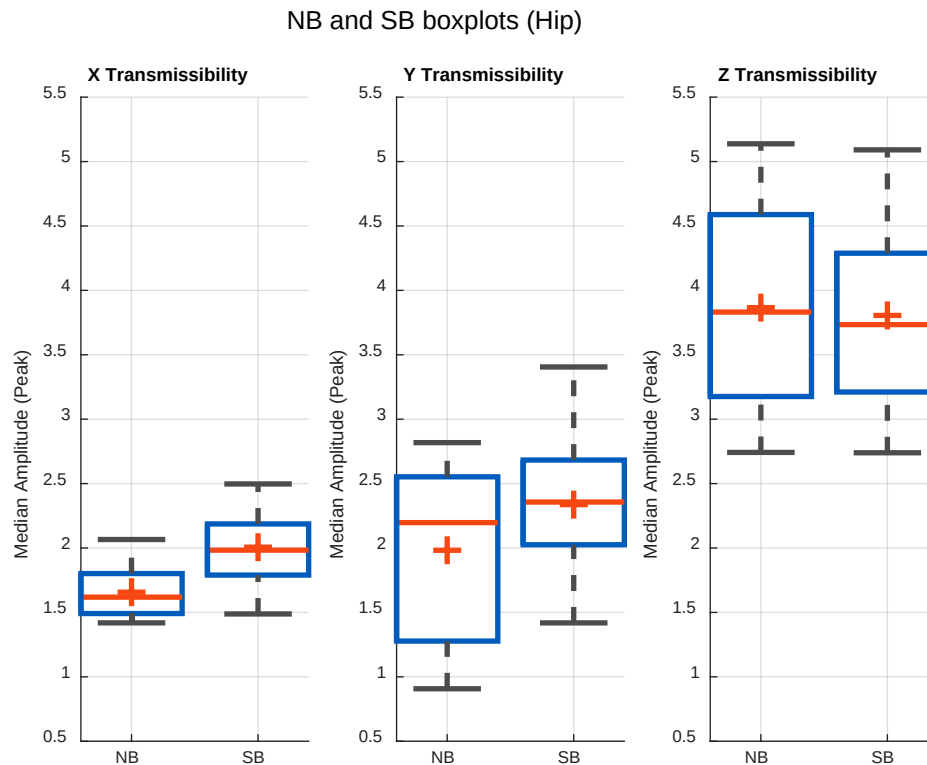


Figure 36: A plot comparing the peak median transmissibility of the non-immobilized and immobilized conditions. Transmissibilities are measured at the hip.

Area under the Transmissibility Curve

Transmissibility plots offer a plethora of information, describing the amplification of the input vibration as a function of frequency. The peak of a transmissibility graph is useful, as it shows the maximum amplification of the system as well as the frequency at which that occurs. However, examining the peak alone does little to quantify the frequency distribution of the amplification or quantify the overall energy transmission.

To extract more information from the transmissibility plots, the Area Under Transmissibility, was introduced. This metric is the integral of the transmissibility plot from 2 Hz to 10 Hz. These limits were chosen because they are equidistant from 6 Hz, the resonant frequency for most graphs. Furthermore, the transmissibility from 0 Hz to 2 Hz and 10 Hz to 20 Hz was very similar in most plots, and those ranges were assumed to have negligible impact on the integral results.

The area underneath the transmissibility curve can be found in Figure 37. The median and mean transmissibilities along the Z axis are similar and have a similar 5th to 95th percentile range. The no board subjects, however, have a larger 5th and 95th percentile value, and have a larger interquartile range.

Head Area Under Transmissibility Curve (Immobilization Type)

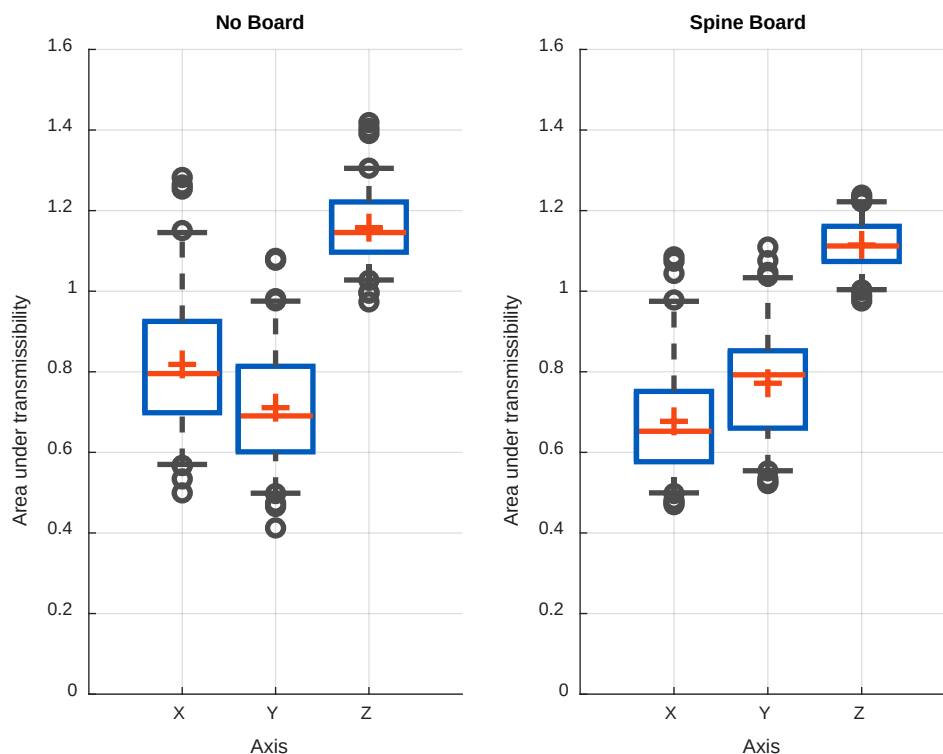


Figure 37: Boxplots representing the area underneath the transmissibility curve, measured at the head and dependent on immobilization.

Boxplots describing the area under the transmissibility curve at the chest can be found in Figure 38. When analyzing the Z axis, the median and mean area are within 5 percent of each other. The no board subjects have a larger interquartile range and 5th to 95th percentile range, as well as a larger 95th percentile value.

Chest Area Under Transmissibility Curve (Immobilization Type)

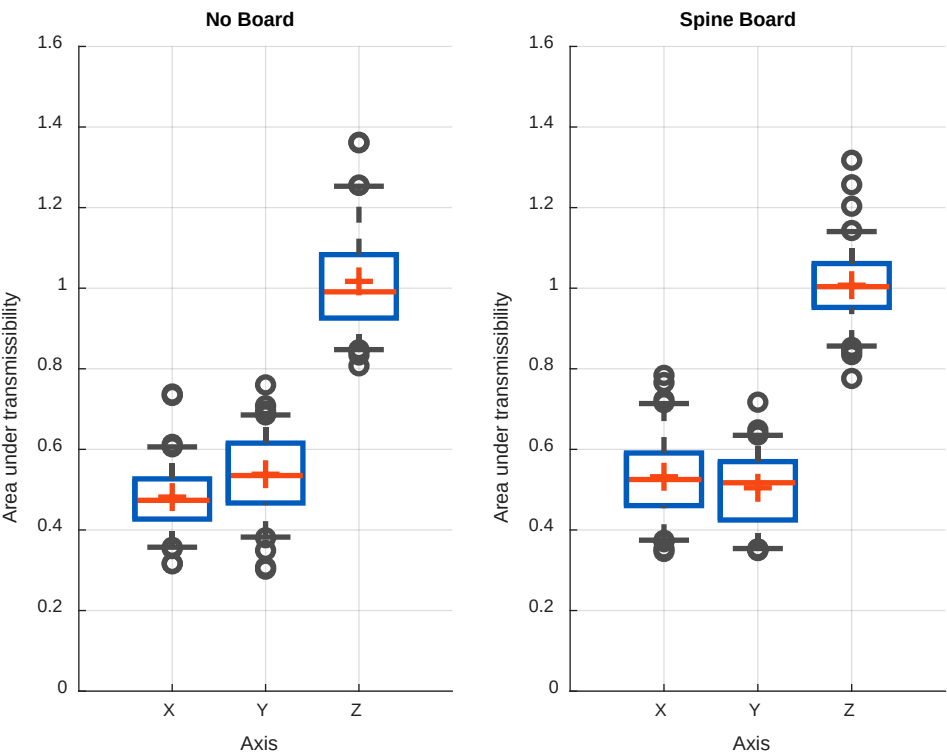


Figure 38: Boxplots representing the area underneath the transmissibility curve, measured at the chest and dependent on immobilization condition.

Figure 39 describes the area under the hip transmissibility curve using boxplots. In this case, only the Z axis was analyzed. For the spine board immobilization, the mean and median transmissibility were over 10 percent greater than the no board immobilization condition. In addition, the interquartile range and 5th to 95th percentile range was larger.

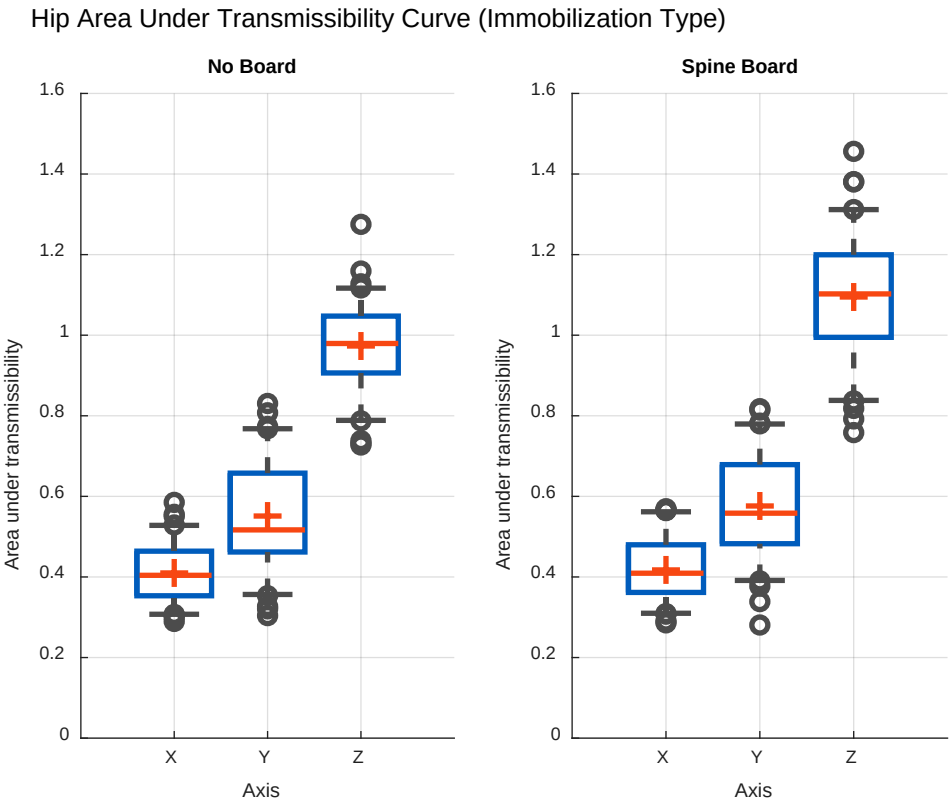


Figure 39: Boxplots representing the area underneath the transmissibility curve, measured at the hip and dependent on immobilization.

A depiction of the effect of subject weight on the area underneath the transmissibility curve can be found in Figure 40. In this instance, only the Z axis was analyzed. There was less than a 5 percent difference in mean and median area between the LW and HW groups. The LW group, however, had a larger interquartile range, and larger 5th and 95th percentile values. The 5th to 95th percentile range was similar between the LW and HW groups.

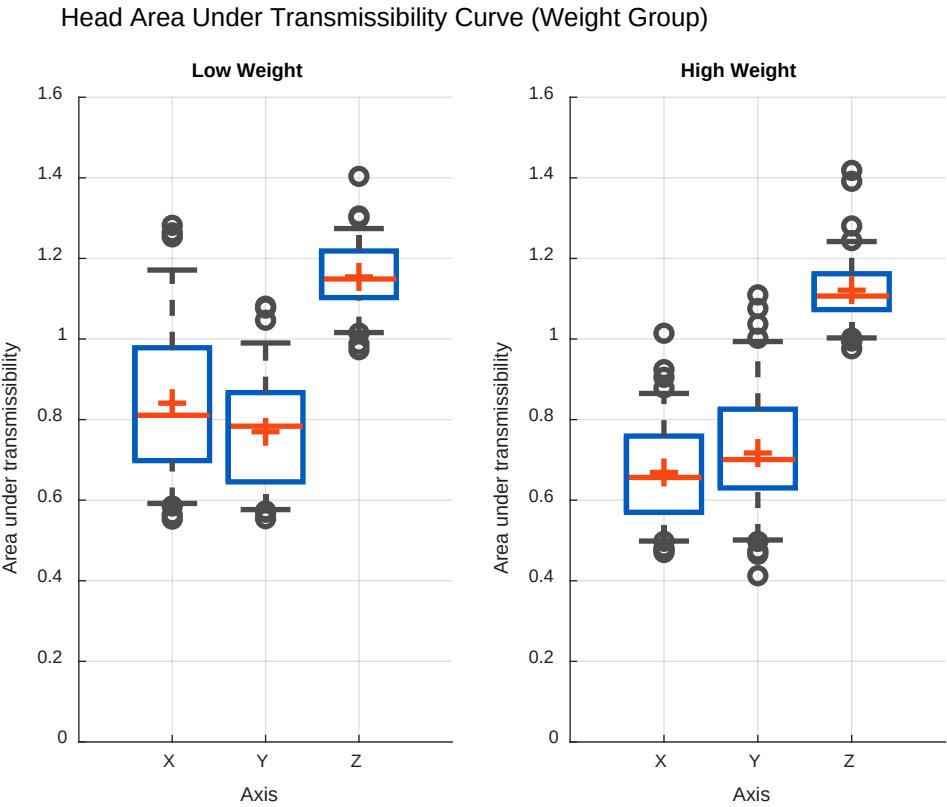


Figure 40: A representation of the effect of weight on area under the transmissibility curve, measured at the head.

Boxplots depicting the area under the transmissibility curve at the chest can be found in Figure 41. When analyzing the Z axis, the mean and median transmissibilities of the LW group were nearly 15 percent larger than that of the HW group. The LW group also had higher 5th and 95th percentile values, as well as a larger 5th to 95th percentile range. The interquartile range of both weight groups were similar, with the LW group having a slightly larger range.

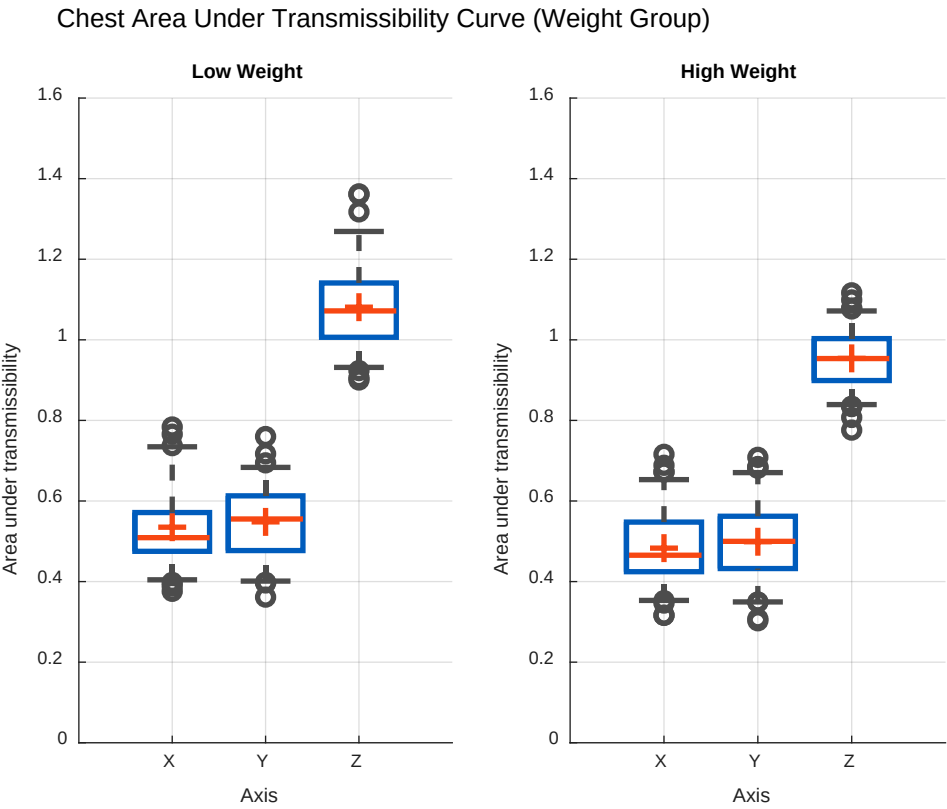


Figure 41: A representation of the effect of weight on the area under the transmissibility curve, measured at the chest.

The area under the transmissibility curve at the hip can be described by the boxplots shown in Figure 42. Only the Z axis was analyzed in this case. The HW group had a larger interquartile range, but smaller 5th to 95th percentile values. The 5th to 95th percentile range was similar between the two weight groups. The mean and median transmissibilities of the LW group were nearly 10 percent higher than those found in the HW group.

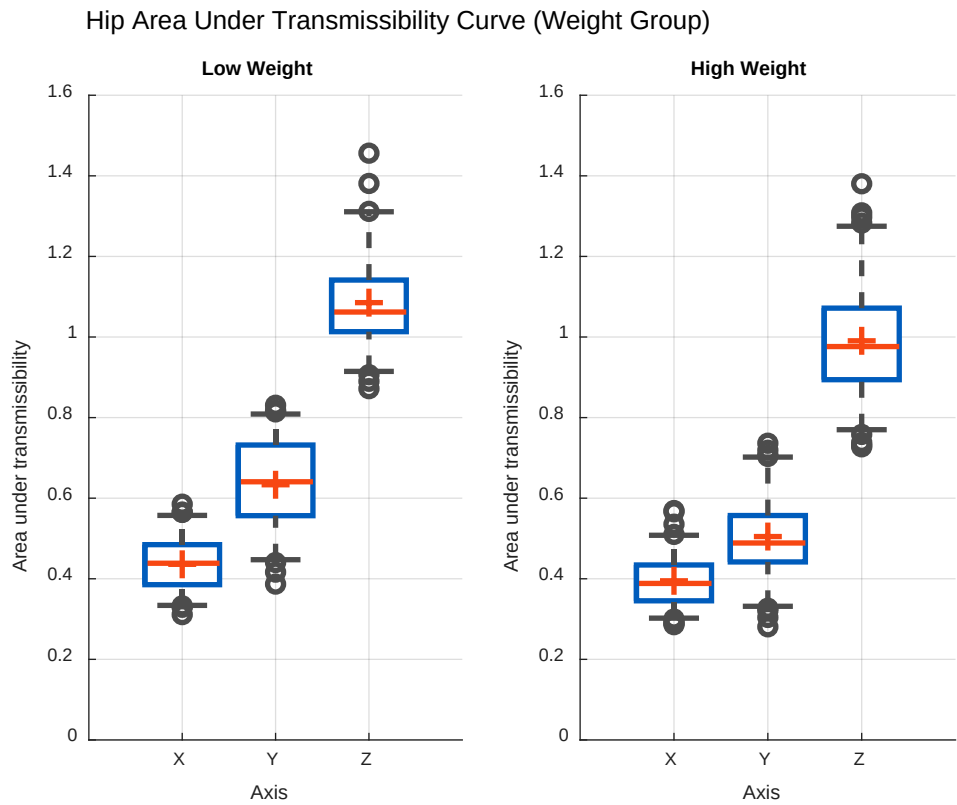


Figure 42: A representation of the effect of subject weight on the area under the transmissibility curve, measured at the hip.

Statistical Analysis

In order to provide a more comprehensive analysis of the gathered data, the results were subdivided based on three factors, as shown in Tables 1 and 2: weight (high or low), immobilization (spine board or no board), and ride profile (all profiles, ground vehicle, aircraft, and 3D vibration). For each subdivided set of results, a set of metrics were calculated, specifically the peak of the Z transmissibility, the area under the Z transmissibility curve (calculated via the integral from 2 Hz to 10 Hz), the resonant frequency (in the Z axis), the RMS Z acceleration, and the RMS of the gyroscope magnitude (the norm of the X, Y, and Z components). The gyroscope metric contains all three axes (rather than just the Z axis) because acceleration in the Z axis can cause rotational velocity about all three axes. The metrics were further analyzed for statistical significance using one-way ANOVA (Hogg, 1987). Results were deemed significant if $p < 0.05$.

Table 1: The effect of immobilization condition on various analysis quantities for low weight subjects. A “*” represents a statistically significant difference between the immobilization conditions, and a “^” represents a statistically significant difference ($p < .05$) between weight groups.

Ride Profile	Segment	Low Weight									
		Z Transmissibility (Peak)		Area under Z Transmissibility		Z Transmissibility Wn (Hz)		RMS Z Acc (g)		RMS Gyro (deg/s)	
		SB	NB	SB	NB	SB	NB	SB	NB	SB	NB
ALL	Head	2.74±0.45*^	5.49±1.06*^	1.12±0.06*	1.19±0.08*^	5.83±0.62*	6.39±0.41*^	0.16±0.04	0.20±0.08	10.04±5.77*	25.91±15.61*
	Chest	3.56±0.55^	3.72±0.54^	1.04±0.09*^	1.12±0.11*^	5.73±0.50^	5.81±0.54^	0.14±0.05	0.15±0.05	9.10±5.06*	12.39±5.86*
	Pelvis	4.24±0.77*	3.72±0.71*	1.15±0.11*^	1.02±0.09*^	5.75±0.45*^	5.22±0.45*^	0.15±0.06	0.14±0.05	14.25±8.03^	17.76±9.78
Ground	Head	2.80±0.44*^	5.75±1.15*	1.17±0.05	1.22±0.08	5.88±0.40*^	6.26±0.23*^	0.18±0.01*	0.22±0.01*	7.32±1.61*	17.73±2.41*
	Chest	3.46±0.53	3.75±0.38^	1.07±0.08	1.14±0.08^	5.84±0.37^	5.82±0.48^	0.17±0.01^	0.17±0.01^	7.24±2.80*	10.17±2.45*^
	Pelvis	3.95±0.68	3.45±0.63	1.13±0.11*	1.00±0.07*	5.82±0.37*^	5.15±0.45*^	0.18±0.01*	0.17±0.01*^	11.84±4.16^	13.64±4.38
Air	Head	2.82±0.51*^	5.52±1.19*	1.08±0.06*	1.17±0.10*	6.30±0.68	6.72±0.41^	0.11±0.01^	0.09±0.05	5.39±1.87*	13.35±3.64*
	Chest	3.81±0.63	4.05±0.61^	1.07±0.10*	1.17±0.12*^	6.09±0.46^	6.06±0.65^	0.08±0.02	0.09±0.02	5.48±1.99*	8.15±2.46*
	Pelvis	4.73±0.89	4.24±0.68	1.20±0.12*	1.07±0.10*^	6.09±0.34*^	5.42±0.51*^	0.07±0.01	0.08±0.01^	7.33±2.29*^	9.79±1.61*^
3D Vibration	Head	2.60±0.41*^	5.20±0.84*	1.11±0.04*	1.17±0.06*^	5.30±0.26*	6.18±0.36*^	0.20±0.01*	0.28±0.02*	17.41±2.97*^	46.65±6.36*
	Chest	3.41±0.45^	3.35±0.37	1.00±0.08^	1.05±0.09^	5.27±0.23^	5.54±0.36^	0.17±0.01^	0.18±0.01^	14.59±4.34*	18.85±5.17*
	Pelvis	4.03±0.49*	3.48±0.58*	1.11±0.10*	1.01±0.07*^	5.35±0.28^	5.09±0.35^	0.20±0.02	0.18±0.02	23.59±5.36*^	29.85±5.91*^

Table 2: The effect of immobilization condition on heavy weight subjects, reflected by various analysis quantities. A ‘*’ represents a statistically significant difference between the immobilization conditions, and a ‘^’ represents a statistically significant difference ($p < .05$) between weight groups.

Ride Profile	Segment	High Weight									
		Z Transmissibility (Peak)		Area under Z Transmissibility		Z Transmissibility Wn (Hz)		RMS Z Acc (g)		RMS Gyro (deg/s)	
		SB	NB	SB	NB	SB	NB	SB	NB	SB	NB
ALL	Head	2.31±0.27*^	6.25±1.60*^	1.11±0.07	1.13±0.09^	5.92±1.49*	5.41±0.43*^	0.16±0.04*	0.19±0.08*	9.11±4.41*	25.87±15.98*
	Chest	3.22±0.44*^	4.33±0.76*^	0.98±0.08*^	0.93±0.06*^	5.38±0.50*^	4.99±0.27*^	0.13±0.04	0.14±0.04	9.71±5.57	10.82±5.76
	Pelvis	4.28±0.77	4.00±0.92	1.05±0.16*^	0.93±0.10*^	5.36±0.43*^	4.82±0.24*^	0.15±0.05	0.14±0.04	20.76±11.66^	22.45±11.79
Ground	Head	2.42±0.29*^	6.43±1.42*	1.17±0.04	1.19±0.09	5.38±0.61^	5.35±0.40^	0.18±0.01*	0.21±0.01*	6.89±1.23*	17.85±2.74*
	Chest	3.23±0.42*	4.30±0.38*^	1.00±0.08	0.96±0.04^	5.45±0.40*^	4.97±0.33*^	0.16±0.01^	0.16±0.00^	7.39±1.96	8.11±1.82^
	Pelvis	4.13±0.71	3.73±0.62	1.04±0.16*	0.93±0.10*	5.38±0.33*^	4.82±0.22*^	0.17±0.01*	0.16±0.01*^	16.37±4.88^	16.62±3.29
Air	Head	2.26±0.28*^	6.50±2.22*	1.06±0.06	1.11±0.10	6.96±1.58*	5.63±0.54*^	0.10±0.01*^	0.09±0.01*	5.52±1.32*	12.54±1.55*
	Chest	3.40±0.49*	5.03±0.73*^	1.00±0.07	0.97±0.04^	5.65±0.56*^	5.12±0.24*^	0.08±0.01	0.08±0.01	5.82±1.84	6.41±1.83
	Pelvis	4.81±0.67	4.80±0.94	1.10±0.18*	0.97±0.10*^	5.65±0.42*^	5.01±0.18*^	0.08±0.02	0.09±0.01^	12.05±3.50^	13.88±3.74^
3D Vibration	Head	2.24±0.21*^	5.83±0.91*	1.10±0.04	1.10±0.06^	5.42±1.56	5.24±0.22^	0.20±0.01*	0.28±0.02*	14.91±1.66*^	47.22±6.52*
	Chest	3.04±0.36*^	3.65±0.35*	0.93±0.07*^	0.87±0.03*^	5.03±0.30^	4.88±0.20^	0.16±0.01^	0.16±0.01^	15.90±5.22	17.92±3.82
	Pelvis	3.89±0.66	3.48±0.57	1.01±0.16*	0.89±0.10*^	5.05±0.31*^	4.63±0.14*^	0.20±0.02*	0.17±0.01*	33.86±10.27^	36.83±8.64^

DISCUSSION

The study shows that on average among the subjects, RMS acceleration at the head is lower when immobilized than not immobilized; this is expected due to the head being secured inside a relatively soft brace. This effect can be observed in Figure 7. Chest acceleration is largely unaffected by immobilization condition, since the subjects are already strapped in around the chest regardless of whether the immobilization system is used or not. In all ride profiles, subjects experience approximately 5 percent more RMS acceleration at the hips when immobilized than when left not immobilized. This increase in acceleration may be caused by the spider straps inability to hold down the hips when moving vertically. Since most of the body is restrained when using spider straps, the energy imparted on the body during vibration escapes through the hips instead. The RMS acceleration of the chest and hips can be visualized in Figure 8 and Figure 9 respectively. These patterns can also be visualized in Figure 16, Figure 17, and Figure 18 when comparing raw RMS acceleration values between immobilization conditions for the head, chest, and hip respectively.

In general, higher weight subjects have a lower RMS vertical acceleration across the whole body in comparison to lighter subjects. Since the MARS can apply the same force to all subjects on all ride profiles, the heavy subjects must have a lower acceleration, due to their increased body mass. Figure 15 depicts this relation at the hips. Figure 13 and Figure 14 also depict this relation, but not as well as Figure 15 since the head acceleration is greatly affected by the subjects anthropometry, and the chest is restrained regardless of the immobilization condition.

At the head, higher weight subjects have a smaller interquartile range, as shown in Figure 7. This difference is thought to be caused by the weight variation between the subjects in the HW group and in the LW group. The heavy subjects' weights vary by a smaller percentage than the LW subjects, which may cause a decrease in the interquartile range. It is also thought that the anthropometry of each subject can play a role in transmissibility. The HW group was thought to have a more variable anthropometry when compared to the LW group. This variation in anthropometry may cause a wider RMS acceleration and rotational velocity range. The immobilization system reduces the effect of the heavy weight subjects' highly variable anthropometry, which in turn may have caused the reduction in the interquartile range. These responses are also true for the subjects' rotational data in the head and hips, but not the chest. HW subjects have a higher interquartile range in the chest when rotating, which may be caused by the increased inertia of their torsos.

In both weight groups, subjects' heads experienced a lower RMS rotational velocity around the Z axis when immobilized due to the head restraint restricting rotational motion. The chest and hips also experience a lower rotational velocity around the Z axis when immobilized because of the spider straps and spine board. These responses are also true when analyzing raw RMS rotation values, such as those found in Figure 22, Figure 23, and Figure 24.

At the head, the HW group will resonate at a lower frequency due to the increased mass in the head. This response can be predicted using Equation 2, and by referencing the data in Figure 25. The chest and hip data presented in Figure 26 and Figure 27 respectively also follow this trend. Also, heavy weight subjects appear to have a higher 95th percentile transmissibility, which may be caused by their highly variable anthropometry. This postulation also applies to the chest and hip data, and median peak transmissibility data found in Figure 31-33.

Two significant takeaways from the tabulated ANOVA analysis are as follows. First, use of the spine board had a significant impact on head motion (as compared to the no board condition) in both the high and low weight conditions. This significance was present in all ride profiles. The impact can most readily be seen as a large (often more than 50%) reduction in the peak Z transmissibility, though significant reduction in most of the other metrics is also apparent. This reduction with respect to the no board condition is logical given that in the spine board condition the head was constrained to the board via a foam block that greatly restricted any motion of the head with respect to the board.

Second, the resonant frequency was significantly impacted by weight. Specifically, the resonant frequency decreased by between 0.5 and 1.5 Hz from the low weight subjects to the high weight subjects. This decrease was statistically significant in every no board condition, as well as in most spine board conditions. Given the direct relationship between mass and resonant frequency (Equation 2), this reduction in frequency for higher weight subjects is not unexpected. Furthermore, though the magnitude of the reduction may seem small, its potential for vibration mitigation should not be underestimated. Even a small (0.5 Hz) shift in resonant frequency can reduce vibration magnitude if the subject's resonant frequency would otherwise line up with the vehicle or aircraft he or she is traveling.

When analyzing Figure 29 and Figure 30, the 95th percentile transmissibility of the immobilized subjects had resonance frequencies that occurred before the non-immobilized subjects, occurring at approximately 2 Hz before and less than .5 Hz before respectively. This shift in resonant frequency was a result of the immobilization system. The spider straps held the subject tighter to the litter, therefore increasing their connection to the system and making the system more rigid. This relation can be described using Equation 2.

When looking at all transmissibility data points for each immobilization condition, such as those found in Figure 34-36, the immobilized subjects had lower median and mean peak transmissibilities. This was caused by the head restraint which significantly reduced the head motion. Across the whole body, immobilized subjects showed a lower interquartile range of transmissibility, as well as a lower 5th to 95th percentile. This may have been caused by increased system rigidity brought on using spider straps.

As evidence of the study, analysis was largely performed on transmissibility, accelerations, and rotations pertaining to the Z axis. These data were also affected on the X and Y axes when the spine board was implemented. Y transmissibility in the chest and hips was adversely affected by the implementation of a spine board, due to the contact surface between the board and the litter. Both the board and the litter had a stiff, smooth surface, therefore the friction between the two was low. This allowed the subject on the spine board to slide along the Y axis easier, increasing transmissibility. The X transmissibility also exhibits similar behavior.

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LIST OF ABBREVIATIONS

3DOF: Three Degree of Freedom

6DOF: Six Degree of Freedom

HW: High Weight

Hz: Hertz

ICP: Intracranial Pressure

LW: Low Weight

MARS: Multi-Axis Ride Simulator

NB: No Board

PSD: Power Spectral Density

RMS: Root Mean Square

SB: Spine Board

USAARL: United States Army Aeromedical Research Laboratory

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Appendix B. USAARL Technical Report No. 2019-18, 2019.

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USAARL Report No. 2019-18

Optimal Physical Space for En Route Care: Medic Posture and Injury Survey Results

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United States Army Aeromedical Research Laboratory

Enroute Care Group

September 2019

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Table of Contents

	Page
Introduction.....	1
Study Background.....	1
Military Relevance.....	2
Previous Studies.....	3
Specific Aims.....	3
Methods.....	4
Data Analysis	5
Results.....	5
Section 1: Basic Information and Demographics	6
Section 2: Platform Design Features that Negatively Affected Performance.....	12
Section 3: Equipment that Caused Awkward/Painful Postures	33
Section 4.1: Relation Between Number of Patients and the Use of Painful Postures	53
Section 4.2: Typical Number of Patients Cared for at One Time	55
Section 5: Frequency of Awkward Postures for a Given Task	56
Section 6: Occupational Injuries/Discomforts	63
Section 7: Reasons for Not Reporting and Primary Sources of Pain.....	73
ANOVA Analysis	76
Fisher's Exact Analysis.....	80
Discussion	88
Recommendations.....	89
Conclusion	90
References.....	91
Appendix.....	94
Acronym/Abbreviation List.....	99

List of Figures

1. Summary of Table 18.....	13
2. Summary of Table 19.....	15
3. Categorized open-ended responses to Q9.	16
4. Categorized open-ended responses to Q10.	17
5. Categorized open-ended responses to Question 11.	18
6. Categorized open-ended responses to Q12.	19
7. Categorized open-ended responses to Q13.	20
8. Categorized open-ended responses to Q14.	21
9. Categorized open-ended responses to Q15.	22
10. Categorized open-ended responses to Q16.	23
11. Categorized open-ended responses to Q17.	24
12. Categorized open-ended responses to Q18.	25
13. Categorized open-ended responses to Q19.	26
14. Categorized open-ended responses to Q20.	27
15. Categorized open-ended responses to Q21.	28

Table of Contents (continued)

List of Figures (continued)

	Page
16. Categorized open-ended responses to Q22.....	29
17. Categorized open-ended responses to Q23.....	30
18. Categorized open-ended responses to Q24.....	31
19. Categorized open-ended responses to Q25.....	32
20. Summary of Table 20.....	34
21. Summary of Table 21.....	36
22. Categorized open-ended responses to Q27 for patient monitors.....	37
23. Categorized open-ended responses to Q27 for defibrillators.....	38
24. Categorized open-ended responses to Q27 for ventilators.....	39
25. Categorized open-ended responses to Q27 for IV pumps.....	40
26. Categorized open-ended responses to Q27 for suction.....	41
27. Categorized open-ended responses to Q27 for EZ I.O.s.....	42
28. Categorized open-ended responses to Q27 for SMEEDs.....	42
29. Categorized open-ended responses to Q27 for medical aid bags.....	43
30. Categorized open-ended responses to Q27 for medication boxes.....	44
31. Categorized open-ended responses to Q27 for fluid warmers.....	45
32. Categorized open-ended responses to Q27 for O ₂ bottles with regulators.....	45
33. Categorized open-ended responses to Q27 for traction splints.....	46
34. Categorized open-ended responses to Q27 for spine boards.....	47
35. Categorized open-ended responses to Q27 for trauma panels.....	48
36. Categorized open-ended responses to Q27 for Sked BRSS.....	49
37. Categorized open-ended responses to Q27 for litters.....	50
38. Categorized open-ended responses to Q27 for litter straps.....	51
39. Categorized open-ended responses to question 27 for other equipment.....	52
40. Pie chart of complete valid survey responses to Question 28.....	53
41. Pie chart of complete and incomplete responses to Q28.....	54
42. Pie chart of complete valid survey responses to Q29.....	55
43. Usual number of patients according to all valid survey responses to Q29.....	56
44. The minimum frequency of bending at the waist for medical tasks.....	57
45. The minimum frequency of overextending for medical tasks.....	58
46. The minimum frequency of kneeling for medical tasks.....	59
47. The minimum frequency of reaching behind you for medical tasks.....	60
48. The minimum frequency of squatting for medical tasks.....	61
49. The minimum frequency of straining to lift a heavy weight for medical tasks.....	62
50. Frequency of occupational injuries.....	64
51. Causes of neck injuries.....	65
52. Causes of knee injuries.....	66
53. Causes of hip injuries.....	67
54. Causes of shoulder injuries.....	68
55. Causes of ankle injuries.....	69
56. Causes of elbow injuries.....	70

Table of Contents (continued)

List of Figures (continued)

	Page
57. Causes of wrist injuries.....	71
58. Causes of upper back injuries.	71
59. Causes of lower back injuries.	72
60. Types and causes of other injuries.....	73
61. Reasons that respondents chose not to report their injuries.....	74
62. Primary sources of pain.	75
63. Injuries not listed previously in the survey.....	76
64. Average experience level of respondents that skipped sections, ordered sequentially from left to right.....	87
A1. Page 1 of the Medical Provider Posture and Injury Survey.....	94
A2. Page 2 of the Medical Provider Posture and Injury Survey.....	95
A3. Page 3 of the Medical Provider Posture and Injury Survey.....	96
A4. Page 4 of the Medical Provider Posture and Injury Survey.....	97
A5. Page 5 of the Medical Provider Posture and Injury Survey.....	98

List of Tables

1. Survey Question Topics.....	4
2. Responses to Q1 – All Surveys.....	6
3. Responses to Q2 – Complete Valid Surveys	7
4. Response to Q2 – All Valid Surveys (Complete and Incomplete)	7
5. Male-to-female Ratio among the Total 68W Population versus Survey Respondents.....	7
6. Responses to Q3 – Complete Valid Surveys	8
7. Responses to Q3 – All Valid Surveys.....	8
8. Responses to Q4 – Complete Valid Surveys	8
9. Responses to Q4 – All Valid Surveys.....	8
10. BMI Statistics of Respondents – Complete Valid Surveys	9
11. BMI Statistics of Respondents – All Valid Surveys.....	9
12. Responses to Q5 – Complete Valid Surveys	9
13. Responses to Q5 – All Valid Surveys.....	10
14. Responses to Q6 – Complete Valid Surveys	10
15. Responses to Q6 – All Valid Surveys.....	11
16. Responses to Q7 – Complete Valid Surveys	11
17. Response to Q7 – All Valid Surveys	11
18. Responses to Q8 – Complete Valid Surveys	12
19. Responses to Q8 – All Valid Surveys.....	14
20. Responses to Q26 – Complete Valid Surveys	33
21. Responses to Q26 – All Valid Surveys.....	35
22. Responses Indicating if an Increasing Number of Patients Increases the Likelihood of Painful Postures from Complete Valid Surveys.....	53

Table of Contents (continued)

List of Tables (continued)

	Page
23. Responses Indicating if an Increasing Number of Patients Increases the Likelihood of Painful Postures from All Valid Surveys	54
24. Number of Patients Usually Cared for at Once According to Complete Valid Surveys	55
25. Number of Patients Usually Cared for at Once According to All Valid Surveys.....	56
26. Tally of Injuries Sustained and their Report Status from Complete Surveys	63
27. Parameters Used for RStudio's Pwr.t2n.test Function.....	77
28. ANOVA Results Comparing Heights of Respondents that Had Injuries vs. Those that Did Not.....	78
29. ANOVA Results Comparing Weights of Respondents that Had Injuries vs. Those that Did Not.....	78
30. ANOVA Results Comparing the Minimum Number of Times a Posture was Required of Respondents that Had Injuries vs. Those that Did Not.....	79
31. ANOVA Results and Power Comparing the Minimum Number of Times a Posture was Required of Respondents ≤ 69.25 in. vs. Those > 69.25 in. Tall.....	80
32. Fisher's Exact Results Comparing Significant and Insignificant Platform Design Features Between Two Height Groups Complete Valid Surveys	81
33. Fisher's Exact Results Comparing Significant and Insignificant Platform Design Features Between Two Height Groups All Valid Surveys.....	82
34. Fisher's Exact Results of 2x2 Tables Comparing Significant and Insignificant Platform Design Features Between Males and Females.....	83
35. Fisher's Exact Results of 2x2 Tables Comparing Significant and Insignificant Platform Design Features Between Males and Females.....	84
36. Fisher's Exact Results of 2x2 Tables Comparing Injury Frequency Between Males and Females	85
37. Tally of Respondents that Skipped Each Section and the Number of Respondents that Skipped the Rest of the Survey After Skipping Each Section.....	86
38. Average Experience Level of Respondents that Skipped Each Section	87

Introduction

This project involved designing a survey to investigate awkward postures associated with delivering patient care in the confined space of common medical evacuation (MEDEVAC) platforms. The survey also related care provider health and efficiency with these postures and resulting injuries. The goal of this work was to provide recommendations for countermeasures to reduce the impact of awkward postures. The survey was presented via email and social media to Active Duty U.S. Army, Reserve, and National Guard en route care medical providers. Valid data were collected from 60 respondents. Statistical analyses were used to define trends in the data. Results will contribute to the long-term health of care providers and to en route care task administration efficiency.

Study Background

Civilian Emergency Management System (EMS) personnel experience muscle fatigue and injury because of their work environment. The back is the body part most often injured during civilian EMS patient movement tasks (Maguire et al., 2005). Many back injuries reported by EMS personnel were related to the stretcher. Toivonen and Fagerstrom (2011) defined the impacts of lifting the stretcher off the ground, carrying the patient, installing auxiliary equipment, and loading everything into the ambulance. Furthermore, bending towards the patient, especially when standing or sitting on the edge of a seat, was one of the leading activities inside a moving ambulance that was shown to cause repetitive muscle strain and lead to developing musculoskeletal disorders (MSDs) (Deros et al., 2016). Analysis of injury and illness data from 2008 through 2013 found that the greatest portion of injuries involved overexertion of the upper and lower trunk (The National Institute for Occupational Safety and Health [NIOSH], 2013). More than half (62 percent [%]) of all prehospital provider back injuries resulted from lifting patients. Their injuries were a consequence of three major factors: significant lifting forces (patient weight), repetitive movements, and awkward positions (Hogya et al., 1990). Johnso (2011) found that force, repetition, and awkward postures experienced while performing EMS job tasks led to a variety of MSDs, including epicondylitis, sciatica, low back pain, carpal tunnel syndrome, and rotator cuff injuries.

An MSD is defined as a condition or disorder that involves the muscles, nerves, tendons, ligaments, joints, cartilage, or spinal discs (Torma-Krajewski et al., 2009a). MSDs develop gradually and increase in frequency when a person handling materials manually engages in repetitive lifting or performs tasks improperly. In ergonomic studies at four sites where people work in confined environments, MSDs were identified as a significant and costly problem (Torma-Krajewski et al., 2009b; Steiner, 2004). Stobbe and Bobick (1986) reported that strain and sprain injuries accounted for almost 25% of all reported injuries for workers in confined environments. The study also indicated that the three most common overload conditions were: (1) bending forward, bending to the side, or twisting the neck or back; (2) unsupported abducted elbows, forearms resting on sharp edges, tossing motions at extremes of range of motion, working with elbows above shoulders; and (3) lifting more than 50 pounds (lbs.) unaided. The

same study showed that at least 35% of workers in confined environments were potentially exposed to each of these three overload conditions.

MSDs can result from suddenly or improperly lifting or handling heavy loads, which can cause excessive stress and strain in certain parts of the musculoskeletal systems. Such disorders can also occur because of musculoskeletal fatigue resulting from prolonged or repeated loading. One example is the process of cable-lifting in underground coal mining. Miners may be required to hold this heavy load for some time while they are stooping or kneeling in confined zones (Gallagher & Unger, 1990). Such a situation will induce musculoskeletal fatigue, a state where workers cannot keep using the same set of muscles and thus unintentionally adopt new postures with different sets of muscles (Alvarez & Semmlow, 2002). The new posture may induce improper loading to the musculoskeletal system and lead to extreme loading on the lower back or joints, which may cause musculoskeletal injuries (Gallagher, Marras, Davis, & Kovacs 2002).

When designing ambulance interiors, safety constraints are sometimes overlooked. Inadequate design of the ambulance interior would expose all occupants of emergency vehicles, providers and patients, to risk of injury (Brice et al., 2012). While EMS personnel are focused on providing patient care and the driver is proceeding in an emergency fashion with lights and sirens, the medical service providers in the rear of the vehicle are often unrestrained. A sudden stop, change in direction or swerve, or crash may result in serious injury to the medical service provider, and quite possibly the patient (Patterson et al., 2010).

There is a current focus on utilizing proper ergonomics to prevent injury in this career field. Labeling and standardizing the medical equipment arrangement inside the ambulance plays an important role during emergency medical service. This activity reduces confusion and places the equipment in the best ergonomic position possible, which may reduce injury (Biesbroek & Teteris, 2012). While significant data exists identifying back injuries as a major problem in the EMS field, the data reported are not separated to show whether the injuries were caused by poor lifting technique, repetitive movement, or posture; however, the data concludes that back injury is a major problem for these medical providers.

Military Relevance

In the military environment, en route care providers are also often exposed to combinations of high forces, awkward postures, continuous or prolonged gripping, and repetitive motions that may lead to symptoms related to long-term MSDs. The nature of the confined spaces of MEDEVAC interiors where care providers normally conduct their tasks during air and ground transport add considerable constraints on their movement and range of motion, and can force them to take extremely awkward postures while subjected to heavy loads. These tasks often impose a localized load on relatively small muscles in different locations on the body and may rapidly lead to muscle fatigue, which will make their tasks even more challenging. It has been shown that posture plays a role in medical provider injuries (Lester, Hsu, & Ahmed, 2012).

En route care providers are often subjected to the similar awkward postures and lifting requirements as industrial workers. Focused research that takes place in the en route care environment is needed to define these stresses and to recommend countermeasures.

Previous Studies

The U.S. Army Aeromedical Research Laboratory (USAARL) conducted a study examining fixed position litter loading (Kinsler & Barazanji, 2011) in a MEDEVAC helicopter. It was observed that the receiving medic inside the aircraft was often challenged to perform lifting of litter-patient packages at awkward angles. USAARL conducted another study to evaluate the adequacy of space available for a Critical Care Flight Paramedic (CCFP) to perform advanced medical treatment scenarios on simulated critical care patients (manikins) in existing MEDEVAC aircraft, e.g., HH-60 and UH-60 (Kinsler et al., 2015). The motion of three flight medics, a second percentile female, seventy-fifth percentile male, and ninety-ninth percentile male (based on height), was recorded while each medic wore a motion capture suit. Neck and back bend angles were calculated and averaged for all scenarios and medical tasks for each medic.

Literature indicates that a 30-degree flexion in upper limbs for an extended time of 5 hours will result in severe pain (Golob & Sykes, 2002; Buckle & Devereaux, 2002; Chaffin, 1973). USAARL's study showed that the medics' neck angles increased with shorter stature, up to 66 degrees for a stature of 4 feet (ft) 11 inches (in.) versus 37 degrees for a 6 ft 5 in. stature. This trend was the same regardless of the platform type. The second percentile medic's neck angle had more than a 30-degree flexion 94% of the time while completing medical tasks and scenarios. Surprisingly, the ninety-ninth percentile medic's neck angle was 28 degrees lower with a back angle slightly higher than the second percentile medic, suggesting complex postures were assumed while accomplishing tasks. The medics' back angles were less sensitive to their stature. It was observed during this study that shorter medics tended to stand and lean over, while the taller medics knelt and then leaned over to perform tasks. This led to the surprising observation that taller medics had smaller neck angles. These findings support the need to further investigate the ergonomic role of postures assumed by medics in causing MSDs.

Specific Aims

This project investigated the postures and injuries associated with working in the confined space of common MEDEVAC platforms.

- (1) Specific aim 1: The team's survey collection goal was 41 complete survey responses. This aim was exceeded because the team received 60 valid responses, 46 of which were fully completed by en route care medical providers.
- (2) Specific aim 2: The team aimed to identify relationships and trends between body mass index (BMI), gender, equipment, injuries, medical environment constraints, medical tasks, and awkward postures by analyzing the survey responses. These relationships were examined using analysis of variance (ANOVA) and Fisher's exact analyses.

A range of care providers were asked about the effects of the environment on their health and efficiency. Anonymous survey responses were received from en route care providers regarding postures assumed during administration of en route critical care tasks, routine medical transport scenarios, and patient loading. The survey inquired about the care provider's experience, tasks, performance, awkward postures experienced, and occupational injuries that occurred as a result of performing their duties, such as back, neck, and joint pain, injuries, and discomfort. The survey questions intended to gather care provider opinions on the awkward postures and lifting demands associated with confined space medical interiors, and any potential association with increased risk for occupational injuries among care providers. Topics addressed in the survey are listed in Table 1.

Table 1. Survey Question Topics

Section Number	Data Element/Variable
Section 1	Gender
	Height
	Weight
	Position title
	Platform or position location
	Length of time in position
Section 2	Aircraft/vehicle/gear design characteristics that impacted mission performance
Section 3	Items in the current aeromedical or ground evacuation Medical Equipment Set (MES) which caused awkward or painful postures
Section 4	If number of patients affects postures
	Number of patients typically cared for
Section 5	Frequency of awkward postures during tasks
Section 6	Occupational injuries or discomfort associated with any postures during patient loading and patient care
Section 7	Reasons for not reporting injuries
	Specific postures or tasks that cause primary source of pain
	Other injuries that were not previously mentioned

Methods

First, the number of respondents needed for statistical significance was calculated using the following parameters:

Threshold probability for rejecting the null hypothesis (Type I error rate),
 α (two-tailed) = 0.050.

Probability of failing to reject the null hypothesis under the alternative hypothesis (Type II error rate), β = 0.800.

The expected correlation coefficient based on past relevant findings, $r = 0.180$.

The standard normal deviate for α , $Z_\alpha = 1.960$.

The standard normal deviate for β , $Z_\beta = -0.842$.

$$C = 0.5 * \ln \left[\frac{1+r}{1-r} \right] = 0.182$$

$$\text{Total sample size} = N = \left[\frac{Z_\alpha + Z_\beta}{C} \right]^2 + 3 = 41$$

Thus, a minimum of 41 respondents were needed for statistical relevance.

The survey was created and distributed online using ClassApps LLC SelectSurvey.NET v4 .154.010. Once the data were gathered, they were organized into a Microsoft Office Professional Plus Excel 2013 (henceforth referenced as Excel) database, where general frequency charts, graphs, and filter tables were created.

Data Analysis

Analysis of variance (ANOVA) was performed by using an Excel filter table to compare the numbers of a single continuous variable between two groups. The two-number lists were examined using the ANOVA single factor feature of Excel's Analysis ToolPak Add-In. Power analyses were performed on the ANOVA results in R 3.6.1 using the `pwr.t2n.test` function from the PWR package.

Fisher's exact analyses were performed in RStudio 0.99.903 using the `fisher.test` function on two-by-two tables created in Excel with the alternative hypothesis set to "two.sided."

Open-ended data were read and categorized according to the content of each comment. The categories were created as the comments were sorted, and the comments were broken down into their components since most comments cited multiple issues. Each part of a comment was either listed under a pre-existing category or a new category was created. The data were then tallied and reported as bar graphs.

Results

The study group expected to collect a minimum of 41 anonymous surveys and exceeded the goal by 47 surveys, with 88 surveys collected in total. Out of those 88 surveys, 24 were invalid because the first question, which would have verified status as an Army en route care provider, was skipped. Out of the 64 remaining surveys, 3 respondents were not en route care medical providers and were notified that they were ineligible to complete the survey. One

response was from a medic that did not answer any questions beyond Question (Q) 1. Once these four surveys were removed, the number of valid surveys received was reduced to 60 total (46 complete responses completed by en route care medical providers and 14 incomplete responses, which contained partial responses from en route care providers).

The 46 valid surveys completed by en route care providers were used for analysis. If the 14 incomplete surveys from en route care providers contained responses for certain sections, a second analysis was performed for that section in isolation to include the responses. Missing data were also analyzed to determine if there were any identifiable trends in the skipped questions.

Throughout this report, tables and graphs containing data from these valid surveys are color coded:

- Grey = Complete Valid Surveys (46 complete responses out of 60 total)
- Green = All Valid Surveys (60 total – includes complete and incomplete responses)

Surveys were considered complete and valid if the respondent reached the end of the survey and had filled out the majority of the information (not necessarily that all answers were filled), and a survey was incomplete yet valid if the respondent had filled out at least the first section and skipped one or more sections. The website used to distribute the surveys identified which respondents had completed their surveys and which ones had not. It is worth noting that some answers were blank in the complete and valid surveys, but because the surveys were completed, these missing data points were interpreted as deliberate negative answers. Blank answers in incomplete surveys were interpreted as skipped questions. Response percentages in graphs were calculated based on how many respondents answered individual questions and not the total number of surveys.

All survey questions (Q1 through Q44) are numbered in the order that they were listed in the survey and summaries of the responses are provided. The first seven questions asked respondents for their basic information and demographics. Results are summarized in Tables 2 through 17.

Section 1: Basic Information and Demographics

Q1. Are you or have you ever been a U.S. Army en route care medical provider (medic, nurse, doctor, etc.)?

Table 2. Responses to Q1 – All Surveys

Response	Number of Responses	Response Percentage
Yes	61	95.3%
No	3	4.7%
Skipped	24	Not Applicable (N/A)

Q2. Are you male or female?

Table 3. Responses to Q2 – Complete Valid Surveys

Complete Valid Survey Responses to Q2		
Response	Number of Responses	Response Percentage
Male	43	93.5%
Female	3	6.5%
Skipped	0	0%

Table 4. Response to Q2 – All Valid Surveys (Complete and Incomplete)

All Valid Survey Responses to Q2		
Response	Number of Responses	Response Percentage
Male	56	93.3%
Female	4	6.7%
Skipped	0	0%

The ratio of male to female differs very little between the group of complete valid surveys and the group of all valid surveys, which includes complete valid responses combined with the incomplete valid responses. However, the ratio is very different from the overall population of U.S. Army medical specialists (68Ws), including Active Duty U.S. Army, National Guard, and Reserve U.S. Army Soldiers, as shown in Table 5. Since the majority of respondents were CCFPs (shown in Table 12), the male-to-female ratio for Active Duty U.S. Army CCFPs is also displayed in Table 5.

Table 5. Male-to-female Ratio among the Total 68W Population versus Survey Respondents

	Total 68W Population		CCFP Population		Survey Respondents			
	Number of Personnel	Percentage of Population	Number of Personnel	Percentage of Population	Complete Valid Surveys		All Valid Surveys	
					Number of Responses	Response Percentage	Number of Responses	Response Percentage
Male	26,136	76.07%	374	89.3%	43	93.5%	56	93.3%
Female	8220	23.93%	45	10.7%	3	6.5%	4	6.7%

The percentage of females represented in the survey respondents is approximately one-fourth of the total percentage of females among the population, and over half the percentage of females in the Active Duty U.S. Army CCFP population.

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Q3. What is your height in inches?

Table 6. Responses to Q3 – Complete Valid Surveys

Complete Valid Survey Responses to Q3					
Average Height	Standard Deviation of Height	Maximum Height	Minimum Height	Response Total	Skipped
70.63 in.	3.06 in.	78.0 in.	63.0 in.	46	0

Table 7. Responses to Q3 – All Valid Surveys

All Valid Survey Responses to Q3					
Average Height	Standard Deviation of Height	Maximum Height	Minimum Height	Response Total	Skipped
70.68 in.	2.97 in.	78.0 in.	63.0 in.	60	0

According to the 2014 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics, the average height for U.S. Army males is 69.09 in. and females is 64.02 in. (Gordon et al., 2014). The averages for both analyses, with and without the incomplete surveys, are close to the national average for males in the U.S. Army, which is reasonable considering the low percentage of females among respondents.

Q4. What is your weight in pounds?

Table 8. Responses to Q4 – Complete Valid Surveys

Complete Valid Survey Responses to Q4					
Average Weight	Standard Deviation of Weight	Maximum Weight	Minimum Weight	Response Total	Skipped
190.0 lbs.	25.44 lbs.	240.0 lbs.	136.0 lbs.	46	0

Table 9. Responses to Q4 – All Valid Surveys

All Valid Survey Responses to Q4					
Average Weight	Standard Deviation of Weight	Maximum Weight	Minimum Weight	Response Total	Skipped
189.7 lbs.	25.02 lbs.	240.0 lbs.	136.0 lbs.	60	0

According to the 2014 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics, the average weight for U.S. Army males is 186.51 lbs. and for females is

147.27 lbs. (Gordon et al., 2014). As was the case with height, the survey respondents' average was slightly above the national average for males, which is reasonable considering the low percentage of females among the respondents.

From the responses of weight and height, the BMI of each respondent was calculated (Tables 10 and 11) using:

$$BMI = 703 * \frac{[weight (lbs)]}{[height (in)]^2}$$

Table 10. BMI Statistics of Respondents – Complete Valid Surveys

BMI Statistics for Complete Valid Survey Responses to Q4			
Average BMI	Standard Deviation of BMI	Maximum BMI	Minimum BMI
26.74	2.83	33.47	19.64

Table 11. BMI Statistics of Respondents – All Valid Surveys

BMI Statistics for All Valid Survey Responses to Q4			
Average BMI	Standard Deviation BMI	Maximum BMI	Minimum BMI
26.66	2.84	33.47	19.64

Q5. What was your job/position as a medical care provider?

Table 12. Responses to Q5 – Complete Valid Surveys

Complete Valid Survey Responses to Q5		
Position Title	Number of Responses	Response Percentage
CCFP	43	93.5%
Ground Medic (GM)	5	10.9%
Standardization Instructor	2	4.3%
Flight Instructor	2	4.3%
Flight Surgeon	2	4.3%
Flight Medic	1	2.2%
None (Skipped Q5)	0	0%

Note. The sum of percentages is over 100% because many medics served in more than one position.

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Table 13. Responses to Q5 – All Valid Surveys

All Valid Survey Responses to Q5		
Type of Respondent	Number of Responses	Response Percentage
CCFP	52	86.7%
GM	6	10.0%
Flight Medic	5	8.3%
Standardization Instructor	2	3.3%
Flight Instructor	2	3.3%
Flight Surgeon	2	3.3%
Crew Chief for MEDEVAC	1	1.7%
None (Skipped)	0	0%

Note 1. The sum of percentages is over 100% because many medics served in more than one position.

Note 2. With the exception of one respondent with experience solely as a Crew Chief for MEDEVAC, all respondents had experience as a 68W at some point in their service.

Q6. What was the general platform/location where you performed the majority of your duties as a medical care provider?

Table 14. Responses to Q6 – Complete Valid Surveys

Complete Valid Survey Responses to Q6		
Platform Type	Number of Responses	Response Percentage
HH-60	31	67.4%
UH-60	26	56.5%
Field Light Ambulance (FLA)/ Ground Vehicle	4	8.7%
Field Hospital/Hospital/Clinic	3	6.5%
Skipped	0	0%

Note. The sum of percentages is over 100% because many medics served in more than one position.

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Table 15. Responses to Q6 – All Valid Surveys

All Valid Survey Responses to Q6		
Platform Type	Number of Responses	Response Percentage
HH-60	39	65.0%
UH-60	34	56.7%
FLA/Ground Vehicle	7	11.7%
Field Hospital/Hospital/Clinic	3	5.0%
Skipped	0	0%

Note. The sum of percentages is over 100% because many medics served in more than one position.

Though the respondents' platform and position were collected as variables, it was determined that these should not be used as comparison filters for analysis because of the excessive overlap in data. There was only one GM who had not held another position, and almost all respondents had been CCFPs at some point in their military career. The platform issue is related to position: the medics had served on multiple different aircraft as well as ground vehicles in some cases, so there was quite a bit of overlap of data. Consequently, any analysis comparing platforms or positions would be unreliable.

Q7. What is the length of time you have been in this position as a medical care provider?

Table 16. Responses to Q7 – Complete Valid Surveys

Complete Valid Survey Responses to Q7				
Average Number of Years	Maximum Number of Years	Minimum Number of Years	Response Total	Skipped
7.15	21.0	.083	46	0

Table 17. Responses to Q7 – All Valid Surveys

All Valid Survey Responses to Q7				
Average Number of Years	Maximum Number of Years	Minimum Number of Years	Response Total	Skipped
7.34	21.25	.083	60	0

Note. All respondents, including those that submitted incomplete surveys, answered the "Respondent Information" section fully.

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Section 2: Platform Design Features that Negatively Affected Performance

Q8. Please select aircraft/vehicle/gear design characteristics from this list that negatively affected your mission performance or caused you to perform your mission as a care provider in awkward or painful postures.

For Q8, the respondents were given a list of 16 specific and 2 “Other” (non-specific, respondent-defined) design characteristics to rate as “Significant” or “Insignificant” with respect to negatively affecting missions. The results of their ratings are summarized in Tables 18 and 19, which are both represented visually in Figures 1 and 2.

Table 18. Responses to Q8 – Complete Valid Surveys

Complete Valid Survey Responses to Q8						
Design Feature	Significant		Insignificant		Response Total	Skipped
Compartment Configurability	37	80.4%	9	19.6%	46	0
Litter System	31	67.4%	15	32.6%	46	0
Compartment Size	31	67.4%	15	32.6%	46	0
Cabin Ergonomics	30	65.2%	16	34.8%	46	0
Patient Loading Capability	29	63.0%	17	37.0%	46	0
Personal Protective Gear (PPG)	28	60.9%	18	39.1%	46	0
Crew Seats	22	47.8%	24	52.2%	46	0
Seat Belts	20	43.5%	26	56.5%	46	0
Windows	20	43.5%	26	56.5%	46	0
Communication System	15	32.6%	31	67.4%	46	0
Environmental Control System	13	28.3%	33	71.7%	46	0
Lighting System	13	28.3%	33	71.7%	46	0
Suction System	12	26.1%	34	73.9%	46	0
Lack of Litter System	12	26.1%	34	73.9%	46	0
Hoist	10	21.7%	36	78.3%	46	0
Oxygen (O ₂) System	8	17.4%	38	82.6%	46	0
Other	6	13.0%	40	87.0%	46	0
Other	2	4.3%	44	95.7%	46	0

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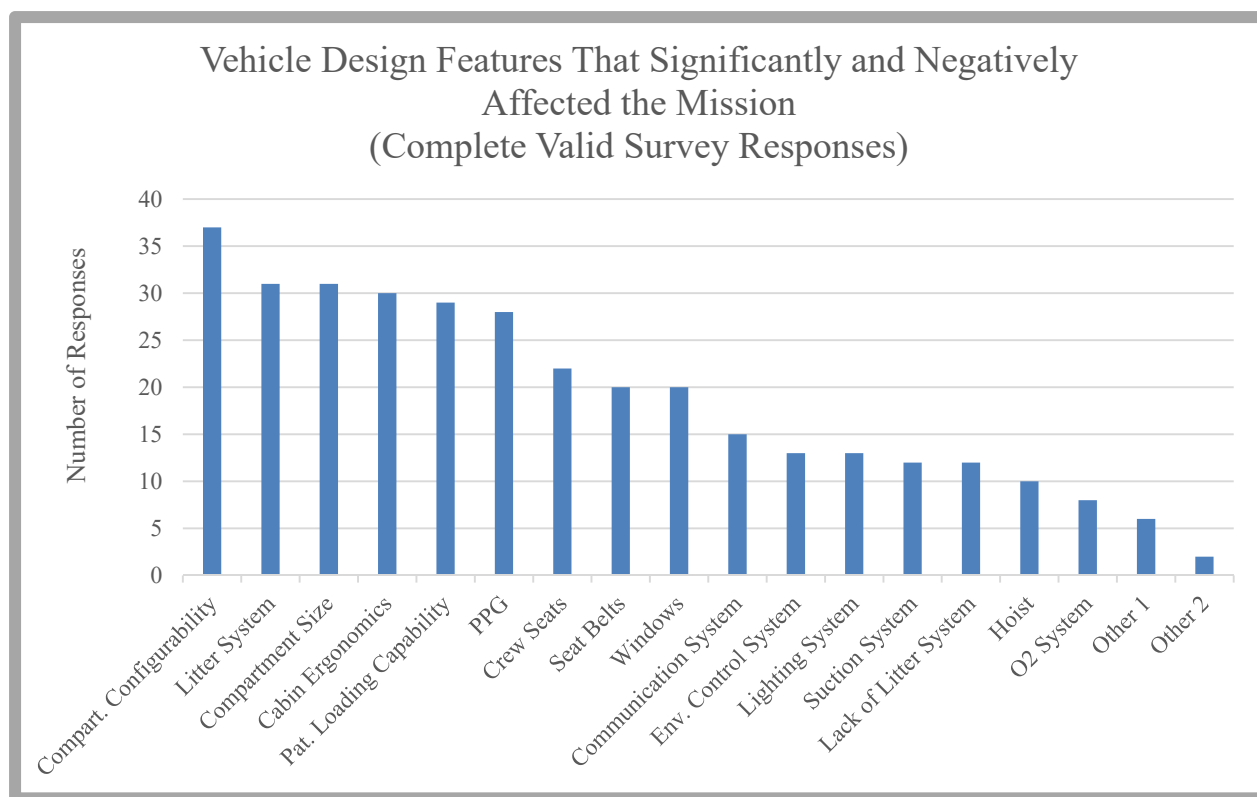


Figure 1. Summary of Table 18.

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Table 19. Responses to Q8 – All Valid Surveys

All Valid Survey Responses to Q8						
Design Feature	Significant		Insignificant		Response Total	Skipped
Compartment Configurability	48	82.8%	10	17.2%	58	2
Litter System	42	72.4%	16	27.6%	58	2
Cabin Ergonomics	41	70.7%	17	29.3%	58	2
Compartment Size	41	70.7%	17	29.3%	58	2
Patient Loading Capability	40	69.0%	18	31.0%	58	2
PPG	36	62.1%	22	37.9%	58	2
Crew Seats	28	48.3%	30	51.7%	58	2
Seat Belts	27	46.6%	31	53.4%	58	2
Windows	26	44.8%	32	55.2%	58	2
Communication System	20	34.5%	38	65.5%	58	2
Lighting System	19	32.8%	39	67.2%	58	2
Hoist	18	31.0%	40	69.0%	58	2
Environmental Control System	17	29.3%	41	70.7%	58	2
Lack of Litter System	17	29.3%	41	70.7%	58	2
Suction System	15	25.9%	43	74.1%	58	2
O ₂ System	12	20.7%	46	79.3%	58	2
Other	9	15.5%	49	84.5%	58	2
Other	2	3.4%	56	96.6%	58	2

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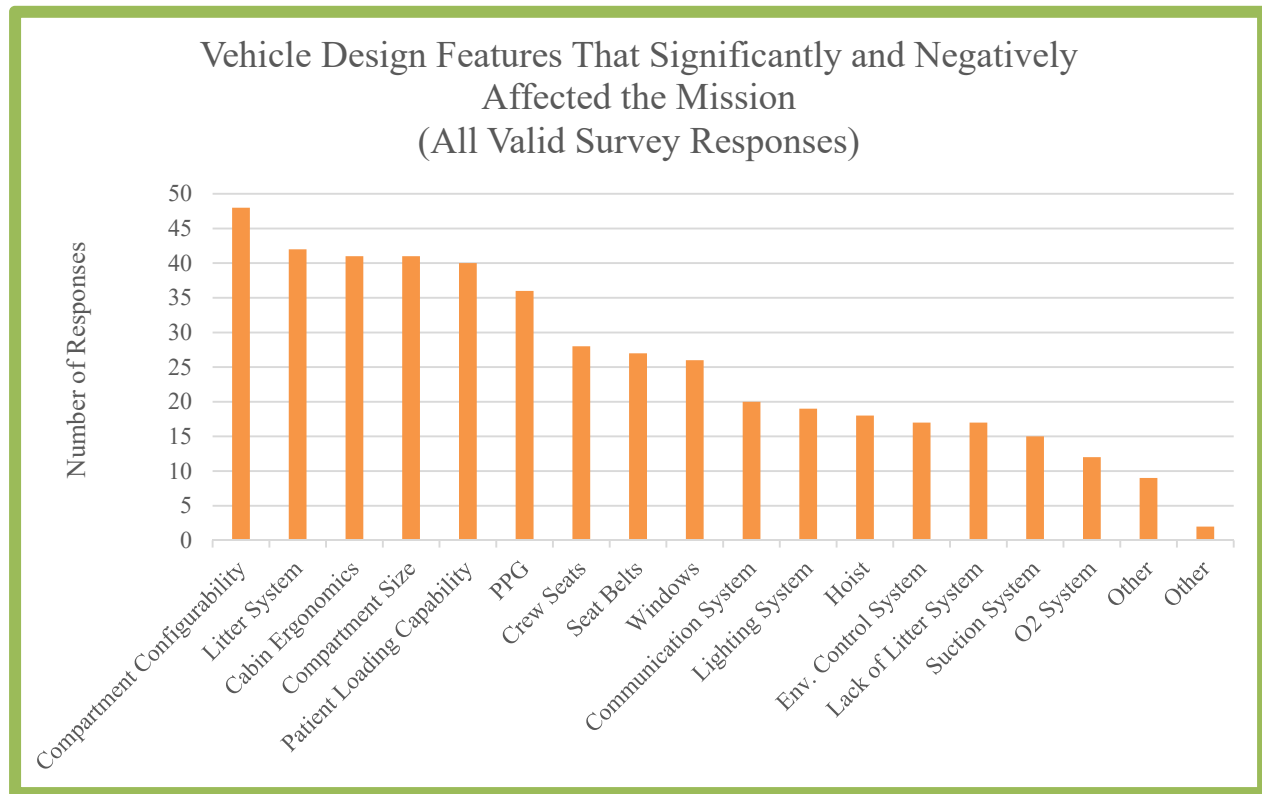


Figure 2. Summary of Table 19.

Every respondent who answered this section answered every question, and so a second analysis that included incomplete valid surveys was performed. Since this question necessitated a dichotomous response (significant or insignificant) it was obvious which respondents with incomplete surveys had answered this section and which ones had not. Out of the 60 valid surveys, 58 respondents answered Q8 and 2 left it blank.

The distribution between complete valid surveys and all valid surveys is nearly identical, except for slight changes in the ranking of “Cabin Ergonomics” and “Compartment Size” on the high end of the graph along with the “Lighting System,” “Hoist,” “Environmental Control System,” and “Suction System” on the lower end. In both graphs, “Compartment Configurability” ranks as the greatest impediment to mission performance, while “Litter System,” “Cabin Ergonomics,” “Compartment Size,” and “Patient Loading Capability” all rank closely behind.

For every platform design feature marked “significant,” the respondent was asked to provide an open-ended response for how the feature negatively impacted the mission. These responses are represented in Figures 3 through 19 for all valid surveys. The number of respondents who found each feature significant is noted in the title of Figures 3 through 19.

Q9. How has patient loading capability negatively impacted you or the mission?

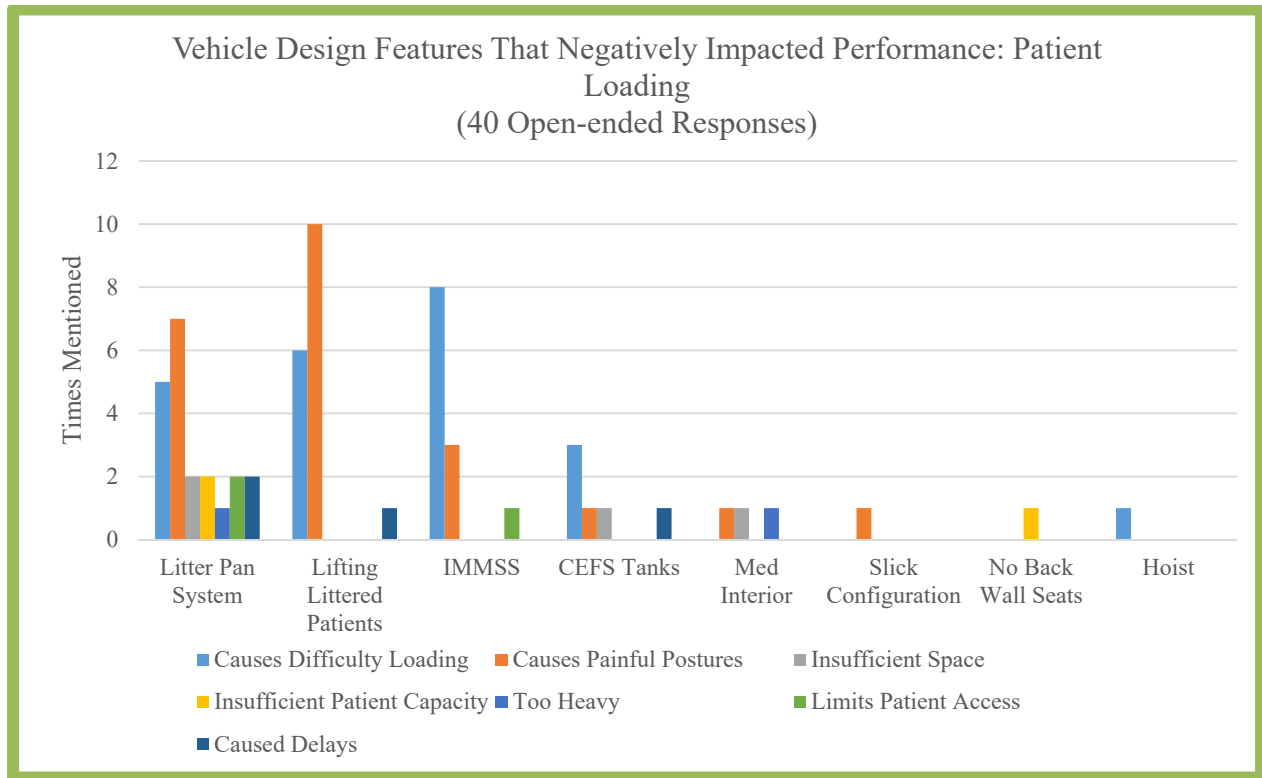


Figure 3. Categorized open-ended responses to Q9.

The most commonly cited issue related to patient loading was the “Litter Pan System,” which was mentioned 21 times by the respondents. Here is a breakdown of the responses to Q9 ranked in order of number of times mentioned from most to least:

- o Litter Pan System – 21 mentions
- o Lifting Littered Patients – 17 mentions
- o Interim Medical Mission Support System (IMMSS) – 12 mentions
- o Crashworthy External Fuel System (CEFS) Tanks – 6 mentions
- o Med Interior – 3 mentions
- o Slick Configuration – 1 mention
- o No Back Wall Seats – 1 mention
- o Hoist – 1 mention

The categories “Causes Difficulty Loading” and “Causes Painful Postures” were the most frequent issues among all Patient Loading features that negatively affected the mission. Respondents indicated the “Litter Pan System” and “Lifting Littered Patients” negatively impacted performance mainly because they caused the respondents to assume painful postures.

The “IMMSS,” “Lifting Littered Patients,” and “Litter Pan System” were all features that significantly contributed to the “Caused Difficulty Loading” category. “Lifting Littered Patients” was the most cited activity that caused painful postures, with the “Litter Pan System” coming in second and the “IMMSS” coming in third.

Q10. How have cabin ergonomics (i.e., crew comfort) negatively affected your mission performance or caused you to perform your mission as a care provider in awkward or painful postures?

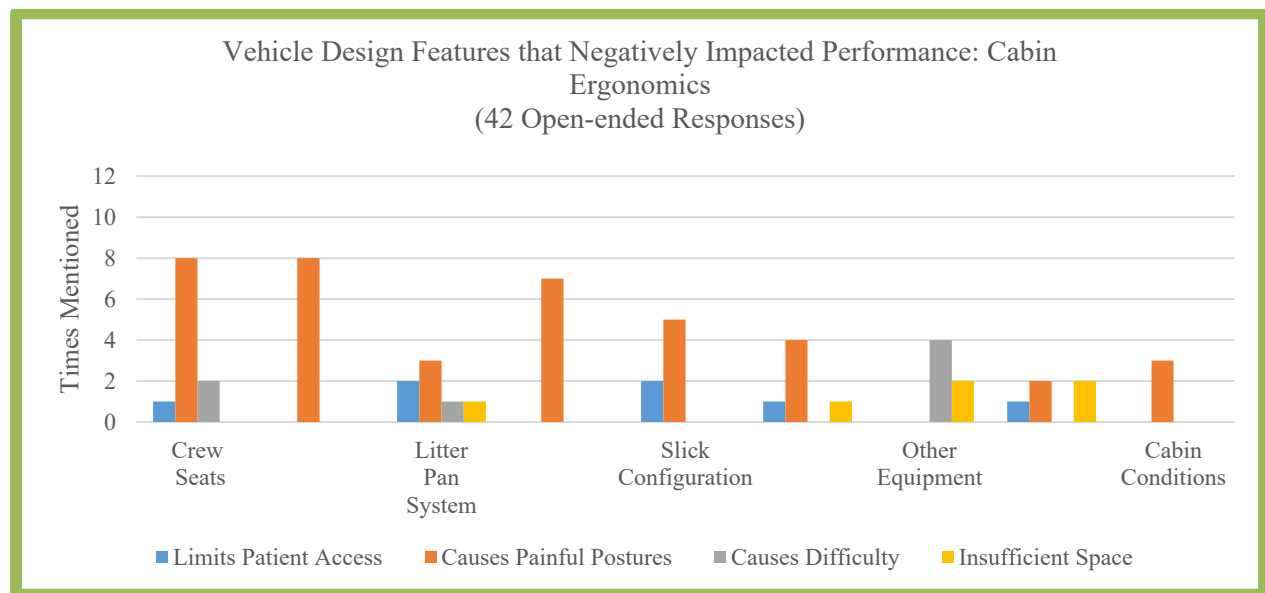


Figure 4. Categorized open-ended responses to Q10.

Overall, the most commonly cited negative feature related to Cabin Ergonomics was the “Crew Seats,” mentioned by 11 respondents. Here is a breakdown of the responses to Q10 ranked in order of number of times mentioned from most to least:

- o Crew Seats – 11 mentions
- o Cabin Height – 8 mentions
- o Litter Pan System – 7 mentions
- o Personal Protective Gear (PPG) – 7 mentions
- o Slick Configuration – 7 mentions
- o Cabin Area – 6 mentions
- o Other Equipment – 6 mentions
- o IMMSS – 5 mentions
- o Cabin Conditions – 3 mentions

The most common issue related to Cabin Ergonomics was “Causes Painful Postures” with “Crew Seats” and “Cabin Height” being the most cited features to cause the painful

postures, both mentioned eight times each. The second most-cited feature to cause painful postures was “PPG,” which was mentioned seven times. The “Slick Configuration,” “Cabin Area,” “Cabin Conditions,” and “Litter Pan System” also were cited, but were lesser issues contributing to painful postures.

Q11. How has cabin/patient compartment configurability negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

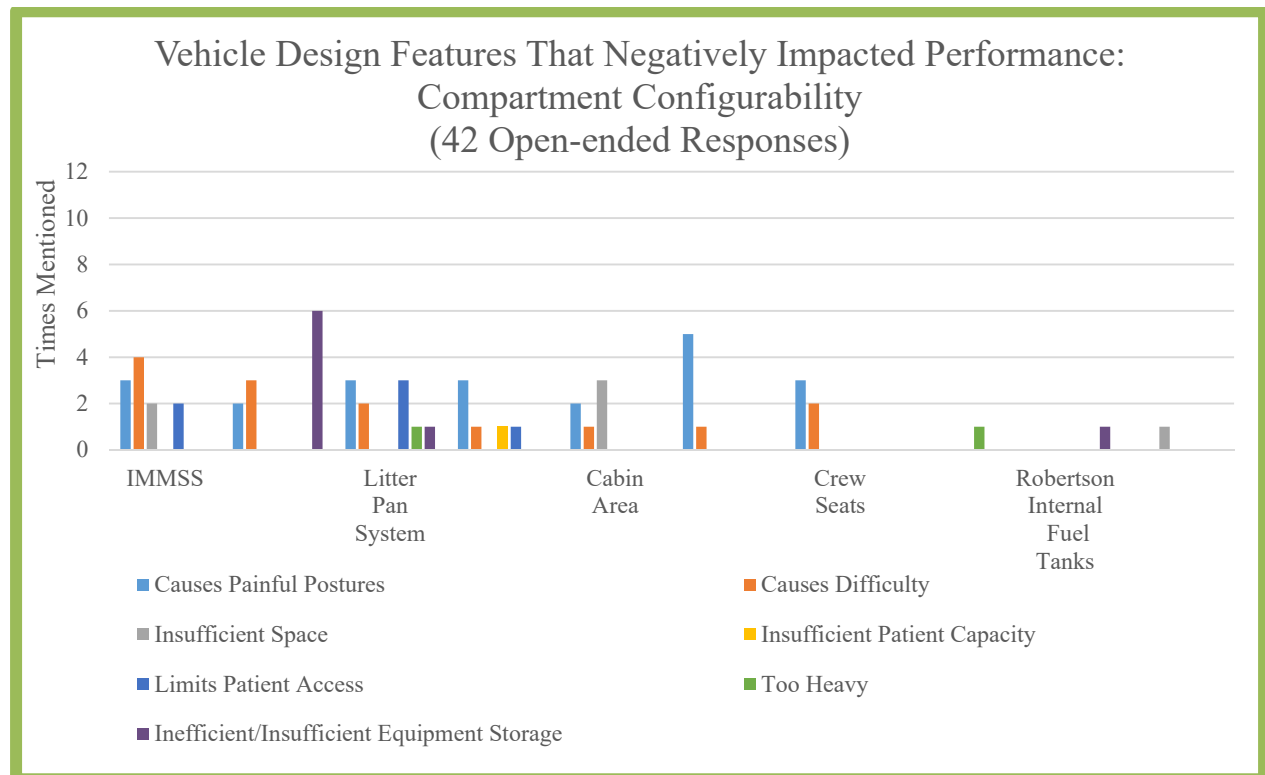


Figure 5. Categorized open-ended responses to Q11.

The features related to Compartment Configurability that were most frequently cited as negatively affecting the mission were the “IMMSS” and “Equipment,” both mentioned 11 times each. Here is a breakdown of the responses to Q11 ranked in order of number of times mentioned from most to least:

- o IMMSS – 11 mentions
- o Equipment – 11 mentions
- o Litter Pan System – 10 mentions
- o Slick Configuration – 6 mentions
- o Cabin Area – 6 mentions
- o Cabin Height – 6 mentions

- o Crew Seats – 5 mentions
- o CEFS Tanks – 1 mention
- o Robertson Internal Fuel Tanks – 1 mention
- o Med Interior – 1 mention

The most common issue related to Compartment Configurability was “Causes Painful Postures,” followed by “Causes Difficulty.” The feature that was mentioned most frequently for causing painful postures was “Cabin Height,” which was mentioned by five respondents. The “IMMSS,” “Litter Pan System,” “Slick Configuration,” “Crew Seats,” “Equipment,” and “Cabin Area” were also mentioned as contributors to painful postures. The feature mentioned most frequently to cause difficulty was the “IMMSS,” which was mentioned by four respondents. However, “Equipment,” “Litter Pan System,” “Crew Seats,” “Slick Configuration,” and “Cabin Area” were also mentioned to cause difficulty.

Q12. How has the hoist negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

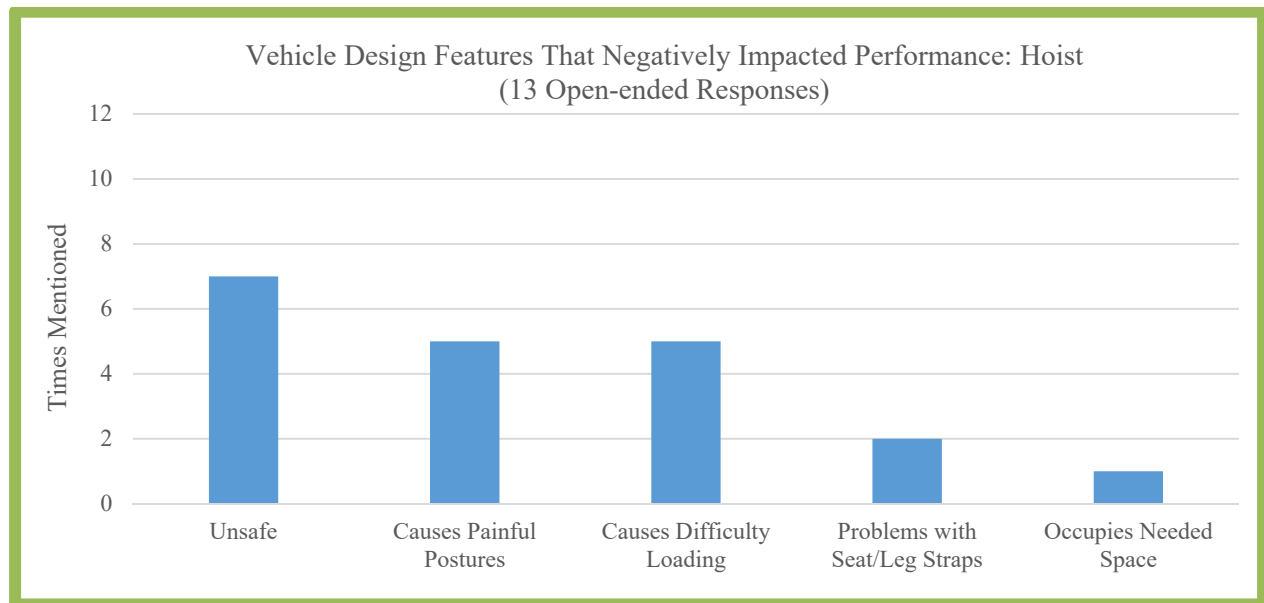


Figure 6. Categorized open-ended responses to Q12.

The most commonly cited issue with the Hoist was that it was “Unsafe” for both the care provider and the patient being lifted (mentioned seven times). Here is a breakdown of the responses to Q12 ranked in order of number of times mentioned from most to least:

- o Unsafe – 7 mentions
- o Causes Painful Postures – 5 mentions
- o Causes Difficulty – 5 mentions

- o Problems with Seat/Leg Straps – 2 mentions
- o Occupies Needed Space – 1 mention

Q13. How has the oxygen system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

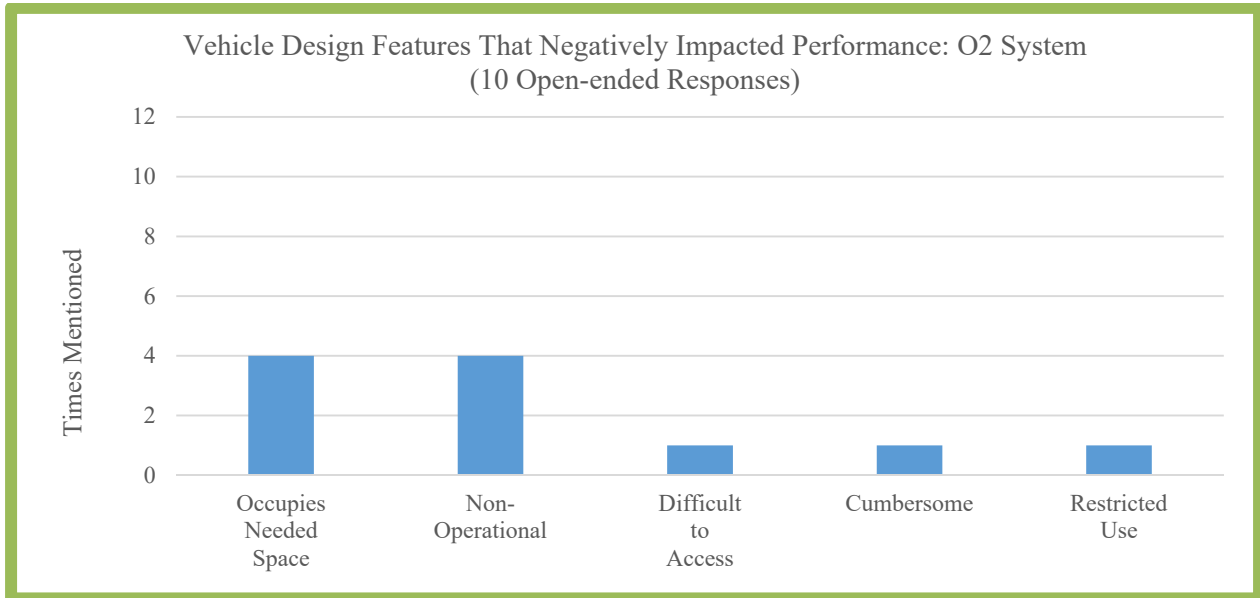


Figure 7. Categorized open-ended responses to Q13.

The O₂ System was the vehicle design feature that had the fewest reported issues (excluding “Other”) among the respondents. The most common issues with the O₂ System were “Occupies Needed Space” and “Non-Operational,” both mentioned four times each. Here is a breakdown of the responses to Q13 ranked in order of number of times mentioned from most to least:

- o Occupies Needed Space – 4 mentions
- o Non-Operational – 4 mentions
- o Difficult to Access – 1 mention
- o Cumbersome – 1 mention
- o Restricted Use – 1 mention

It was specifically stated that the “Restricted Use” system was the On-Board Oxygen Generation System (OBOGS).

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Q14. How has the environmental control system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

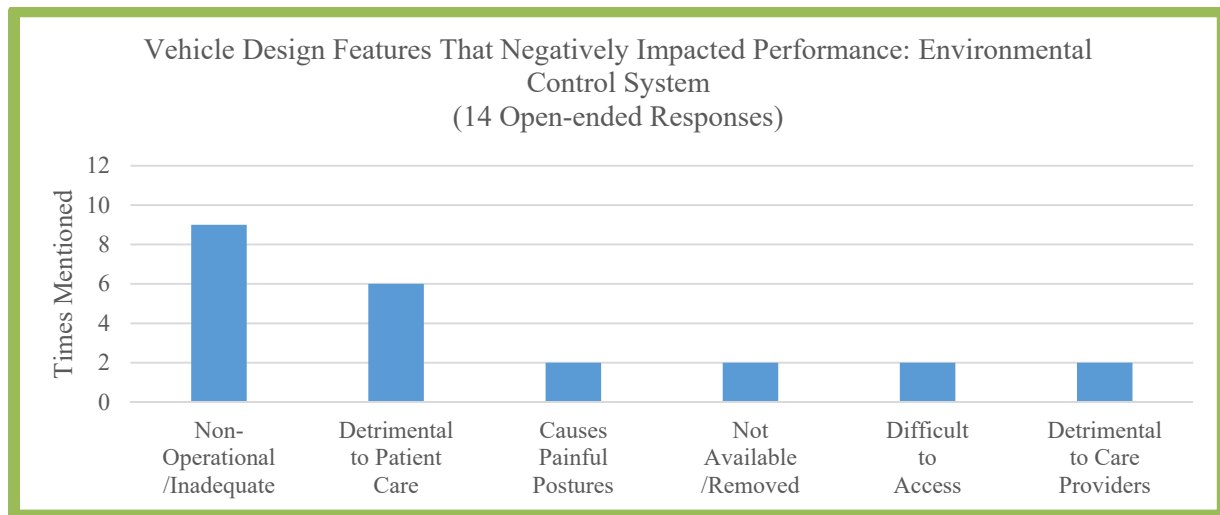


Figure 8. Categorized open-ended responses to Q14.

The most commonly cited issue with the Environmental Control System was that the system was “Non-Operational/Inadequate,” which was mentioned nine times. Here is a breakdown of the responses to Q14 ranked in order of number of times mentioned from most to least:

- o Non-Operational/Inadequate – 9 mentions
- o Detrimental to Patient Care – 6 mentions
- o Causes Painful Postures – 2 mentions
- o Not Available/Removed – 2 mentions
- o Difficult to Access – 2 mentions

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Q15. How has the suction system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

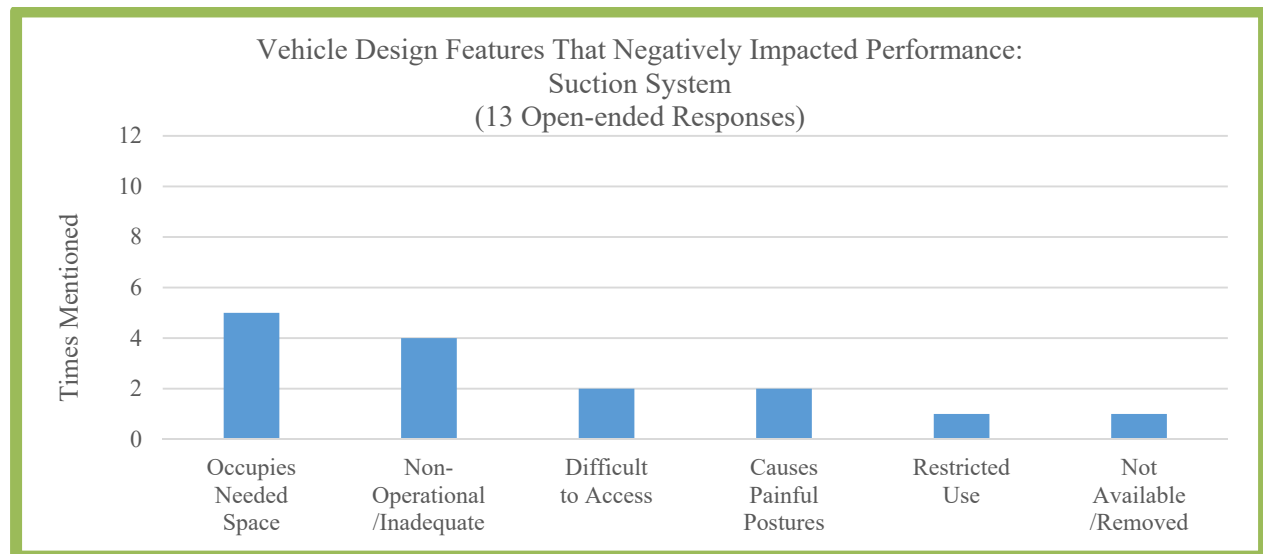


Figure 9. Categorized open-ended responses to Q15.

The most commonly cited issue with the Suction System was that it “Occupies Needed Space” due to its size (mentioned five times). Here is a breakdown of the responses to Q15 ranked in order of number of times mentioned from most to least:

- o Occupies Needed Space – 5 mentions
- o Non-Operational/Inadequate – 4 mentions
- o Difficult to Access – 2 mentions
- o Causes Painful Postures – 2 mentions
- o Restricted Use – 1 mention
- o Not Available/Removed – 1 mention

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Q16. How has the lighting system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

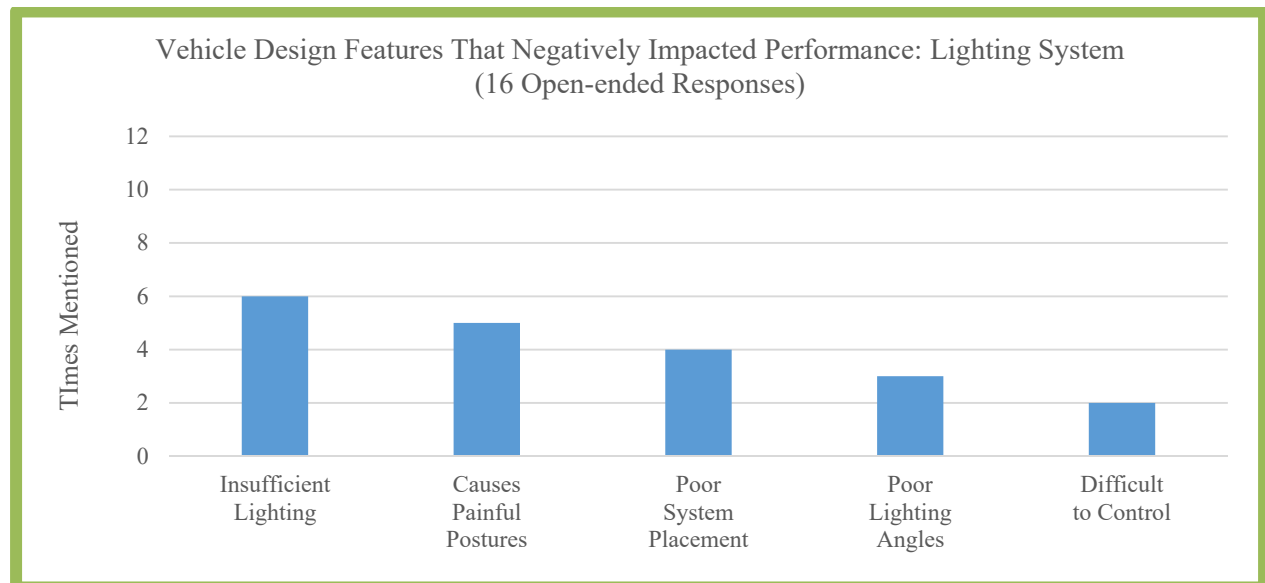


Figure 10. Categorized open-ended responses to Q16.

The most commonly cited issue with the Lighting System was “Insufficient Lighting” (mentioned six times). Here is a breakdown of the responses to Q16 ranked in order of number of times mentioned from most to least:

- Insufficient Lighting – 6 mentions
- Causes Painful Postures – 5 mentions
- Poor System Placement – 4 mentions
- Poor Lighting Angles – 3 mentions
- Difficult to Control – 2 mentions

Note that the “Poor System Placement” issue was specifically cited as resulting in helmet collisions.

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Q17. How have the seatbelts negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

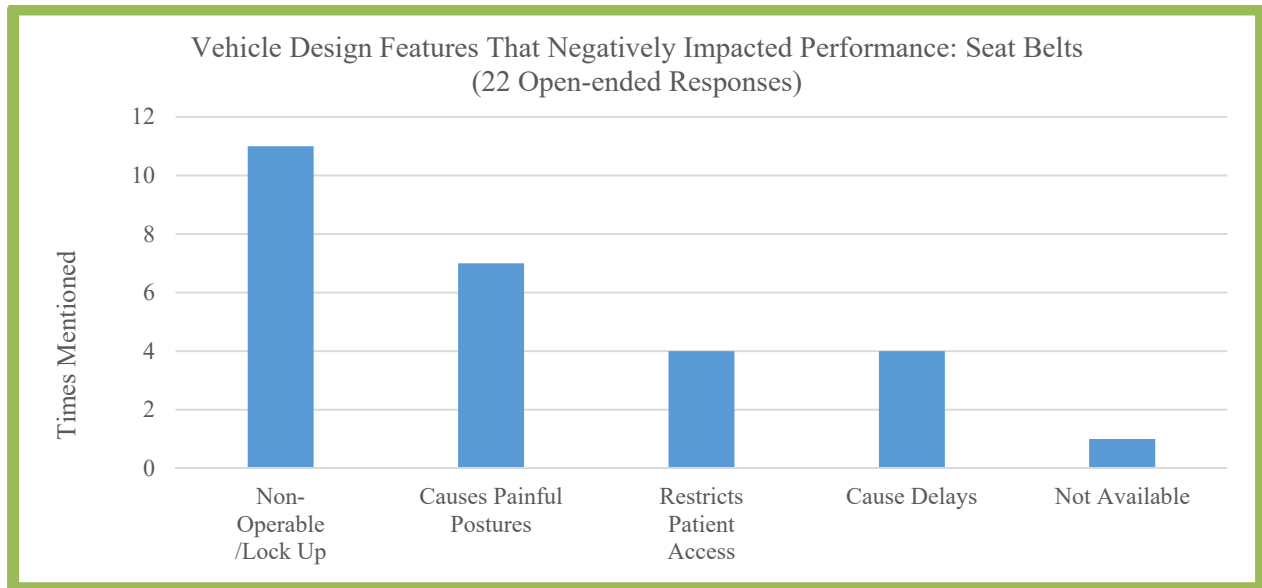


Figure 11. Categorized open-ended responses to Q17.

The most commonly cited issue with the Seat Belts was “Non-Operable/Lock Up” meaning the belts often got stuck, came loose, or were difficult to secure, which were mentioned 11 times. Here is a breakdown of the responses to Q17 ranked in order of number of times mentioned from most to least:

- o Non-Operable/Lock Up – 11 mentions
- o Causes Painful Postures – 7 mentions
- o Restricts Patient Access – 4 mentions
- o Cause Delays – 4 mentions
- o Not Available – 1 mention

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Q18. How has the litter system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

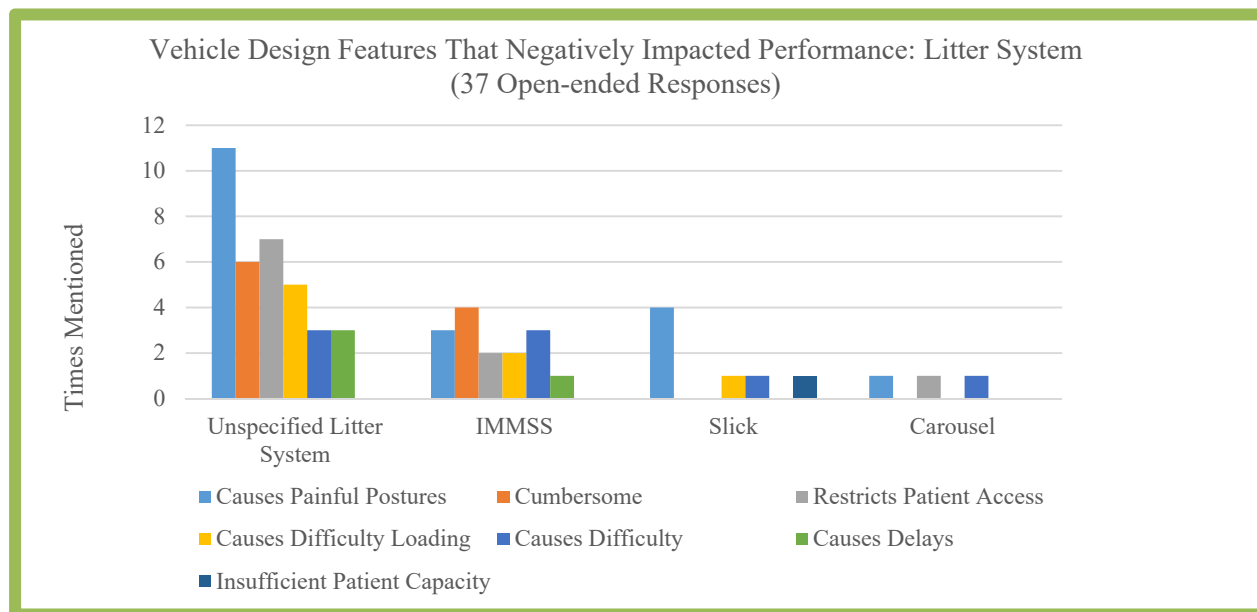


Figure 12. Categorized open-ended responses to Q18.

The type of Litter System that was most commonly cited as being problematic was the “Unspecified Litter System,” which was mentioned 35 times. Here is a breakdown of the responses to Q18 ranked in order of number of times mentioned from most to least:

- o Unspecified Litter System – 35 mentions
- o IMMSS – 15 mentions
- o Slick – 7 mentions
- o Carousel – 3 mentions

The most commonly mentioned issue across all four types of Litter Systems was that the systems caused painful postures. “Unspecified Litter Systems” were mentioned most often in this specific category (11 mentions), along with the “Slick” configuration (4 mentions), “IMMSS” (3 mentions), and “Carousel” (1 mention).

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Q19. How has the lack of a litter system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

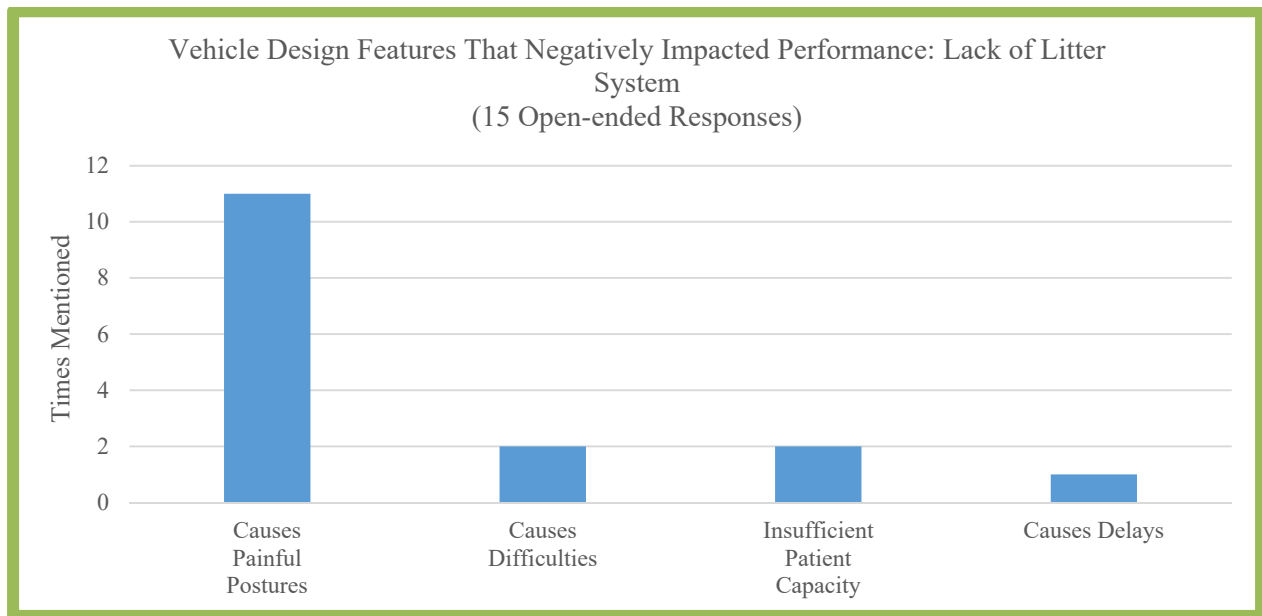


Figure 13. Categorized open-ended responses to Q19.

The most commonly cited issue with the Lack of Litter System was “Causes Painful Postures,” mentioned 11 times. Respondents specifically stated that it caused the care provider to assume painful postures when loading or providing care to the patients. Here is a breakdown of the responses to Q19 ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 11 mentions
- o Causes Difficulty – 2 mentions
- o Insufficient Patient Capacity – 2 mentions
- o Causes Delays – 1 mention

Respondents stated that the lack of a litter system caused difficulty for the care providers when strapping down multiple patients and with the equipment being on the floor.

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Q20. How has the cabin/patient compartment size (dimensions-length, width, height) negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

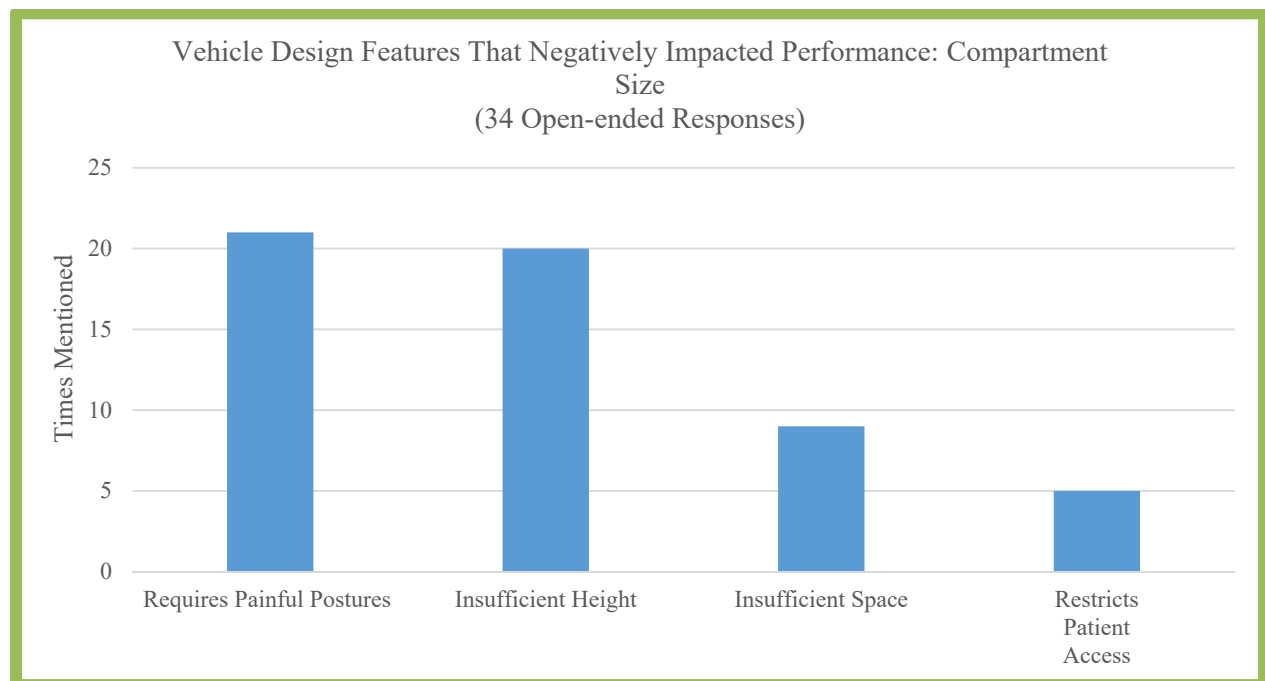


Figure 14. Categorized open-ended responses to Q20.

The most common issue with the Compartment Size was “Requires Painful Postures,” mentioned 21 times. This was often coupled with the “Insufficient Height,” which was mentioned 20 times. Here is a breakdown of the responses to Q20 ranked in order of number of times mentioned from most to least:

- o Requires Painful Postures – 21 mentions
- o Insufficient Height – 20 mentions
- o Insufficient Space – 9 mentions
- o Restricts Patient Access – 5 mentions

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Q21. How have the windows negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

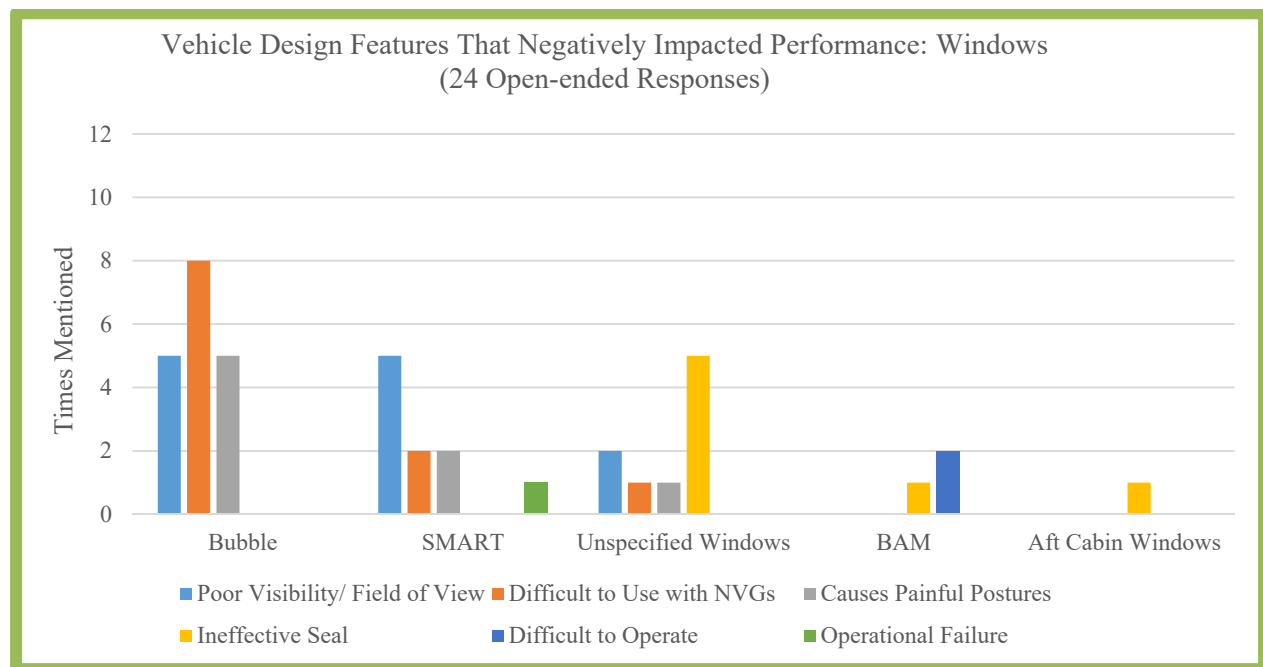


Figure 15. Categorized open-ended responses to Q21.

The type of Windows that most frequently caused issues for care providers were the “Bubble” windows, mentioned 18 times. Here is a breakdown of the responses to Q21 ranked in order of number of times mentioned from most to least:

- o Bubble – 18 mentions
- o SMART – 10 mentions
- o Unspecified Windows – 9 mentions
- o Black Hawk Advanced MEDEVAC (BAM) – 3 mentions
- o Aft Cabin Windows – 1 mention

The most commonly cited issue with all types of windows was “Poor Visibility/Field of View” (mentioned 12 times). The “Bubble” windows and “SMART” windows were the most mentioned when referring to visibility issues (mentioned five times), and the “Unspecified Windows” also contributed to this category (mentioned two times). The “BAM” windows and “Aft Cabin Windows” did not have any reported issues of visibility. The next-most common issue with the windows was that they were difficult to use with night vision goggles (NVGs) (mentioned 11 times). The “Bubble” window was the hardest to use with NVGs (mentioned eight times), while the “SMART” windows also were problematic in this area (mentioned two times), along with “Unspecified Windows” as well (mentioned once). Some common issues

related to using the windows with NVGs were that the field of view became distorted, or the goggles would collide with the windows and prevent the appropriate clearing of the aircraft.

Q22. How have the crew seats negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

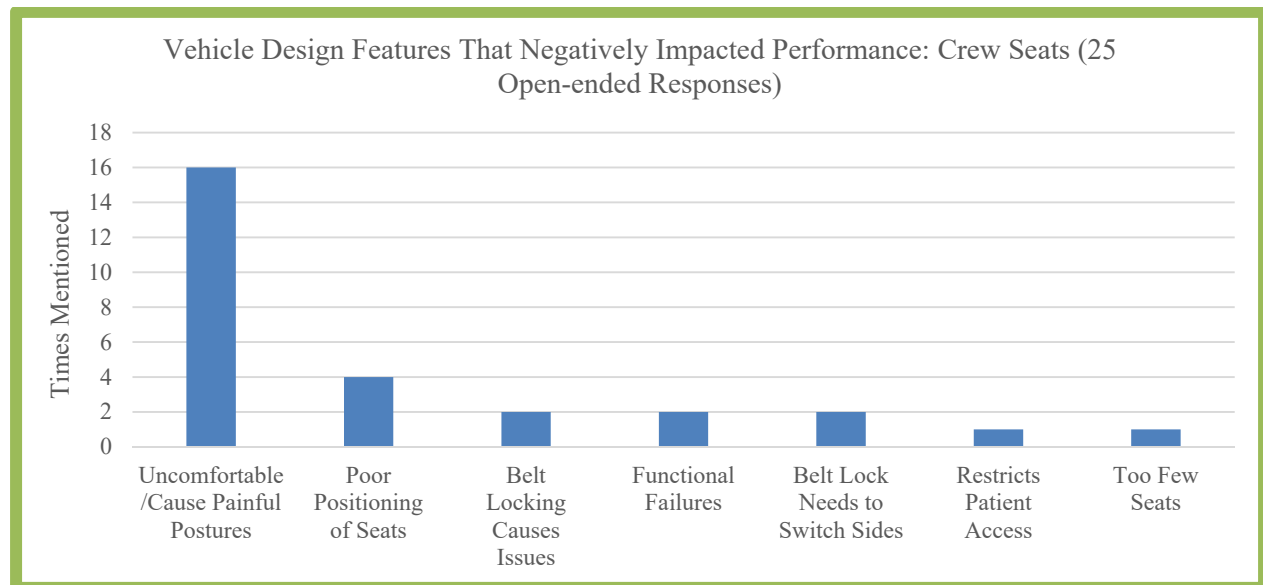


Figure 16. Categorized open-ended responses to Q22.

The most commonly cited issue with the crew seats was “Uncomfortable/Cause Painful Postures (mentioned 16 times). Here is a breakdown of the responses to Q22 ranked in order of number of times mentioned from most to least:

- o Uncomfortable/Cause Painful Postures – 16 mentions
- o Poor Positioning of Seats – 4 mentions
- o Belt Locking Causes Issues – 2 mentions
- o Functional Failures – 2 mentions
- o Belt Lock Needs to Switch Sides – 2 mentions
- o Restricts Patient Access – 1 mention
- o Too Few Seats – 1 mention

The respondents often cited the seats as causing them to sit hunched forward, which resulted in back pain. The seat stiffness was specifically cited as causing discomfort.

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Q23. How has the communication system negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

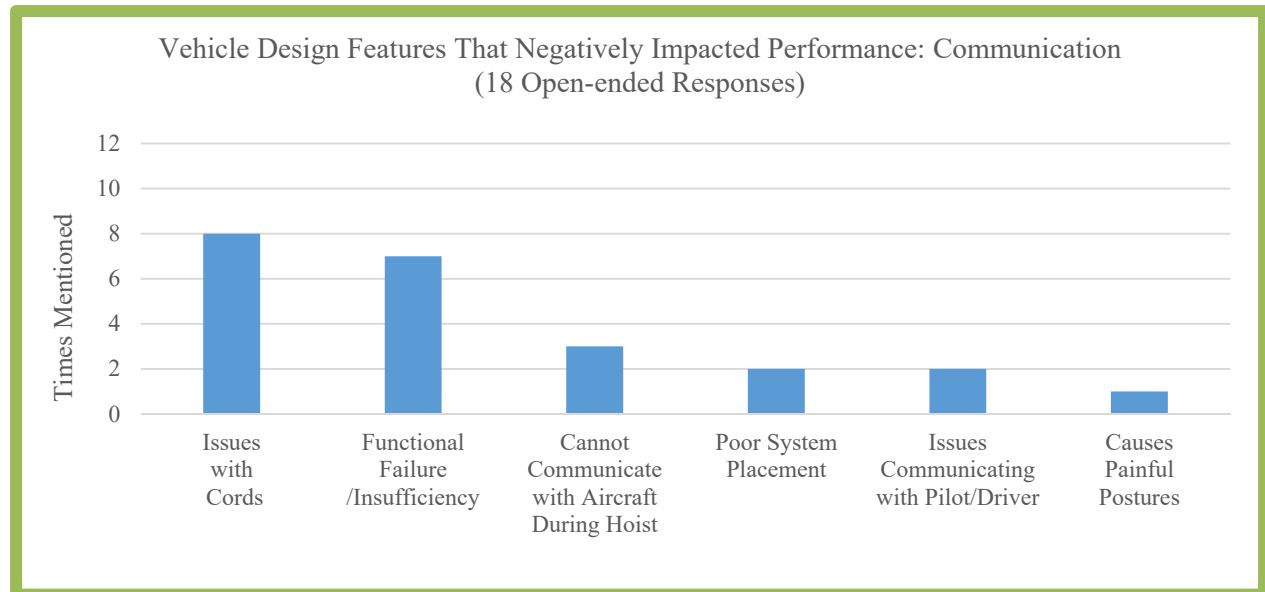


Figure 17. Categorized open-ended responses to Q23.

The most commonly cited issue with the communication system was Issues with Cords (mentioned eight times). The integrated communication system (ICS) cords were reported to often tangle and make maneuvering about the cabin difficult. Note that many respondents expressed a desire to change to a wireless mode of communication. Here is a breakdown of the responses to Q23 ranked in order of number of times mentioned from most to least:

- o Issues with Cords – 8 mentions
- o Functional Failure/Insufficiency – 7 mentions
- o Cannot Communicate with Aircraft During Hoist – 3 mentions
- o Poor System Placement – 2 mentions
- o Issues Communicating with Pilot/Driver – 2 mentions
- o Causes Painful Postures – 1 mention

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Q24. How has the personal protective gear (body armor/helmet) negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture?

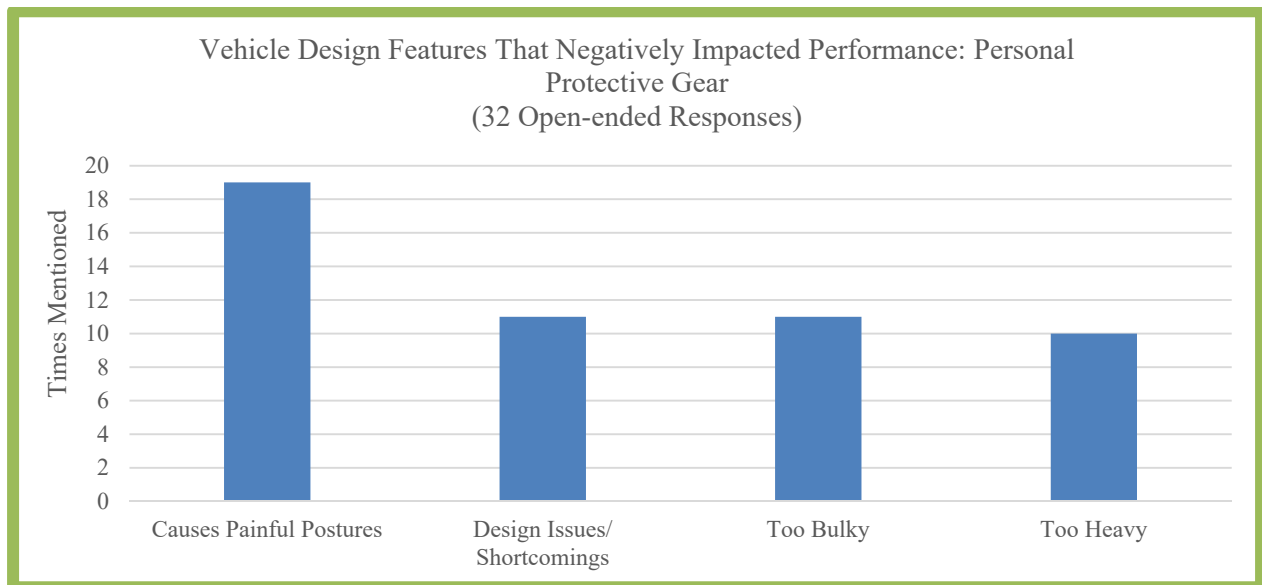


Figure 18. Categorized open-ended responses to Q24.

The most commonly cited issue with PPG was “Causes Painful Postures,” which was mentioned 19 times. Here is a breakdown of the responses to Q24 ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 19 mentions
- o Design Issues/Shortcomings – 11 mentions
- o Too Bulky – 11 mentions
- o Too Heavy – 10 mentions

The PPG was most often said to cause neck and back strain due to the distribution of weight in the body armor. The design issues were said to be the lack of ballistic protection offered by the helmets.

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Q25. You selected “Other” as a choice. Please tell what has negatively affected your mission performance or caused you to perform your mission as a care provider in an awkward or painful posture and what those impacts were?

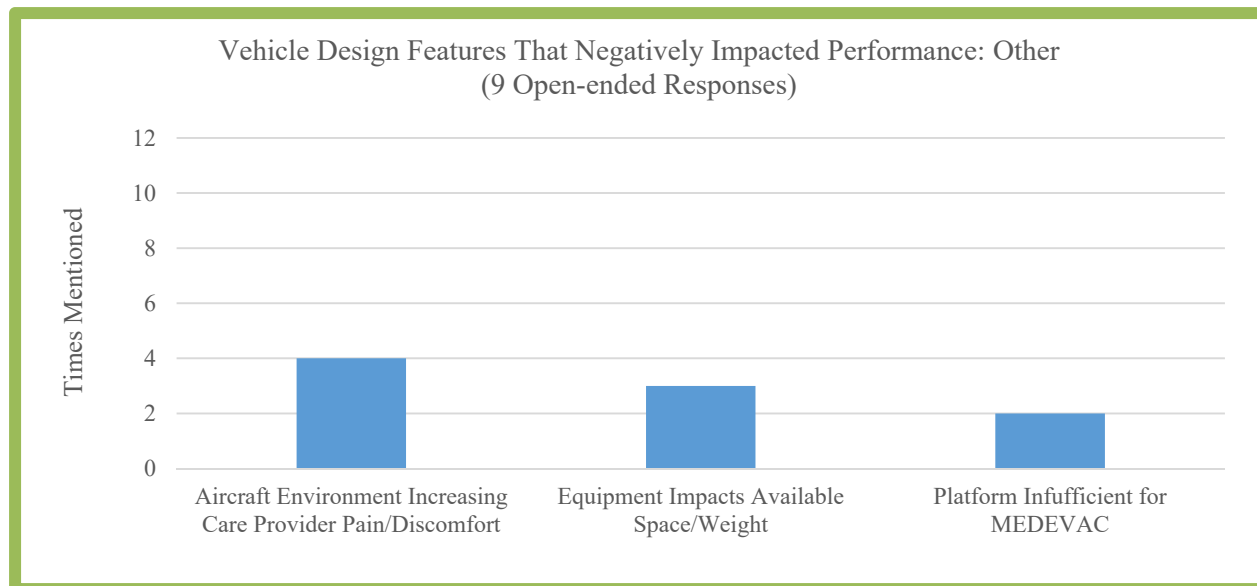


Figure 19. Categorized open-ended responses to Q25.

The most commonly cited issue in the “Other” category was “Aircraft Environment Increasing Care Provider Pain/Discomfort,” mentioned four times. The responses were most often related to remaining in one position for an extended period of time as necessitated by the platform arrangement as well as the vibration of the environment. Here is a breakdown of the responses to Q25 ranked in order of number of times mentioned from most to least:

- Aircraft Environment Increasing Care Provider Pain/Discomfort – 4 mentions
- Equipment Impacts Available Space/Weight – 3 mentions
- Platform Insufficient for MEDEVAC – 2 mentions

The responses in the last category pertained to the UH-60L and the HH-60M. The complaint for the UH-60L was that there was not enough room for proper patient treatment, and the complaint for the HH-60M was that the platform could either be for casualty evacuation and have the medical interior on both sides of the cabin, or be for MEDEVAC and only have the medical interior on one side.

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Section 3: Equipment that Caused Awkward/Painful Postures

Q26. Did any of the following items in the current Aeromedical or Ground Evacuation Medical Equipment Sets cause you to use an awkward or painful posture?

After being asked Q26, respondents were presented with 20 specific and 2 optional “Other” pieces of equipment to indicate whether or not they caused awkward/painful postures by responding “yes” or “no.” Table 20 and Figure 20 show the responses given in the complete valid surveys. Table 21 and Figure 21 show the responses given in all valid surveys (complete and incomplete valid surveys).

Table 20. Responses to Q26 – Complete Valid Surveys

Complete Valid Survey Responses to Q26				
Equipment Description	Number of Yes Responses	Number of No Responses	Response Total	Skipped
Litter	14	32	46	0
Monitor	10	36	46	0
Defibrillator	9	37	46	0
Sked® Basic Rescue System (BRS)	9	37	46	0
Special Medical Emergency Evacuation Device (SMEED)	8	38	46	0
Oxygen Bottle with Regulator	8	38	46	0
Trauma Panel	8	38	46	0
Traction Splint	7	39	46	0
Intravenous (IV) Pump	6	40	46	0
Suction	6	40	46	0
Medical Aid Bag	6	40	46	0
Ventilator	5	41	46	0
Medicine (Med.) Box	5	41	46	0
Fluid Warmer	5	41	46	0
Spine Board	5	41	46	0
Litter Straps	5	41	46	0
EZ Intraosseus (I.O.) Kit	1	45	46	0
Other	1	45	46	0
Spine Splint	0	46	46	0
Thermometer	0	46	46	0
Glucometer	0	46	46	0
Other	0	46	46	0

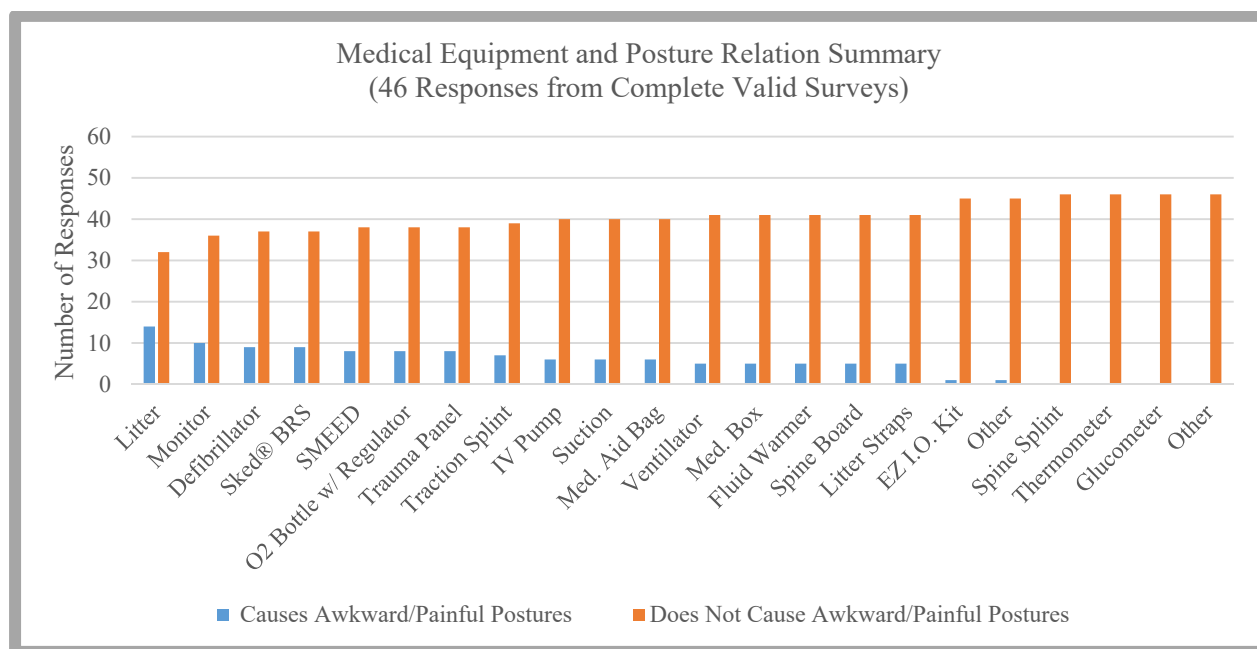


Figure 20. Summary of Table 20.

In general, the medical equipment did not significantly contribute to painful postures expected during MEDEVAC scenarios. The piece of equipment that caused awkward or painful postures most often was the litter, marked by 14 respondents.

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Table 21. Responses to Q26 – All Valid Surveys

All Valid Survey Responses to Q26				
Equipment Description	Number of Yes Responses	Number of No Responses	Response Total	Skipped
Litter	16	36	52	8
Monitor	12	40	52	8
Defibrillator	11	41	52	8
Oxygen Bottle with Regulator	10	42	52	8
Trauma Panel	10	42	52	8
Sked [®] BRS	10	42	52	8
IV Pump	8	44	52	8
Suction	8	44	52	8
SMEED	8	44	52	8
Ventilator	7	45	52	8
Traction Splint	7	45	52	8
Med. Aid Bag	6	46	52	8
Med. Box	6	46	52	8
Spine Board	6	46	52	8
Litter Straps	6	46	52	8
Fluid Warmer	5	47	52	8
EZ I.O. Kit	1	51	52	8
Spine Splint	1	51	52	8
Other	1	51	52	8
Thermometer	0	52	52	8
Glucometer	0	52	52	8
Other	0	52	52	8

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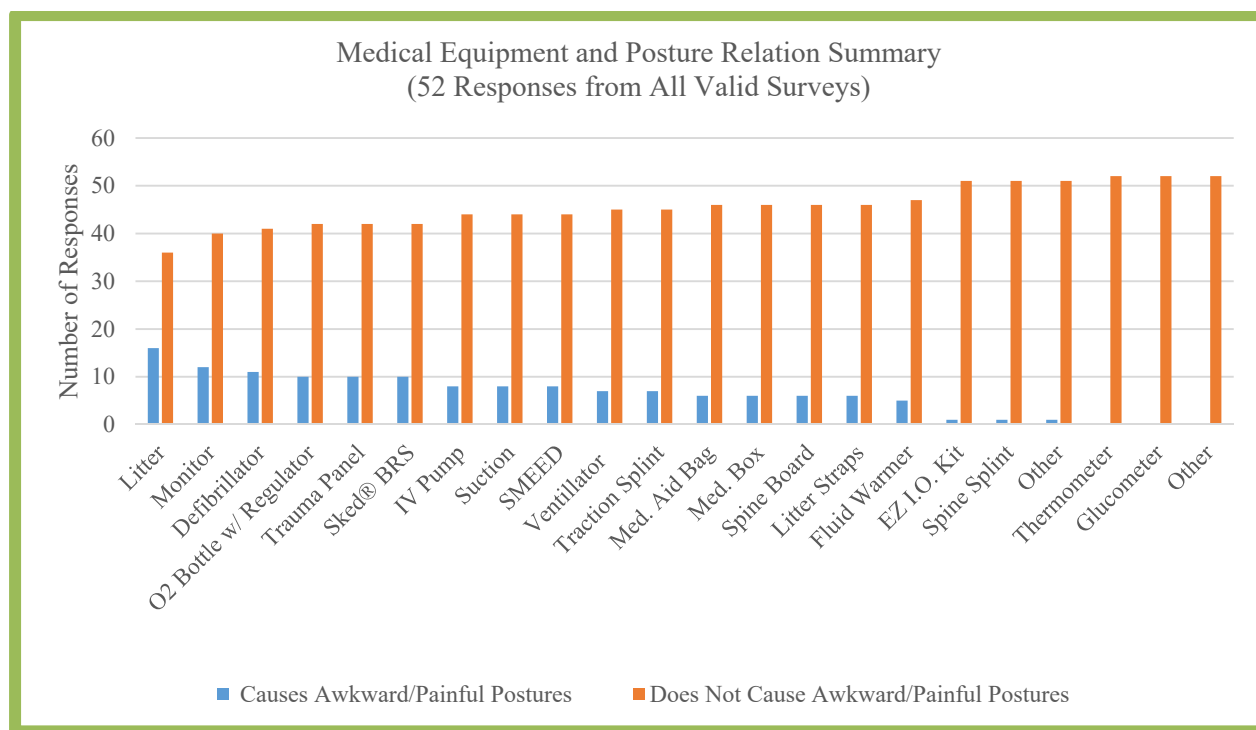


Figure 21. Summary of Table 21.

Just as in the analysis of the complete valid surveys, the litter was again the most marked piece of equipment as causing painful postures in all valid surveys, as marked by 16 respondents.

A second analysis was performed on the responses to Q26 which included all valid surveys because respondents who completed this section answered every question in the section, whether their survey was complete or not.

If a respondent marked a piece of equipment as causing awkward/painful postures, they were then asked to provide an open-ended response describing how the equipment caused the posture. The categorized responses to those questions are shown in Figures 22 through 38. Since the responses more often expressed general issues with the piece of equipment rather than how it caused awkward postures, the graphs categorize how the equipment negatively affected the mission, rather than how it caused awkward/painful postures. The open-ended responses of all valid surveys were analyzed for Figures 22 through 39, and the number of respondents that found each piece of equipment significant and provided an open ended response can be found in the figure titles.

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Q27. How did the use of [piece of equipment] cause you to use an awkward or painful posture?

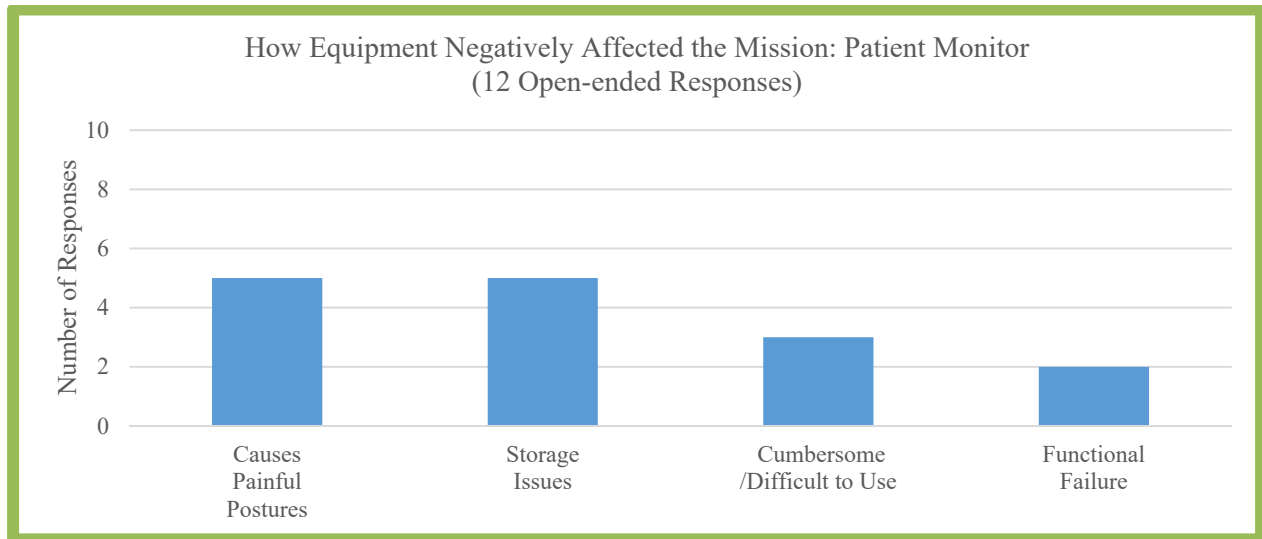


Figure 22. Categorized open-ended responses to Q27 for patient monitors.

The most common issues with the patient monitor were that it caused painful postures and was difficult to store properly. Here is a breakdown of the responses to Q27 for patient monitors ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 5 mentions
- o Storage Issues – 5 mentions
- o Cumbersome/Difficult to Use – 3 mentions
- o Functional Failure – 2 mentions

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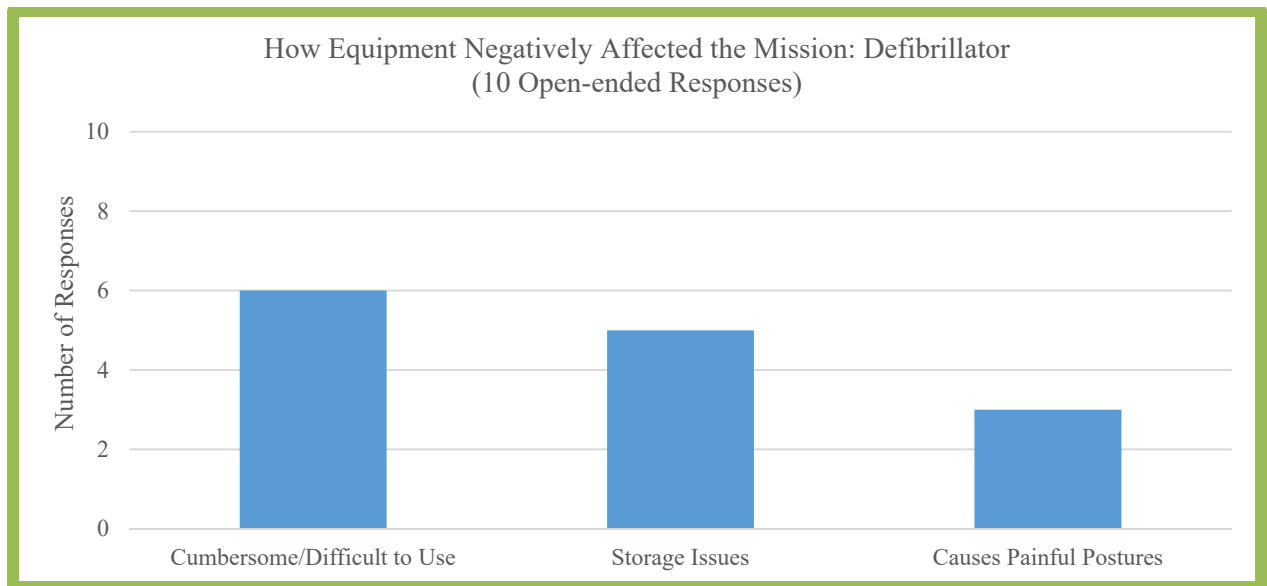


Figure 23. Categorized open-ended responses to Q27 for defibrillators.

The most commonly cited issue with the defibrillator was that it was cumbersome or difficult to use. Here is a breakdown of the responses to Q27 for defibrillators ranked in order of number of times mentioned from most to least:

- o Cumbersome/Difficult to Use – 6 mentions
- o Storage Issues – 5 mentions
- o Causes Painful Postures – 3 mentions

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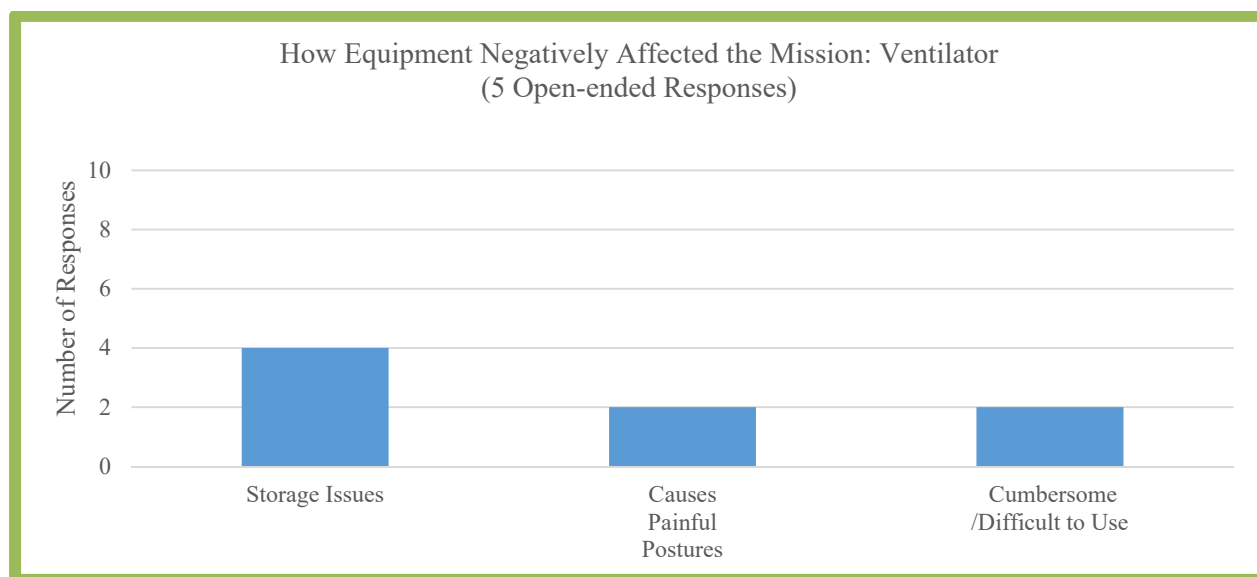


Figure 24. Categorized open-ended responses to Q27 for ventilators.

The most commonly cited issue with the ventilator was “Storage Issues.” Here is a breakdown of the responses to Q27 for ventilators ranked in order of number of times mentioned from most to least:

- o Storage Issues – 4 mentions
- o Causes Painful Postures – 2 mentions
- o Cumbersome/Difficult to Use – 2 mentions

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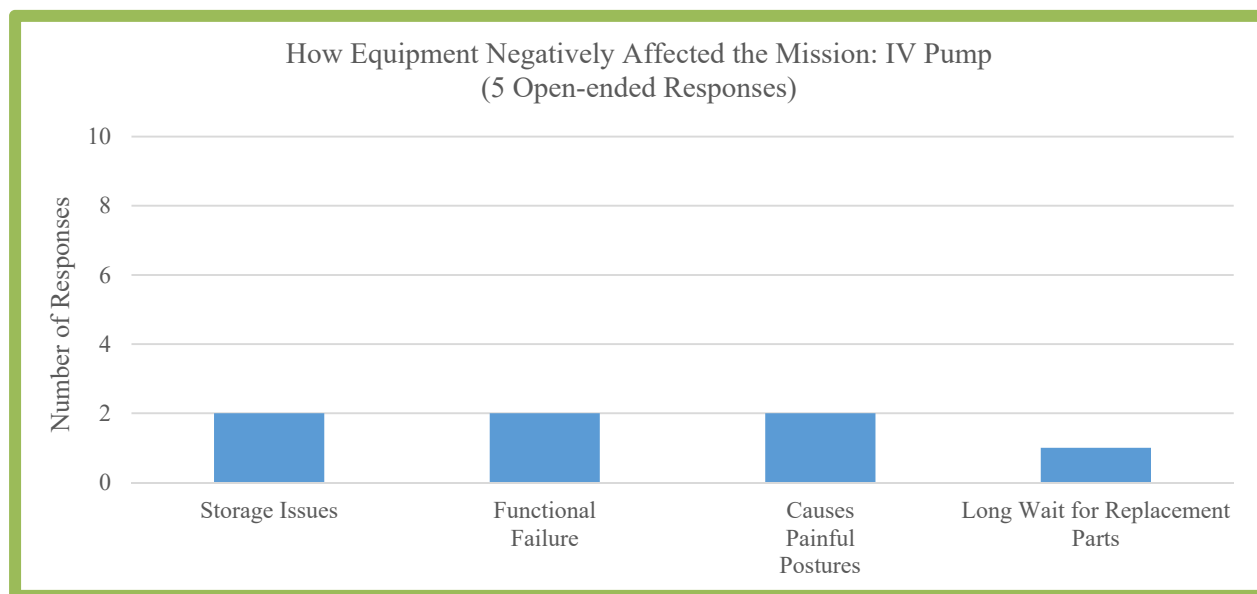


Figure 25. Categorized open-ended responses to Q27 for IV pumps.

The most commonly cited issues with the IV pump were “Storage Issues,” “Functional Failure,” and “Causes Painful Postures.” Here is a breakdown of the responses to Q27 for IV pumps ranked in order of number of times mentioned from most to least:

- o Storage Issues – 2 mentions
- o Functional Failure – 2 mentions
- o Causes Painful Postures – 2 mentions
- o Long Wait for Replacement Parts – 1 mention

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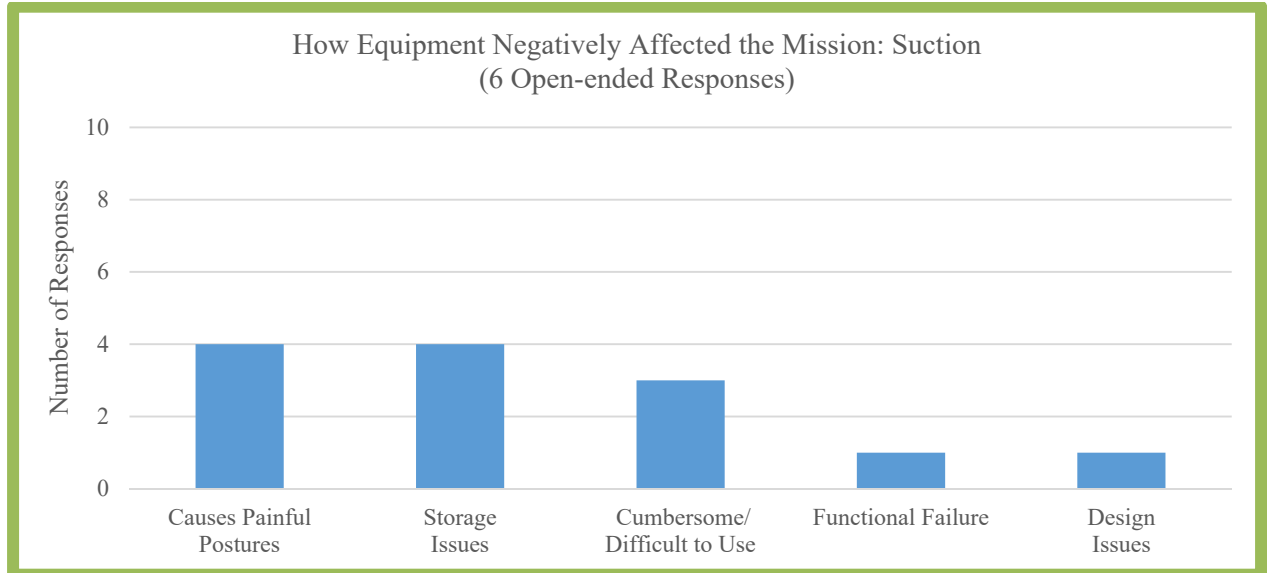


Figure 26. Categorized open-ended responses to Q27 for suction.

The most commonly cited issues with the suction system were “Causes Painful Postures” and “Storage Issues.” Here is a breakdown of the responses to Q27 for suction ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 4 mentions
- o Storage Issues – 4 mentions
- o Cumbersome/Difficult to Use – 3 mentions
- o Functional Failure – 1 mention
- o Design Issues – 1 mention

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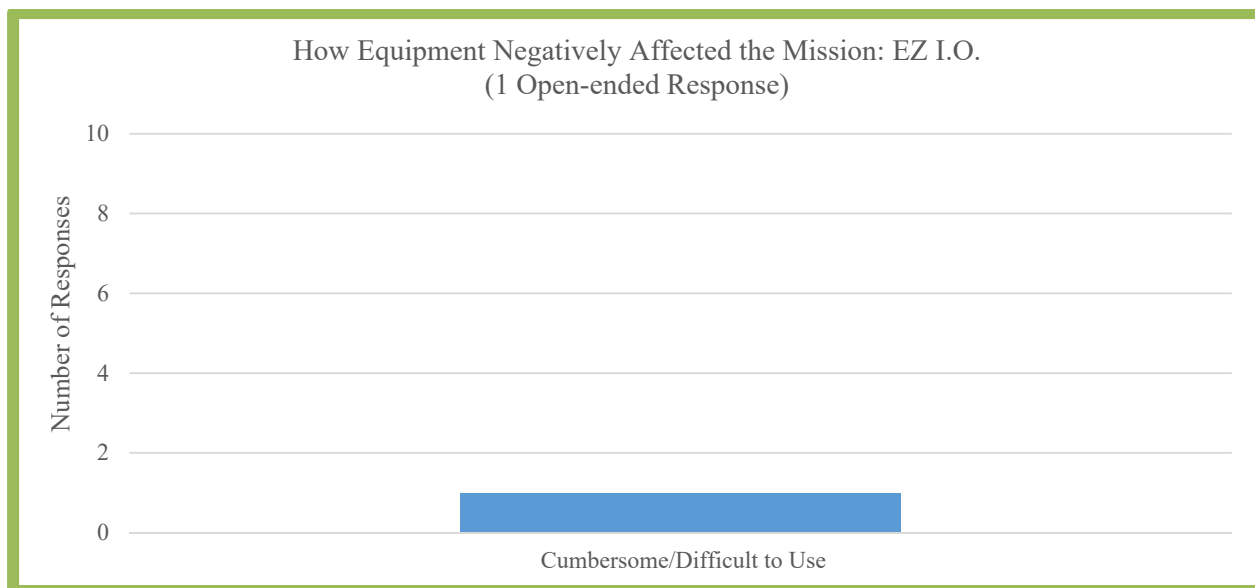


Figure 27. Categorized open-ended responses to Q27 for EZ I.O.

The only issue cited with the EZ I.O. was that it was cumbersome or difficult to use, mentioned one time.

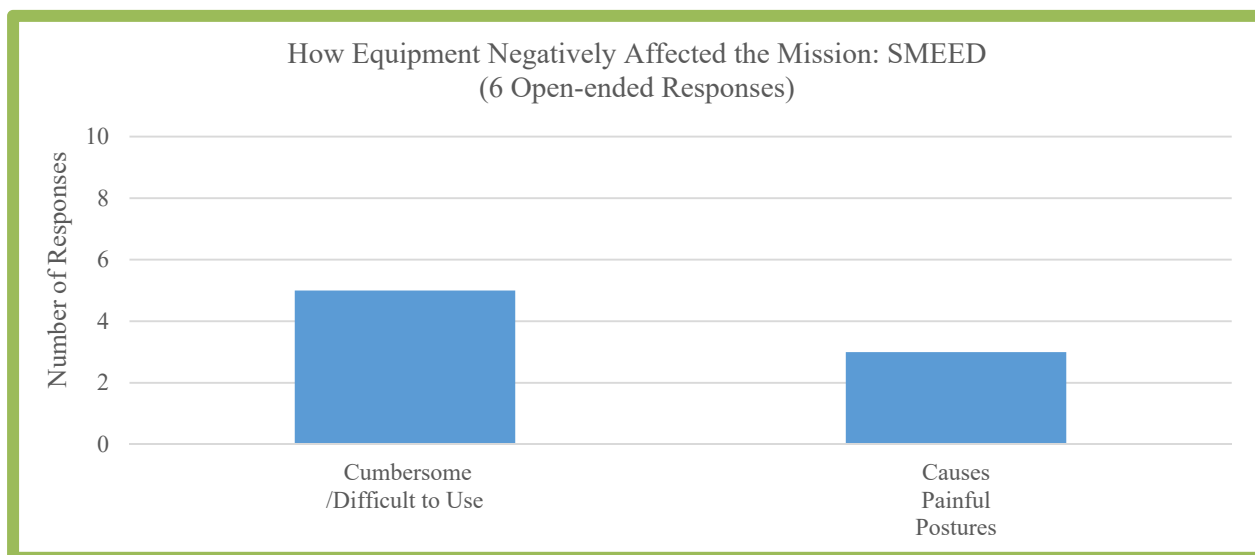


Figure 28. Categorized open-ended responses to Q27 for SMEEDs.

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The most commonly cited issue with the SMEED was “Cumbersome/Difficult to Use.” Here is a breakdown of the responses to Q27 for SMEEDs ranked in order of number of times mentioned from most to least:

- o Cumbersome/Difficult to Use – 5 mentions
- o Causes Painful Postures – 3 mentions

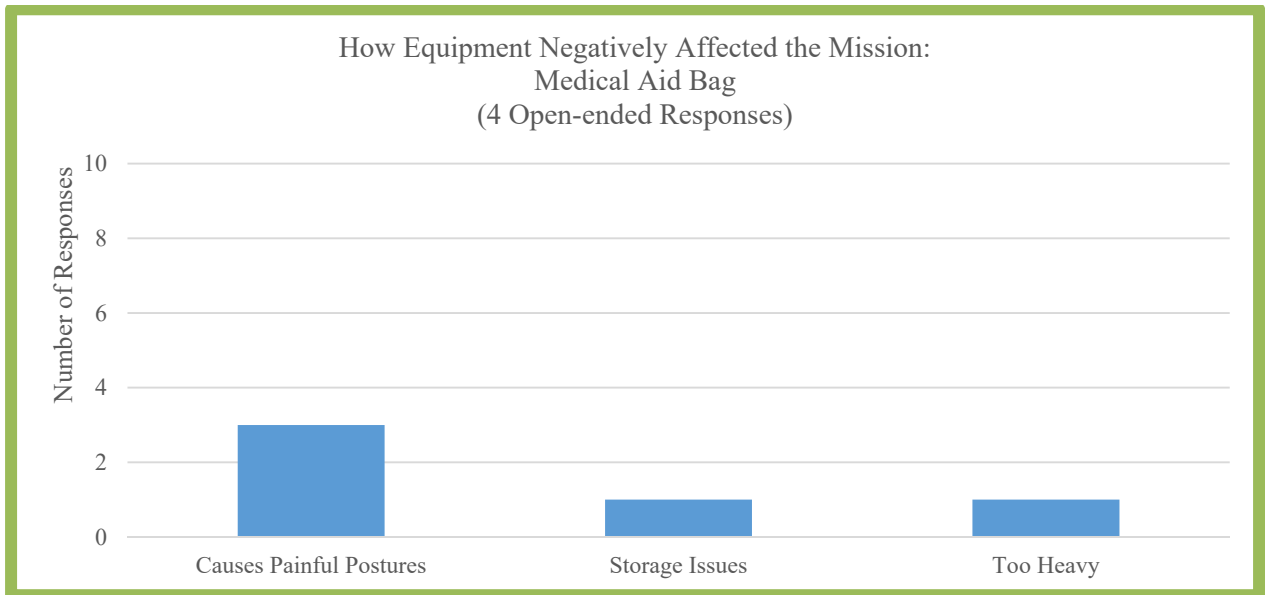


Figure 29. Categorized open-ended responses to Q27 for medical aid bags.

The most commonly cited issue with the medical aid bag was “Causes Painful Postures.” Here is a breakdown of the responses to Q27 for medical aid bags ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 3 mentions
- o Storage Issues – 1 mentions
- o Too Heavy – 1 mentions

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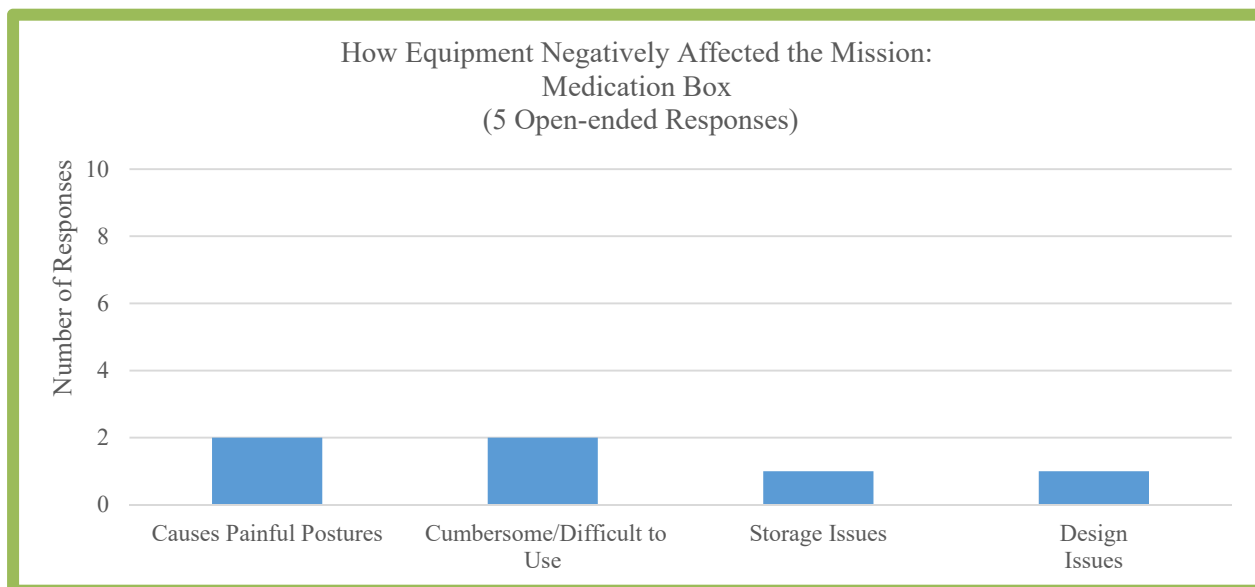


Figure 30. Categorized open-ended responses to Q27 for medication boxes.

The most common issues with the medication box were “Causes Painful Postures” and “Cumbersome/Difficult to Use.” Here is a breakdown of the responses to Q27 for medication boxes ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 2 mentions
- o Cumbersome/Difficult to Use – 2 mentions
- o Storage Issues – 1 mention
- o Design Issues – 1 mention

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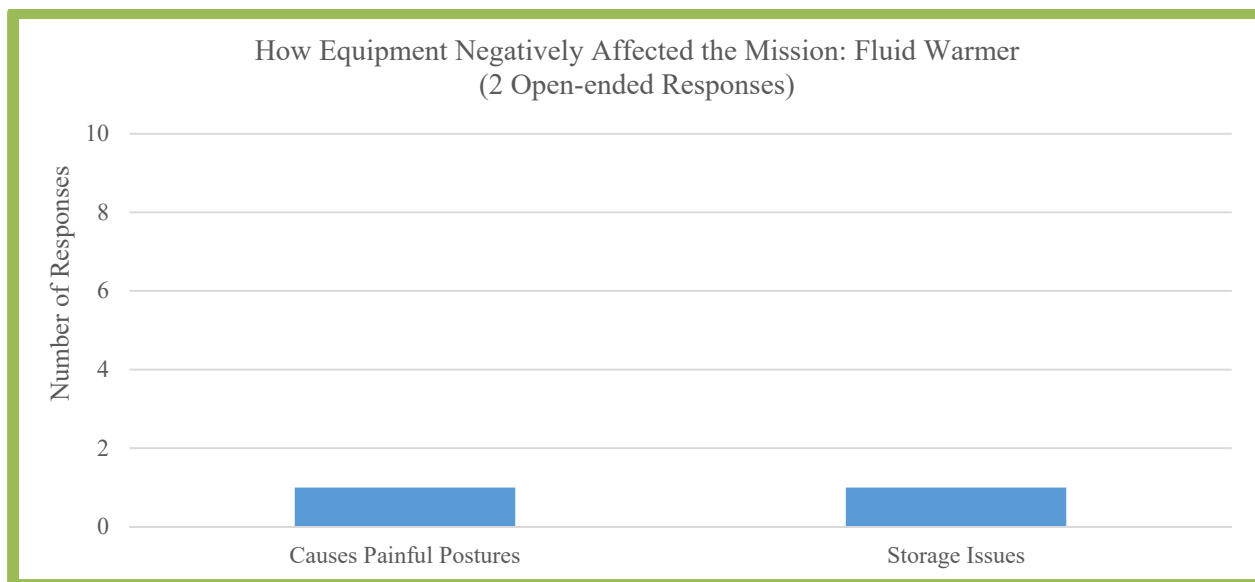


Figure 31. Categorized open-ended responses to Q27 for fluid warmers.

Only two issues were identified with the fluid warmer and each was cited once: the fluid warmer was cited as causing care providers to assume painful postures and being difficult to store.

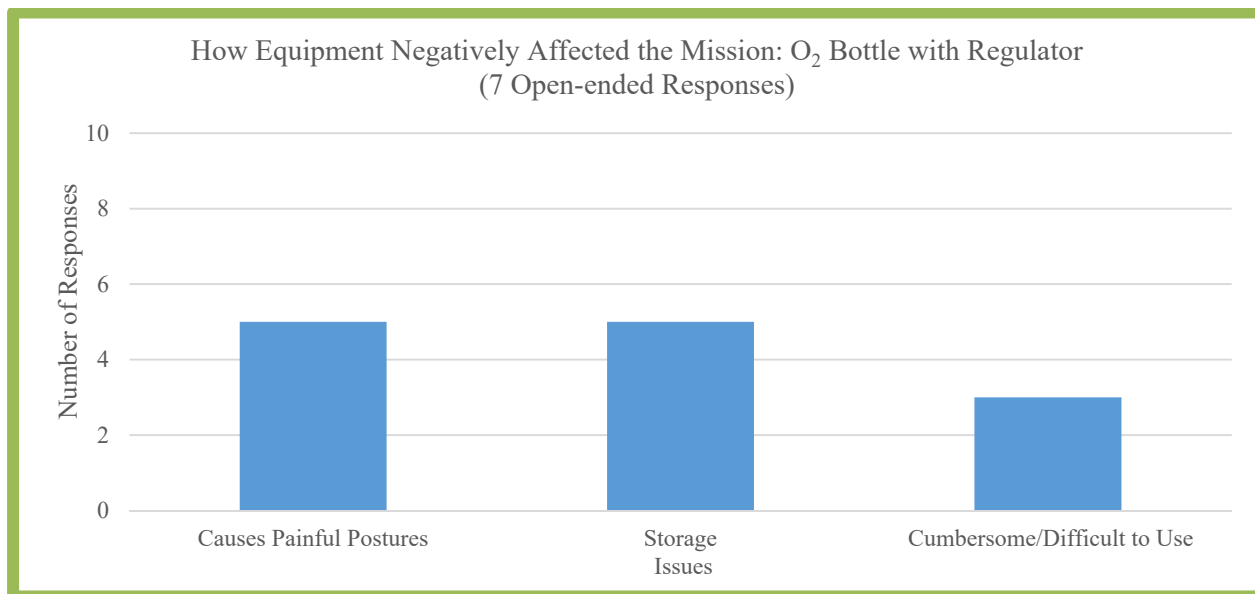


Figure 32. Categorized open-ended responses to Q27 for O₂ bottles with regulators.

The most commonly cited issues with the O₂ bottle with regulator were “Causes Painful Postures” and “Storage Issues.” Here is a breakdown of the responses to Q27 O₂ bottles with regulators ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 5 mentions
- o Storage Issues – 5 mentions
- o Cumbersome/Difficult to Use – 3 mentions

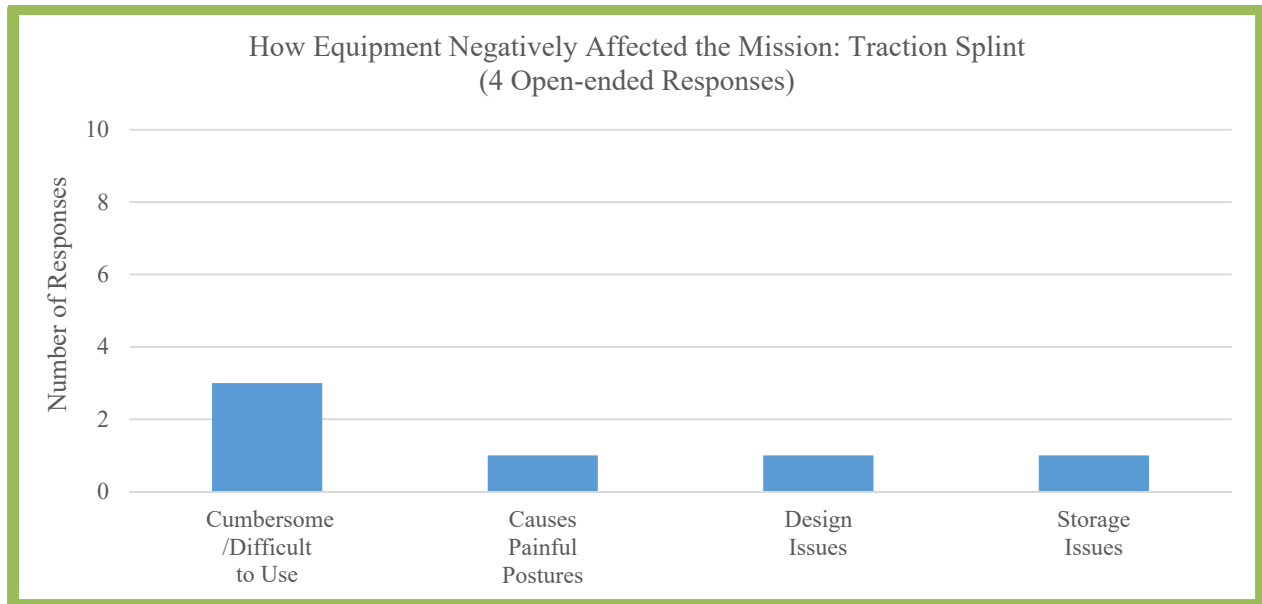


Figure 33. Categorized open-ended responses to Q27 for traction splints.

The most commonly cited issue with the traction splint was “Cumbersome/Difficult to Use.” Here is a breakdown of the responses to Q27 for traction splints ranked in order of number of times mentioned from most to least:

- o Cumbersome/Difficult to Use – 3 mentions
- o Causes Painful Postures – 1 mention
- o Design Issues – 1 mention
- o Storage Issues – 1 mention

The design issue mentioned was that the traction splint could not fit tall patients, and necessitated placing the patient in an angled position or removing the splint if multiple patients were onboard.

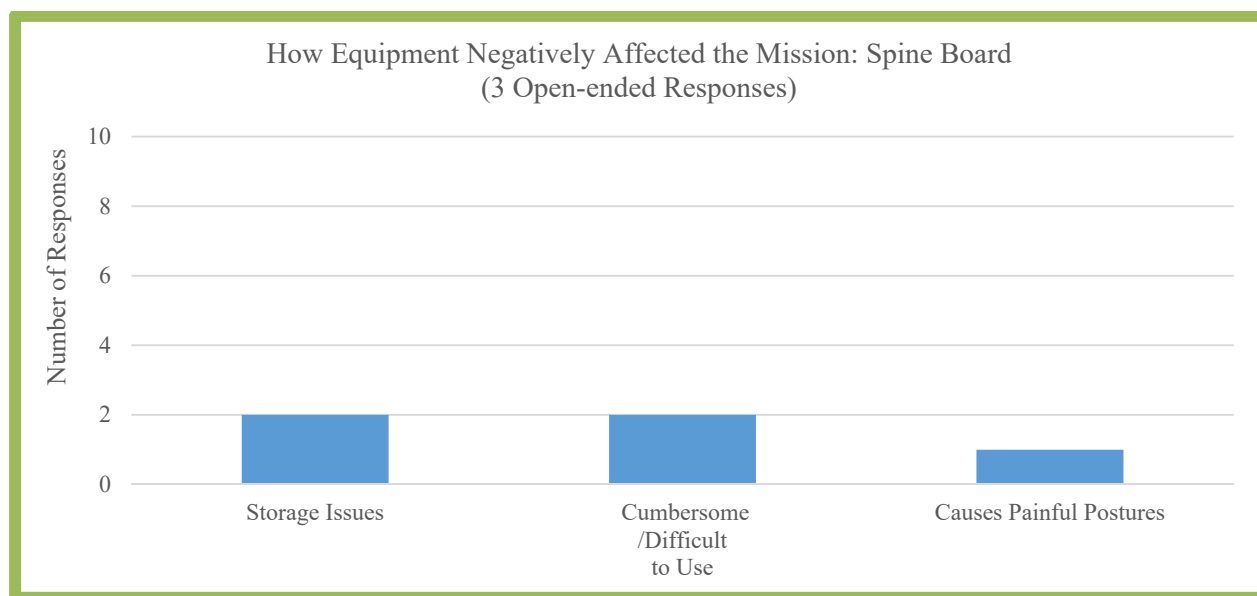


Figure 34. Categorized open-ended responses to Q27 for spine boards.

The most commonly cited issues with the spine board were “Storage Issues” and “Cumbersome/Difficult to Use.” Here is a breakdown of the responses to Q27 for spine boards ranked in order of number of times mentioned from most to least:

- o Storage Issues – 2 mentions
- o Cumbersome/Difficult to Use – 2 mentions
- o Causes Painful Postures – 1 mention

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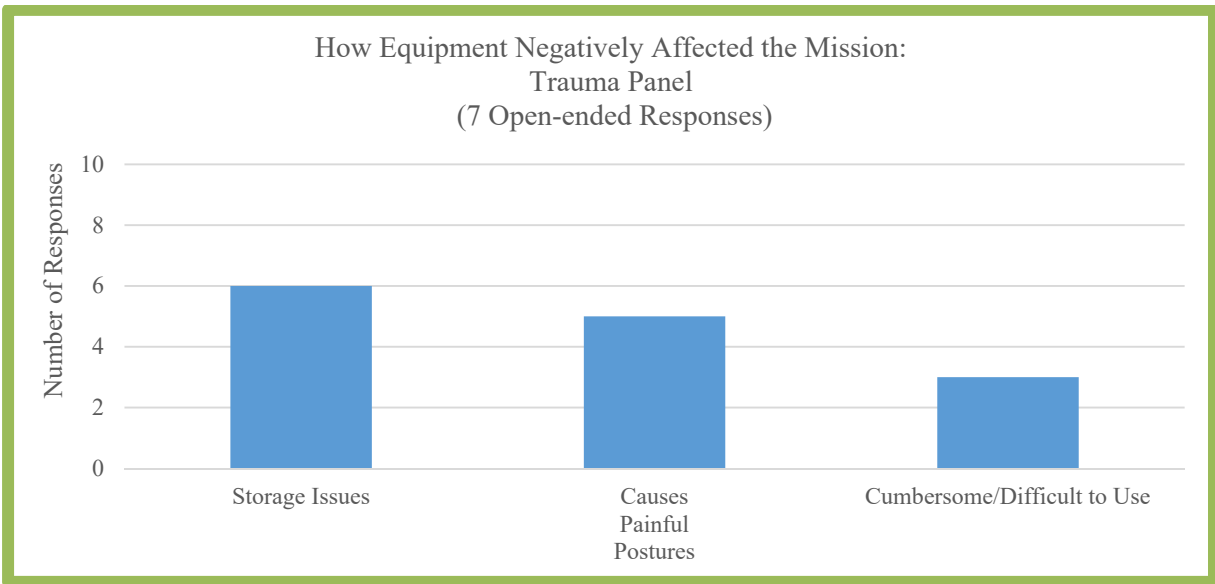


Figure 35. Categorized open-ended responses to Q27 for trauma panels.

The most commonly cited issue with the trauma panel was “Storage Issues.” Here is a breakdown of the responses to Q27 for trauma panels ranked in order of number of times mentioned from most to least:

- o Storage Issues – 6 mentions
- o Causes Painful Postures – 5 mentions
- o Cumbersome/Difficult to Use – 3 mentions

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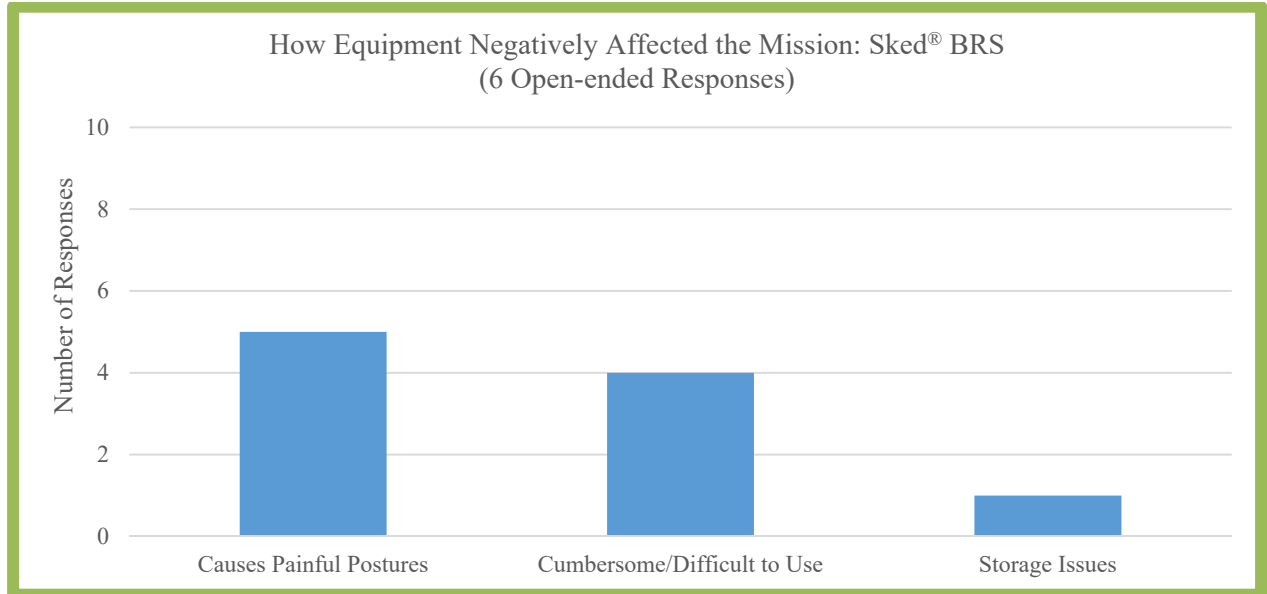


Figure 36. Categorized open-ended responses to Q27 for Sked® BRSs.

The most commonly cited issue with the Sked® BRS was “Causes Painful Postures.” Here is a breakdown of the responses to Q27 for medication boxes ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 5 mentions
- o Cumbersome/Difficult to Use – 4 mentions
- o Storage Issues – 1 mention

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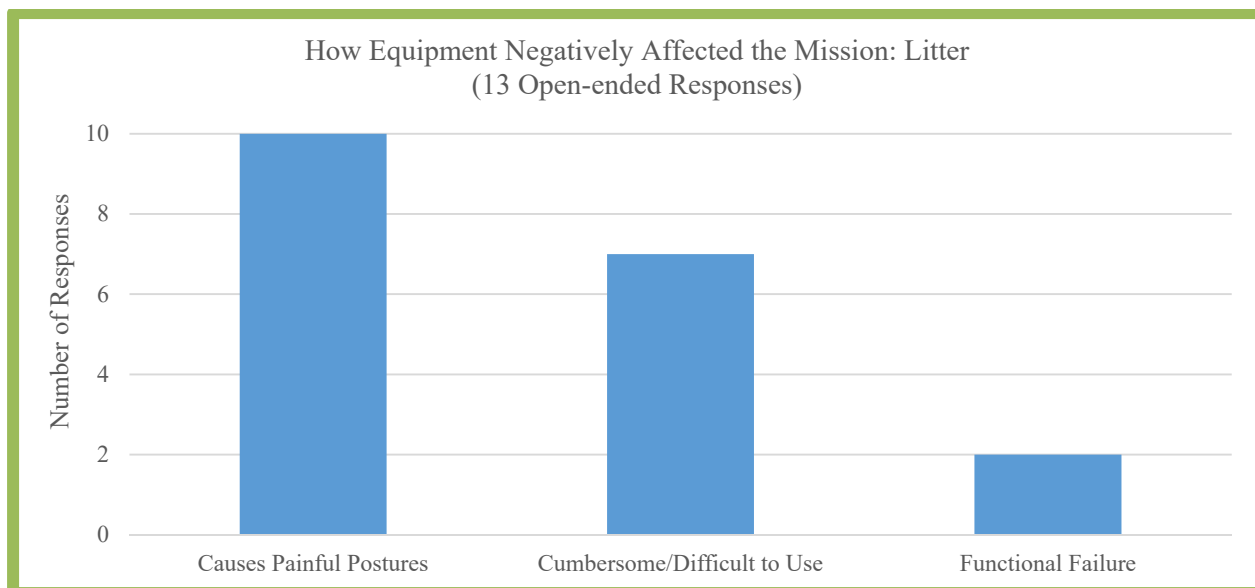


Figure 37. Categorized open-ended responses to Q27 for litters.

The most commonly cited issue with the litter was “Causes Painful Postures” Here is a breakdown of the responses to Q27 for litters ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 10 mentions
- o Cumbersome/Difficult to Use – 7 mentions
- o Functional Failure – 2 mentions

The functional failures mentioned included the litter support brackets collapsing under heavy loads and the North American Rescue Talon II® 90C Collapsible Handle Litter coming unlocked during use.

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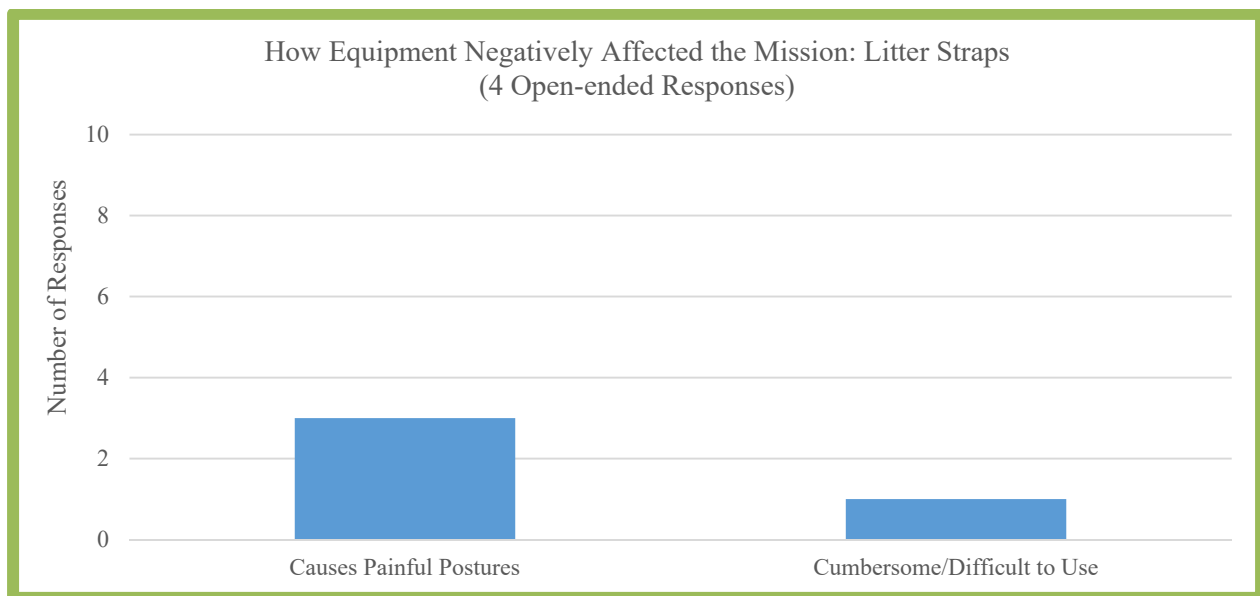


Figure 38. Categorized open-ended responses to Q27 for litter straps.

The most commonly cited issue with the litter straps was “Causes Painful Postures.” Here is a breakdown of the responses to Q27 for litter straps ranked in order of number of times mentioned from most to least:

- o Causes Painful Postures – 3 mentions
- o Cumbersome/Difficult to Use – 1 mention

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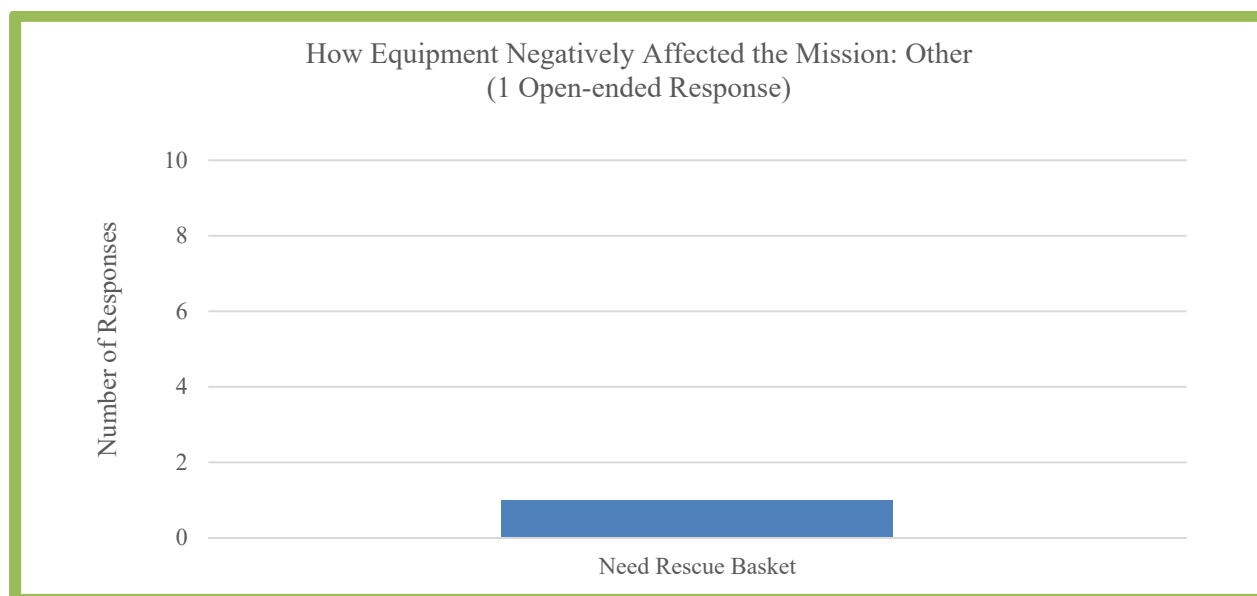


Figure 39. Categorized open-ended responses to Q27 for other equipment.

The only issue related to other equipment was that a medic stated the rescue basket would be a faster option for extracting conscious patients, versus a Sked[®] BRS or Rescue Seat.

Some respondents marked certain equipment as affecting the mission negatively, but did not provide the reasoning, and sometimes the respondents marked a piece of equipment as not being a significant factor but still commented on how that piece of equipment had negatively affected the mission. Also, some respondents mentioned more than one way a piece of equipment negatively affected the mission. As a result of these imbalances, the numbers on the graph are not necessarily a direct reflection of the number of responses in Table 19.

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Section 4.1: Relation Between Number of Patients and the Use of Painful Postures

Q28. Assuming the average transport time will be approximately 30 minutes (min), would the number of patients cared for increase the likelihood of awkward or painful postures for the care provider?

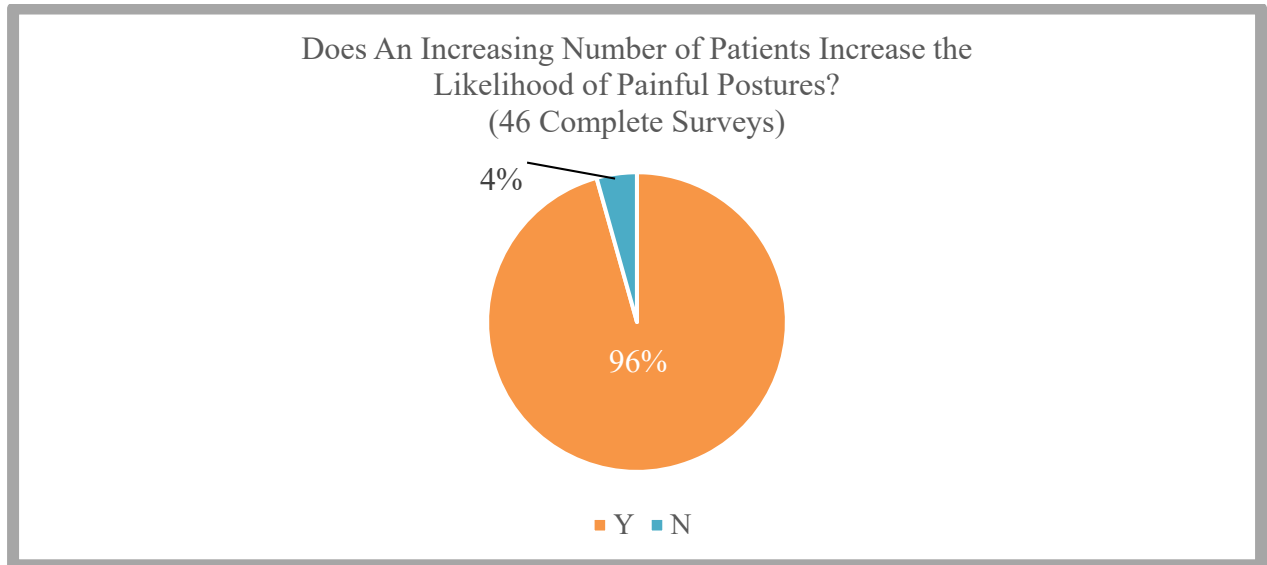


Figure 40. Pie chart of complete valid survey responses to Q28.

Table 22. Responses Indicating if an Increasing Number of Patients Increases the Likelihood of Painful Postures from Complete Valid Surveys

Response	Number of Responses	Response Percentage
Yes	44	95.7%
No	2	4.3%
Skipped	0	0%

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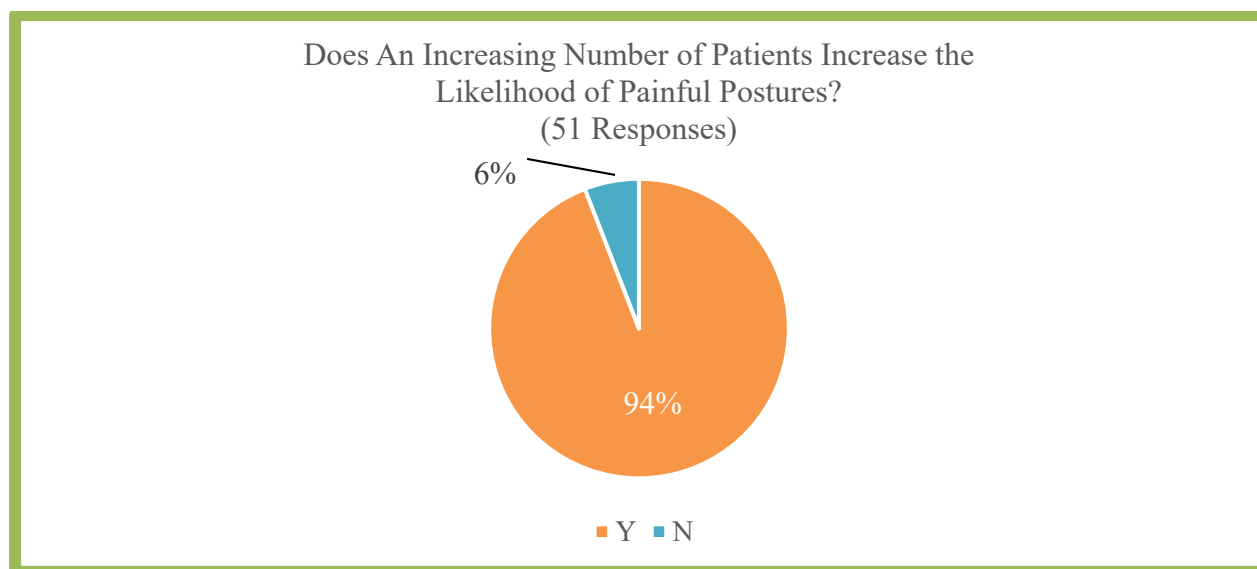


Figure 41. Pie chart of complete and incomplete responses to Q28.

Table 23. Responses Indicating if an Increasing Number of Patients Increases the Likelihood of Painful Postures from All Valid Surveys

Response	Number of Responses	Response Percentage
Yes	48	94.1%
No	3	5.9%
Skipped	9	0%

In both analyses, complete surveys and complete combined with incomplete, the overwhelming majority of respondents agree that increasing the number of patients will increase the likelihood that the care provider will need to assume painful postures to provide treatment.

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Section 4.2: Typical Number of Patients Cared for at One Time

Q29. On average, how many patients do you typically provide care for at one time?

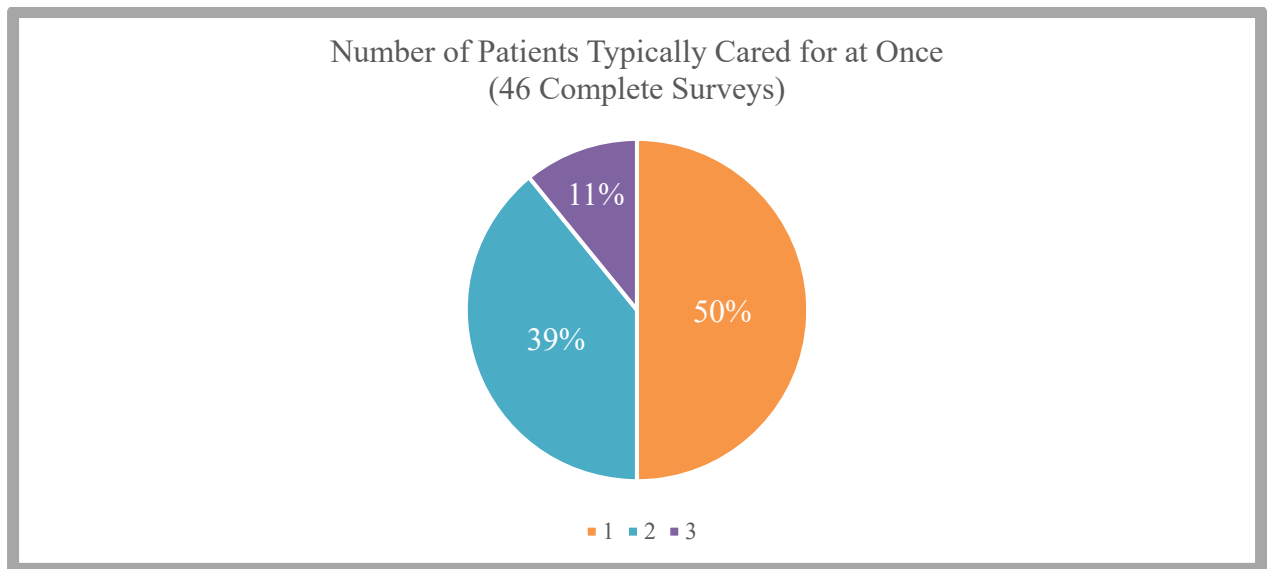


Figure 42. Pie chart of complete valid survey responses to Q29.

Table 24. Number of Patients Usually Cared for at Once According to Complete Valid Surveys

Response	Number of Responses	Response Percentage
1	23	50.0%
2	18	39.1%
3	5	10.9%
Skipped	0	0%

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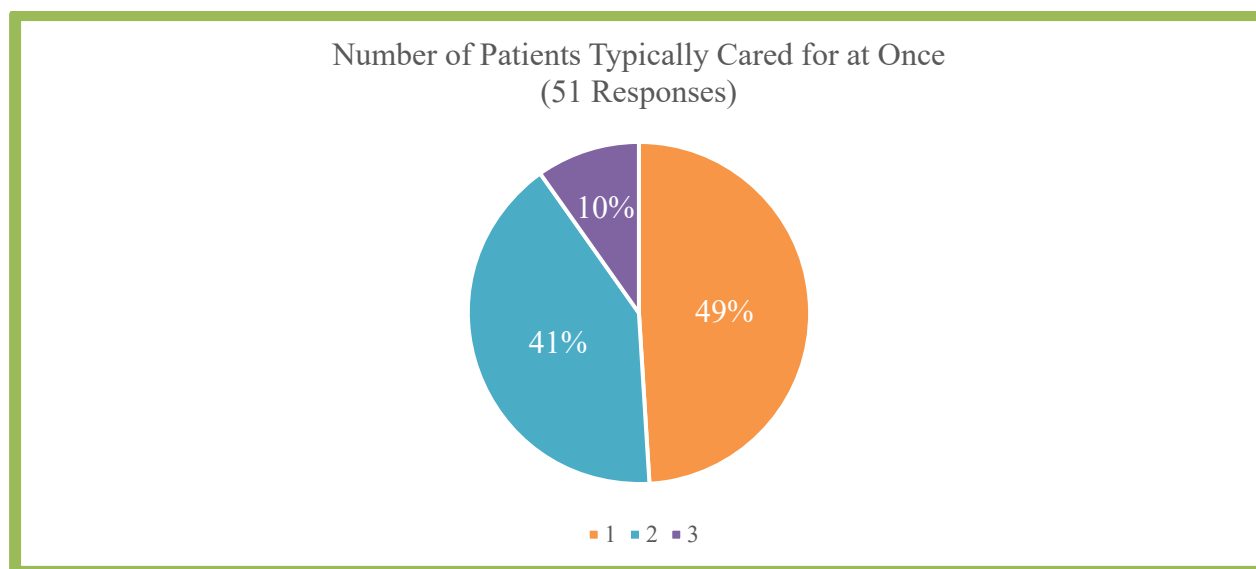


Figure 43. Usual number of patients according to all valid survey responses to Q29.

Table 25. Number of Patients Usually Cared for at Once According to All Valid Surveys

Response	Number of Responses	Response Percentage
1	25	49.0%
2	21	41.2%
3	5	9.8%
Skipped	9	0%

The percentages between complete valid surveys and all valid surveys varies only very slightly. Most often respondents usually care for one patient at a time, second-most often they care for two patients at a time, and a small percentage of respondents care for three patients at a time. The ratio in both analyses is approximately 5:4:1 in order of increasing number of patients.

Section 5: Frequency of Awkward Postures for a Given Task

Q30. Please read each task and check the box under the frequency you have experienced each awkward posture during each task listed. If you have not experienced the posture, leave the box unchecked.

After answering Q30, the respondents were presented with 27 specific tasks, 1 optional “Other” task, and 6 possible postures that might be utilized to perform each task. The possible postures were bending at the waist, kneeling, squatting, overextending, reaching behind you, and

straining to lift heavy weight. Respondents indicated if this posture was required once or more than once per patient for the associated task.

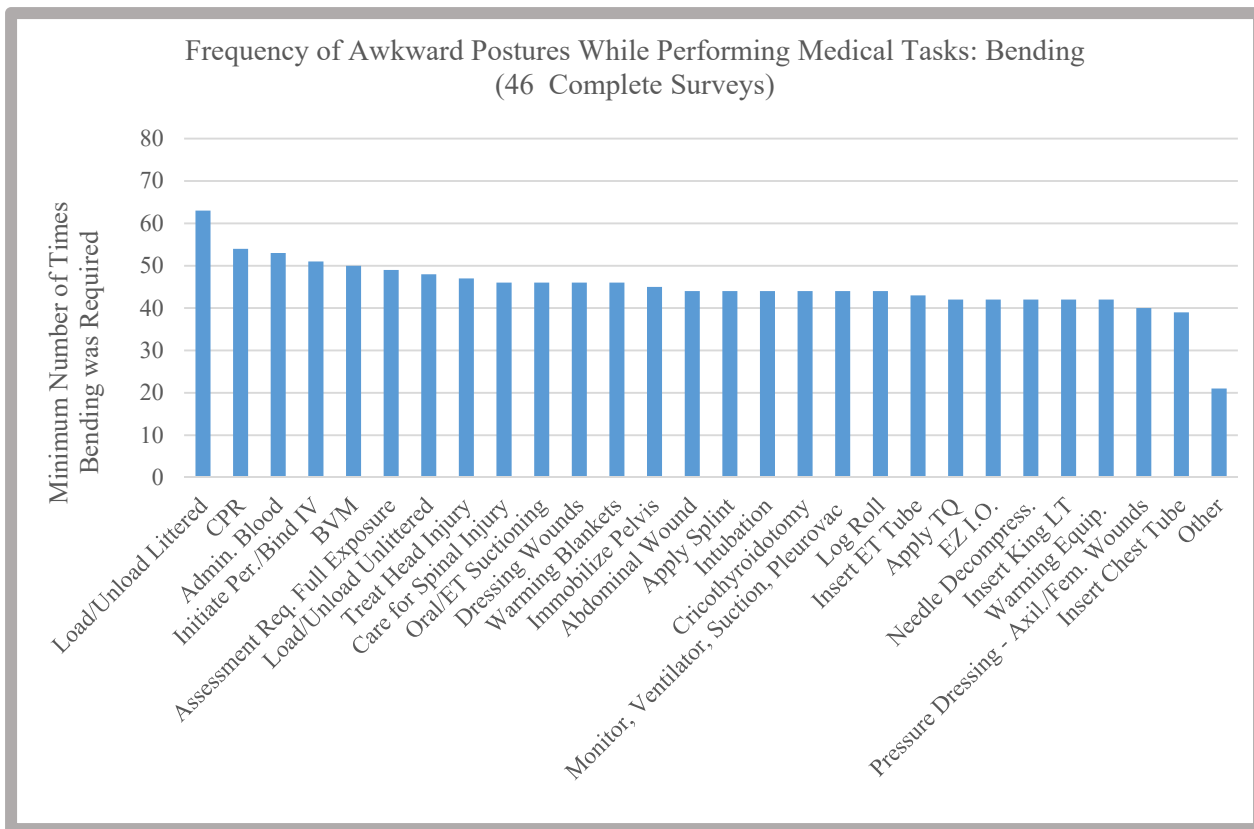


Figure 44. The minimum frequency of bending at the waist for medical tasks.

The task that required “Bending at the Waist” most frequently was “Load/Unload Littered Patients,” cited as being required a minimum of 63 times when combining answers that said the posture was required once or more-than-once per patient among the complete valid surveys.

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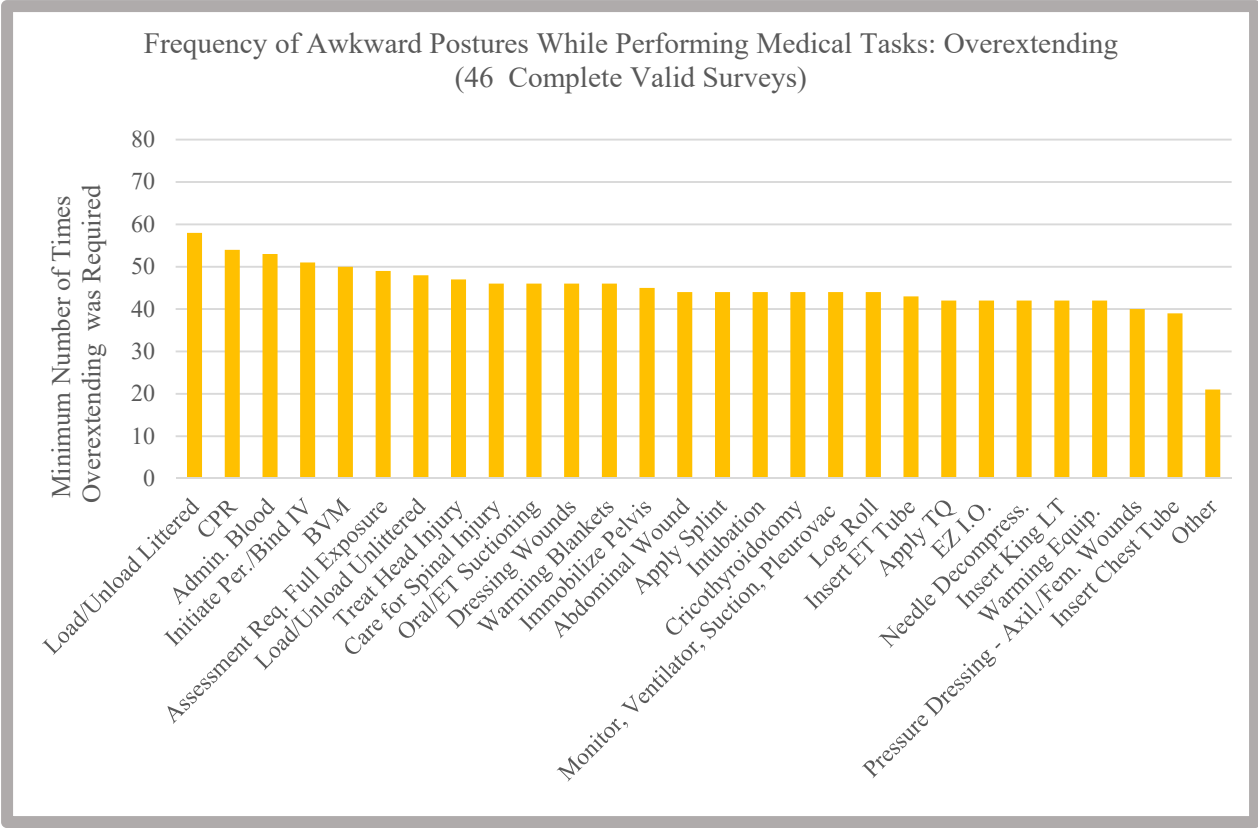


Figure 45. The minimum frequency of overextending for medical tasks.

The task that required “Overextending” most frequently was “Load/Unload Littered Patients,” cited as being required a minimum of 58 times when combining answers that said the posture was required once or more-than-once per patient among the complete valid surveys.

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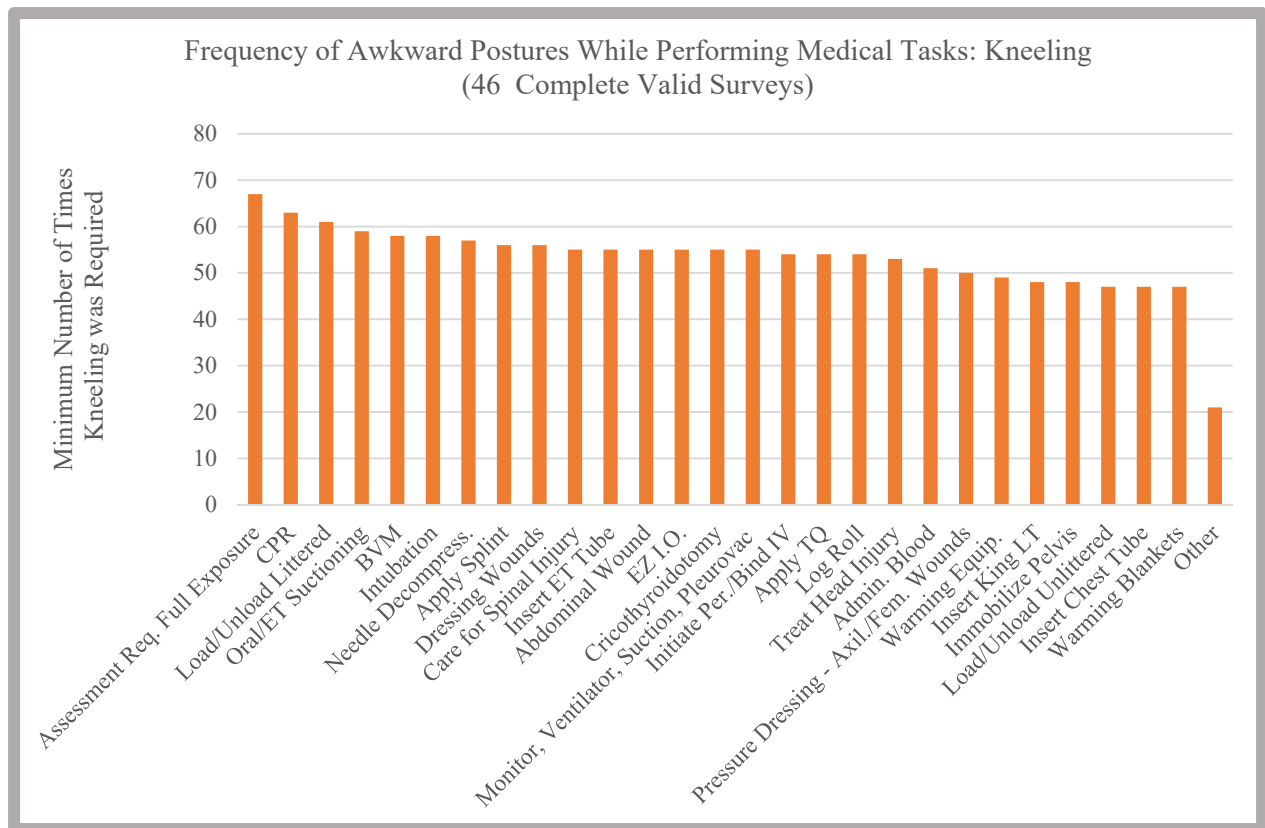


Figure 46. The minimum frequency of kneeling for medical tasks.

The task that required “Kneeling” most frequently was “Assessment Requiring Full Exposure” of the patient, cited as being required a minimum of 67 times when combining answers that said the posture was required once or more-than-once per patient among the complete valid survey.

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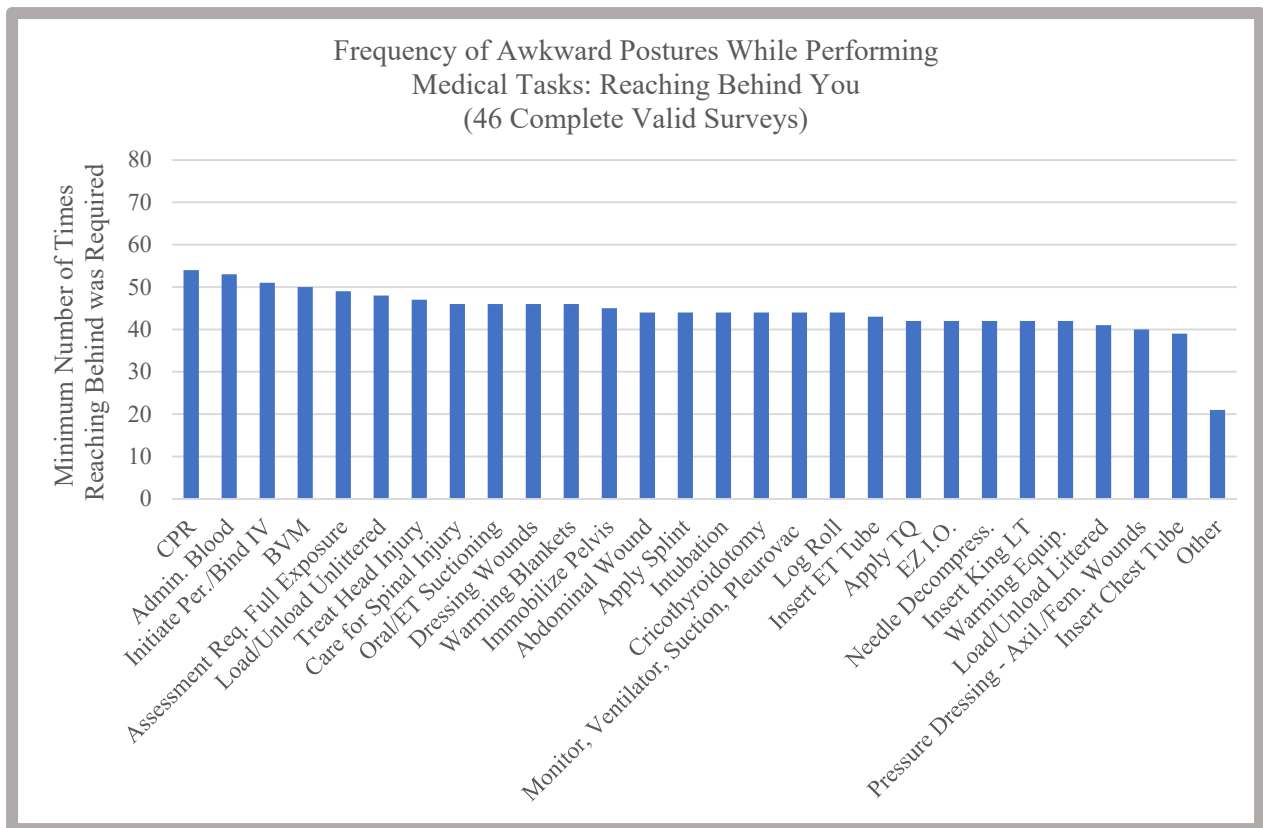


Figure 47. The minimum frequency of reaching behind you for medical tasks.

The task that required “Reaching Behind You” most frequently was “CPR,” cited as being required a minimum of 54 times when combining answers that said the posture was required once or more-than-once per patient among the complete valid survey.

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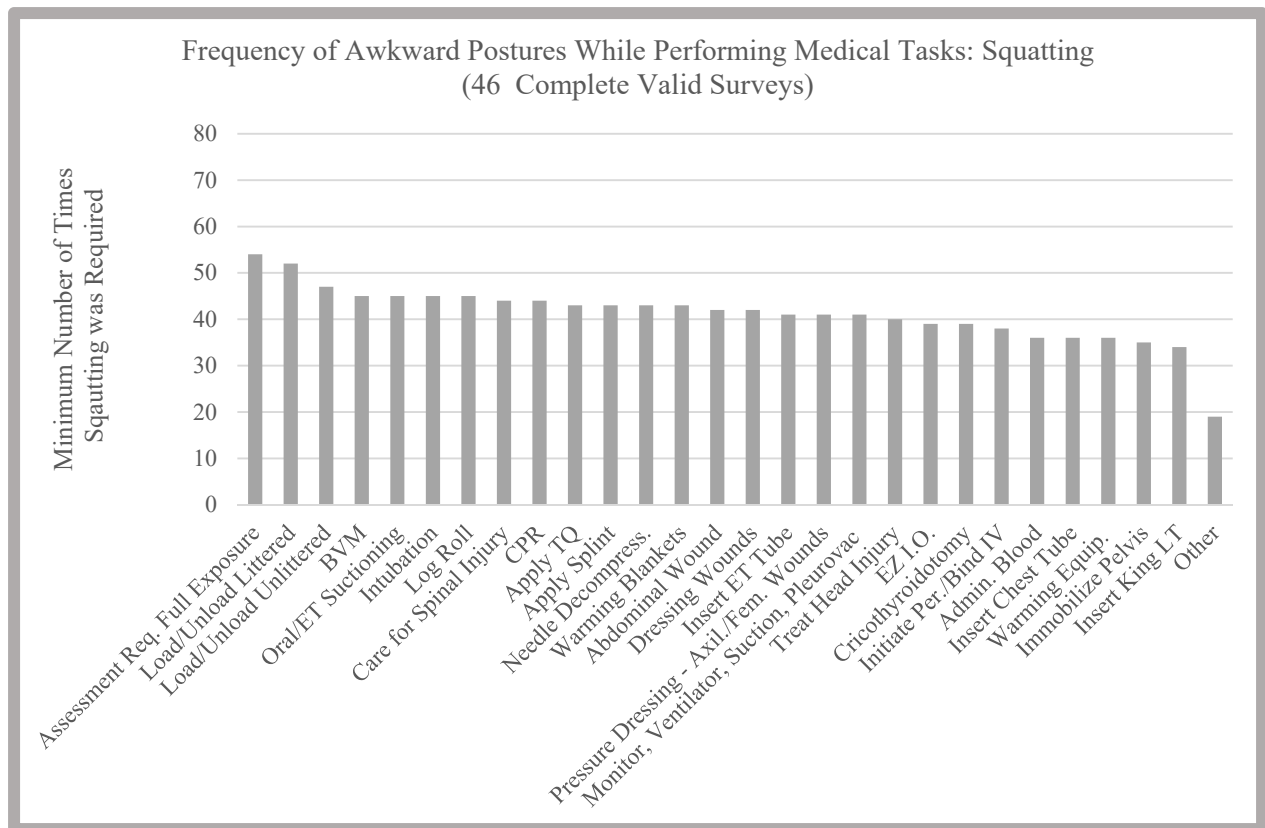


Figure 48. The minimum frequency of squatting for medical tasks.

The task that required “Squatting” most frequently was “Assessment Requiring Full Exposure,” cited as being required a minimum of 54 times when combining answers that said the posture was required once or more-than-once per patient among the complete valid surveys.

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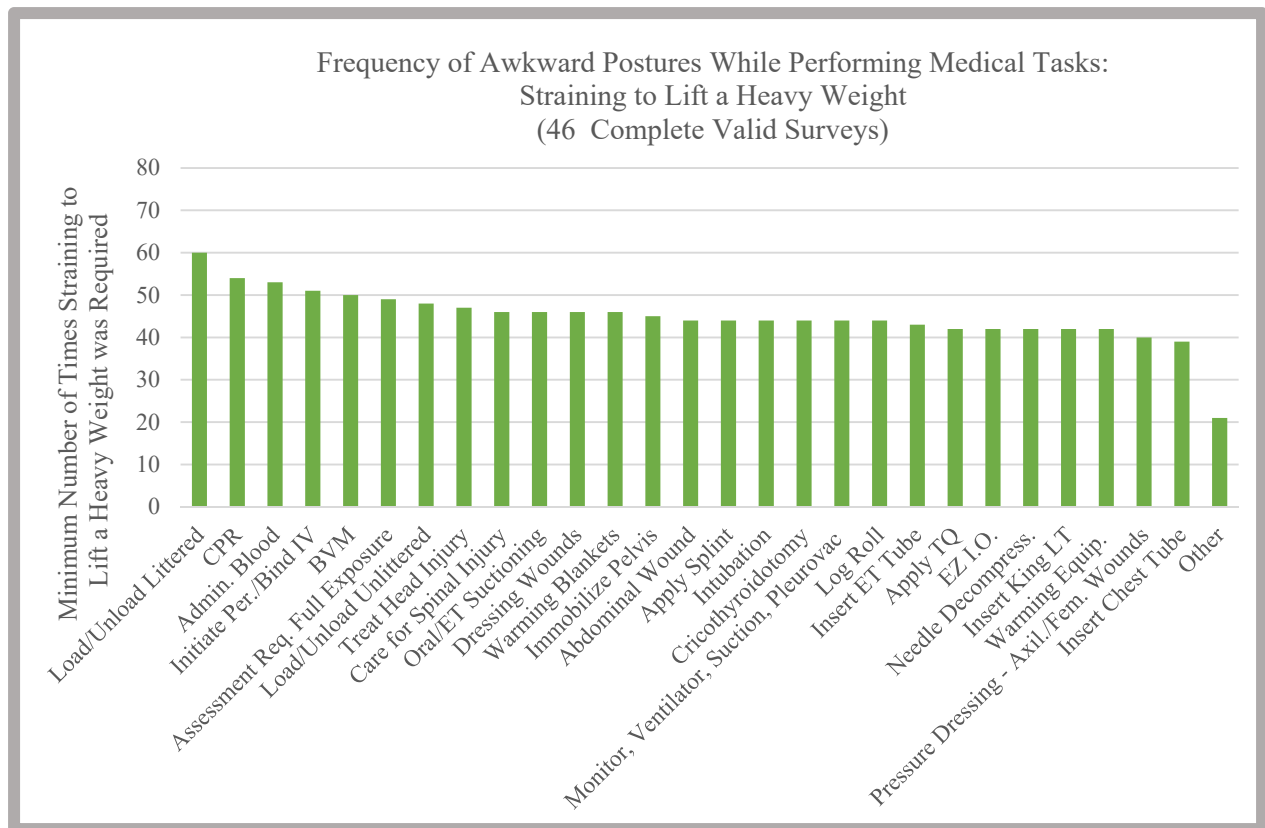


Figure 49. The minimum frequency of straining to lift a heavy weight for medical tasks.

The task that required “Straining to Lift a Heavy Weight” most frequently was “Load/Unload a Littered Patient,” cited as being required a minimum of 60 times when combining answers that said the posture was required once or more-than-once per patient among the complete valid surveys.

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A second analysis for all valid surveys was not performed on the postures section because if a posture was not required for an action, the posture was to be left unmarked. This method left the deliberately unmarked posture responses indistinguishable from the skipped questions in this section. Due to the fact that most respondents with incomplete valid surveys did not mark any postures for any actions, it is reasonable to assume that the section was skipped (instead of left blank, which would have meant that the actions did not require painful postures) and not include the incomplete surveys in the frequency analysis.

Section 6: Occupational Injuries/Discomforts

Q31. Check the boxes below for any occupational injuries or discomfort you have experienced associated with any postures during patient loading and patient care.

Table 26. Tally of Injuries Sustained and Report Status from Complete Surveys

Location of Injury	Reported/Treated	Not Reported	Total Number of Injuries	Area Uninjured
Lower Back	18	23	41	6
Knee injury	12	25	37	9
Neck	10	22	32	14
Shoulder Injury	13	14	27	19
Upper Back	9	13	22	24
Ankle	4	9	13	33
Hip Injury	4	7	11	35
Wrist	4	7	11	35
Other	2	9	11	35
Elbow	4	6	10	36

Note. One respondent reported more than one back injury, which is why the total number of injuries plus uninjured areas for the lower back category is greater than 46.

None of the incomplete valid surveys contained information on injuries sustained, making it impossible to distinguish between uninjured areas and skipped questions. Due to the large amount of unanswered questions surrounding the injury section of the questionnaire in the incomplete surveys, it is likely that these sections were skipped, so only the complete valid surveys were analyzed. Skipped answers in complete valid surveys were interpreted as the area not being injured due to the format of the survey (respondents only marked areas injured, there was not an option to mark an area uninjured, as uninjured areas were intended to be left blank).

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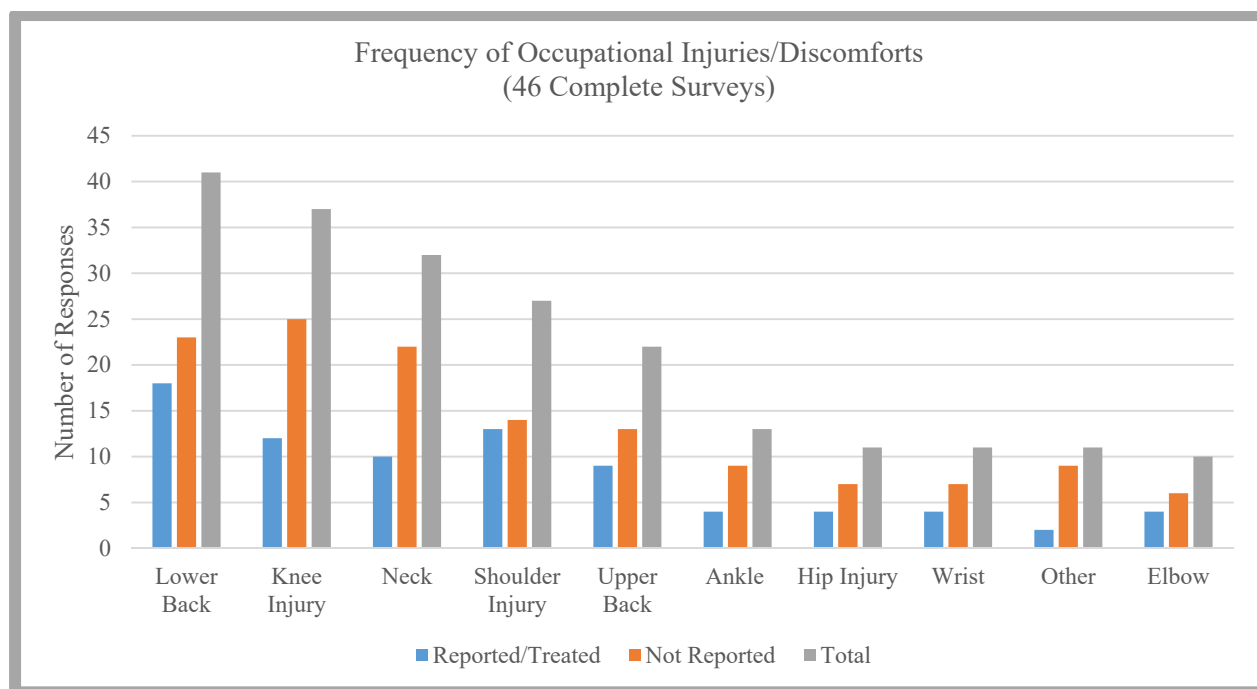


Figure 50. Frequency of occupational injuries.

Lower back, knee, neck, shoulder, and upper back injuries were prevalent among respondents. For all injuries, more cases were unreported than were reported. Lower back injuries were the most common, suffered by 87% of respondents (one respondent reported two lower back injuries).

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Q32. What caused your (un)reported neck injury/discomfort?

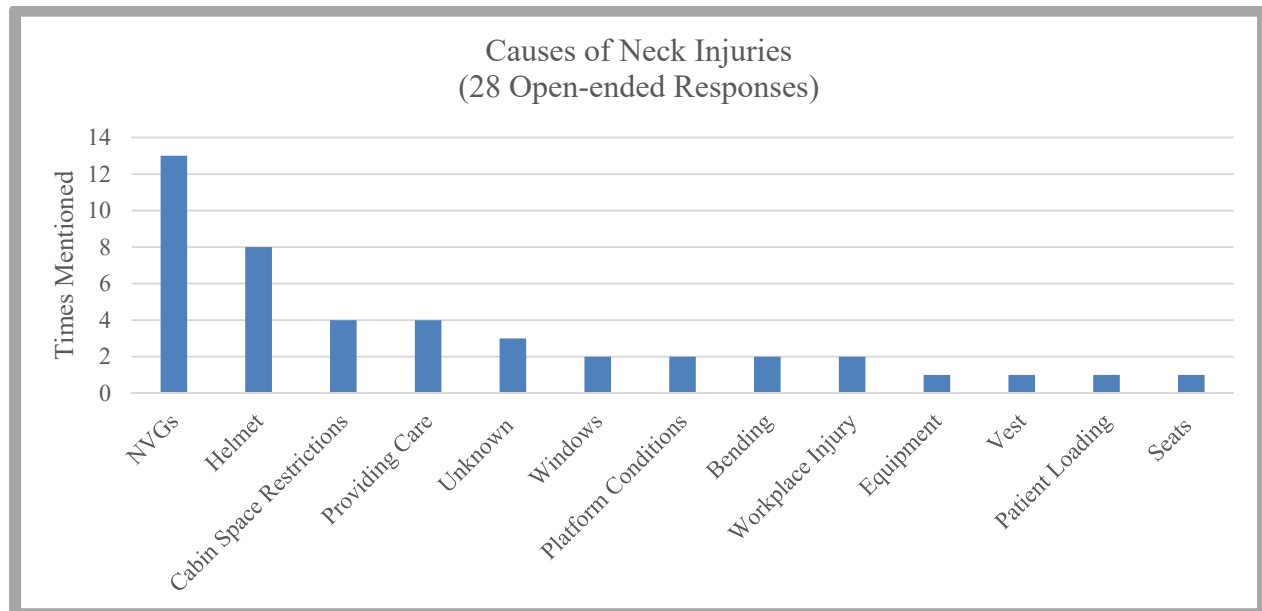


Figure 51. Causes of neck injuries.

The most commonly cited cause of neck injuries among respondents was “NVGs.” Here is a breakdown of the responses to Q32 ranked in order of number of times mentioned from most to least:

- o NVGs – 13 mentions
- o Helmet – 8 mentions
- o Cabin Space Restrictions – 4 mentions
- o Providing Care – 4 mentions
- o Unknown – 3 mentions
- o Windows – 2 mentions
- o Platform Conditions – 2 mentions
- o Bending – 2 mentions
- o Workplace Injury – 2 mentions
- o Equipment – 1 mention
- o Vest – 1 mention
- o Patient Loading – 1 mention
- o Seats – 1 mention

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Q33. What caused your (un)reported knee injury/discomfort?

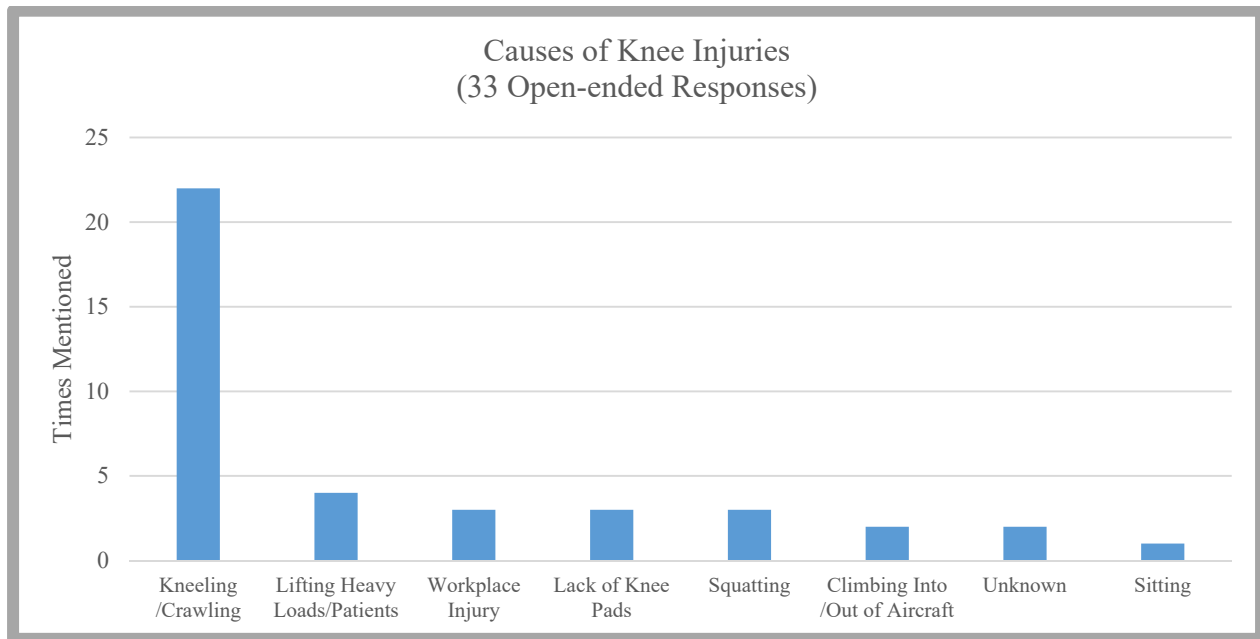


Figure 52. Causes of knee injuries.

The most commonly cited cause of knee injuries among respondents was “Kneeling/Crawling,” which were often required during patient care. Here is a breakdown of the responses to Q33 ranked in order of number of times mentioned from most to least:

- o Kneeling/Crawling – 22 mentions
- o Lifting Heavy Loads/Patients – 4 mentions
- o Workplace Injury – 3 mentions
- o Lack of Knee Pads – 3 mentions
- o Squatting – 3 mentions
- o Climbing Into/Out of Aircraft – 2 mentions
- o Unknown – 2 mentions
- o Sitting – 1 mention

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Q34. What caused your (un)reported hip injury/discomfort?

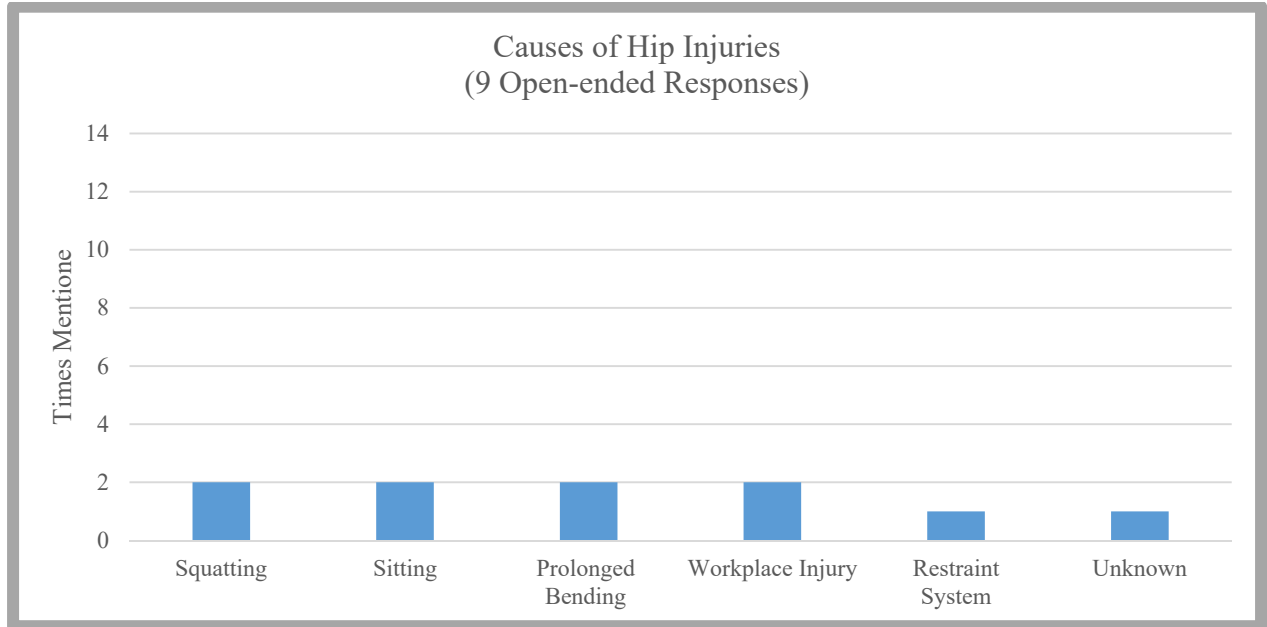


Figure 53. Causes of hip injuries.

The most commonly cited causes of hip injuries among respondents were “Squatting,” “Sitting,” “Prolonged Bending,” and “Workplace Injury.” Here is a breakdown of the responses to Q34 ranked in order of number of times mentioned from most to least:

- o Squatting – 2 mentions
- o Sitting – 2 mentions
- o Prolonged Bending – 2 mentions
- o Workplace Injury – 2 mentions
- o Restraint System – 1 mention
- o Unknown – 1 mention

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Q35. What caused your (un)reported shoulder injury/discomfort?

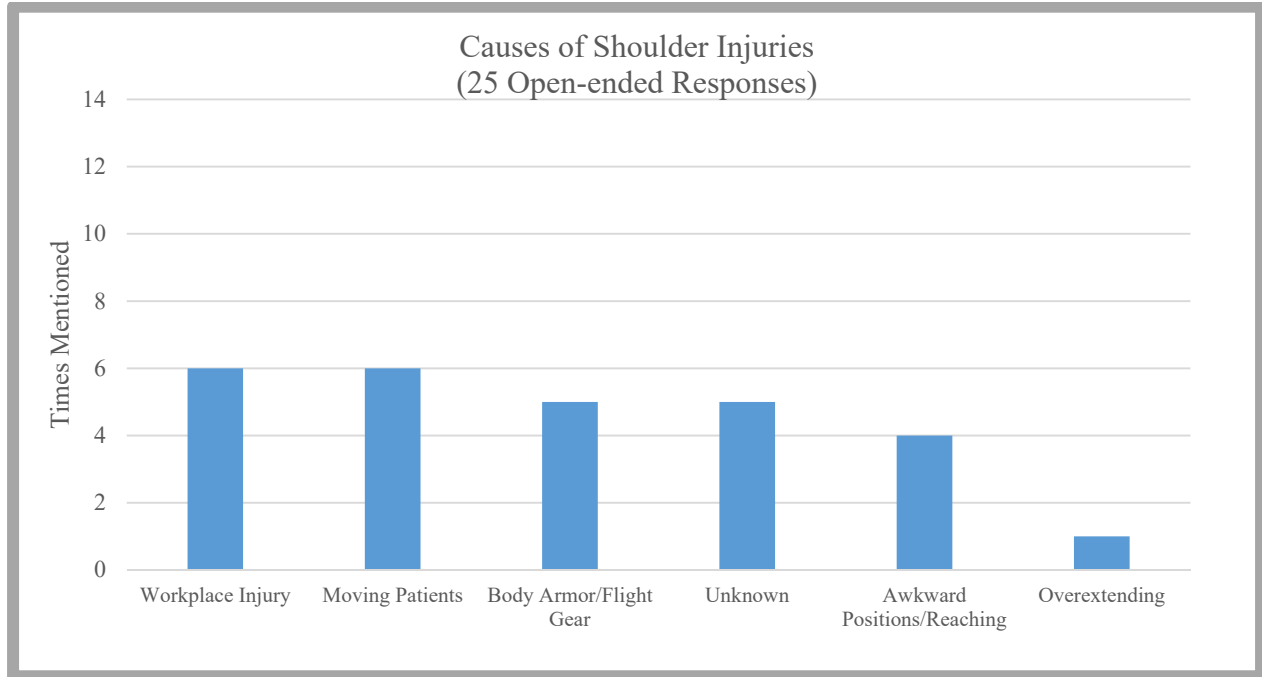


Figure 54. Causes of shoulder injuries.

The most commonly cited causes of shoulder injuries among respondents were “Workplace Injury” and “Moving Patients.” Here is a breakdown of the responses to Q35 ranked in order of number of times mentioned from most to least:

- o Workplace Injury – 6 mentions
- o Moving Patients – 6 mentions
- o Body Armor/Flight Gear – 5 mentions
- o Unknown – 5 mentions
- o Awkward Positions/Reaching – 4 mentions
- o Overextending – 1 mention

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Q36. What caused your (un)reported ankle injury/discomfort?

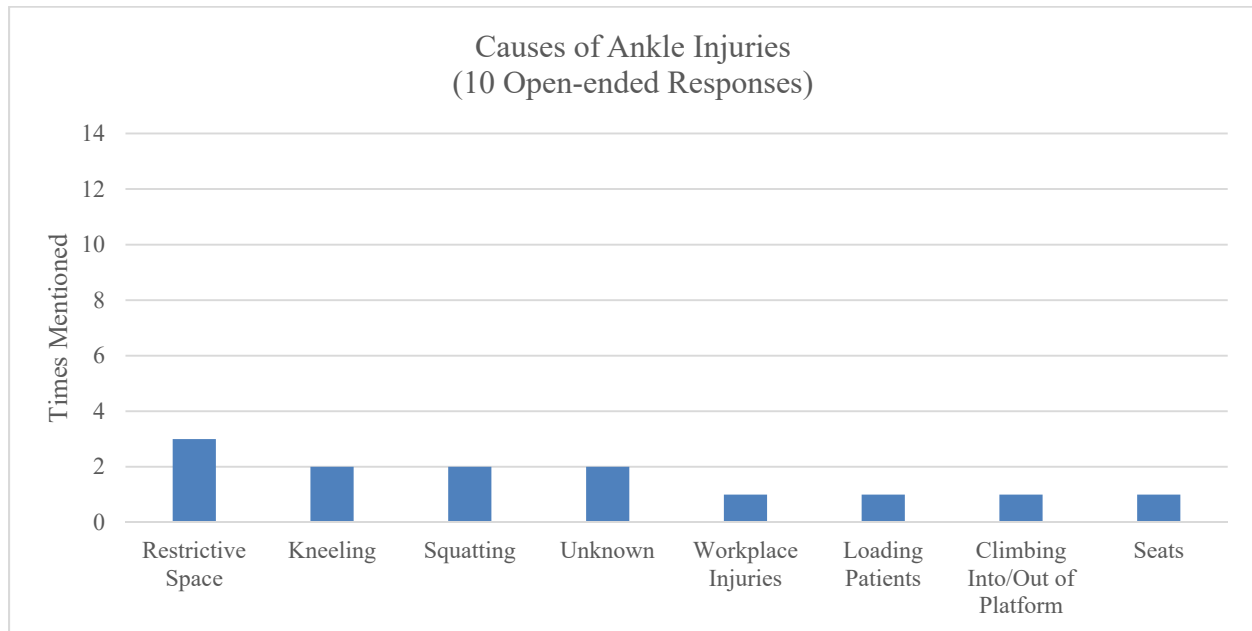


Figure 55. Causes of ankle injuries.

The most commonly cited cause of ankle injuries among respondents was “Restrictive Space.” Here is a breakdown of the responses to Q36 ranked in order of number of times mentioned from most to least:

- o Restrictive Space – 3 mentions
- o Kneeling – 2 mentions
- o Squatting – 2 mentions
- o Unknown – 2 mentions
- o Workplace Injury – 1 mention
- o Loading Patients – 1 mention
- o Climbing Into/Out of Platform – 1 mention
- o Seats – 1 mention

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Q37. What caused your (un)reported elbow injury/discomfort?

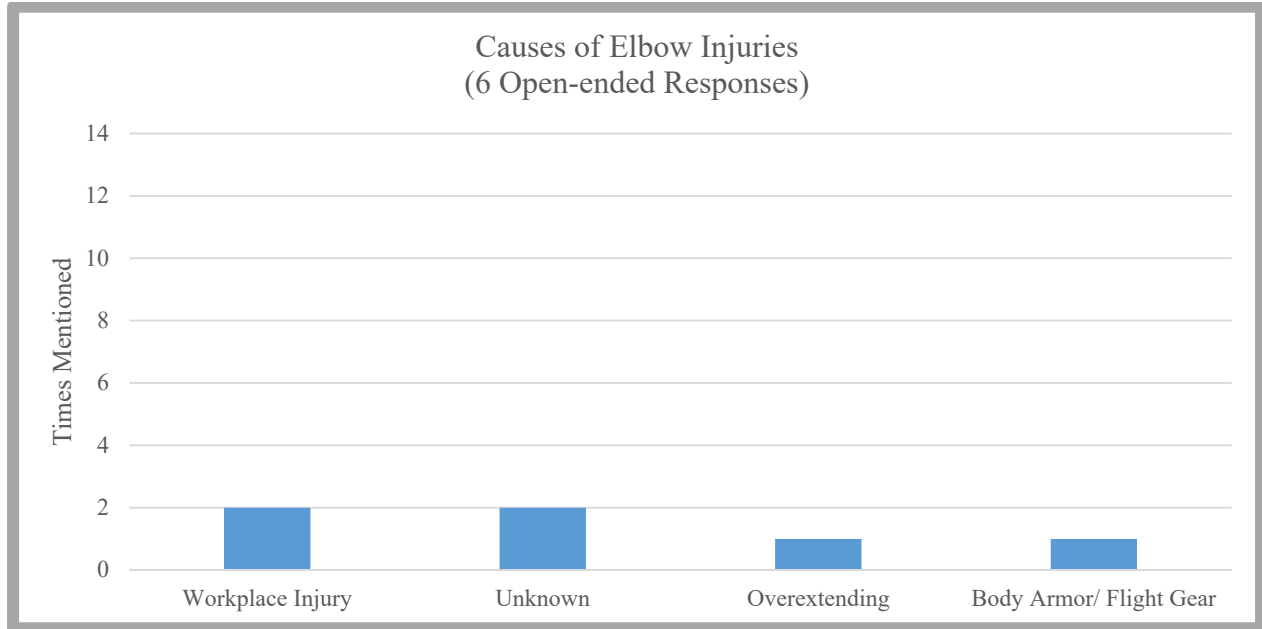


Figure 56. Causes of elbow injuries.

The most commonly cited causes of elbow injuries among respondents were “Workplace Injury” and “Unknown.” Here is a breakdown of the responses to Q37 ranked in order of number of times mentioned from most to least:

- o Workplace Injury – 2 mentions
- o Unknown – 2 mentions
- o Overextending – 1 mention
- o Body Armor/Flight Gear – 1 mention

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Q38. What caused your (un)reported wrist injury/discomfort?

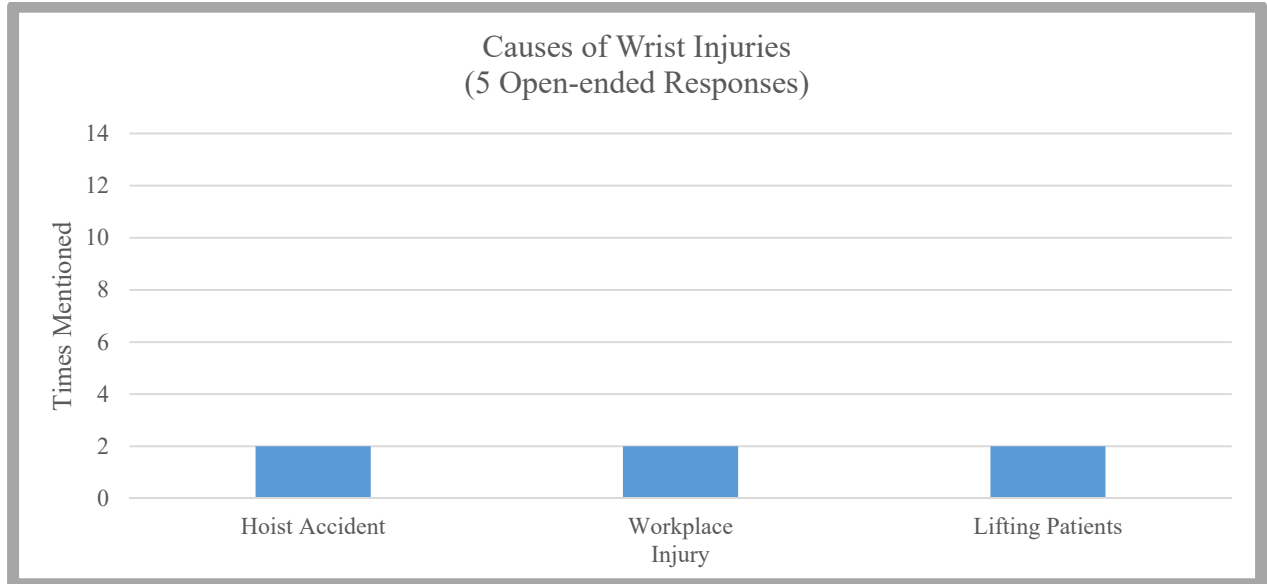


Figure 57. Causes of wrist injuries.

All causes of wrist injuries were equally common, they include “Hoist Accident,” “Workplace Injury,” and “Lifting Patients,” all mentioned two times.

Q39. What caused your (un)reported upper back injury/discomfort?

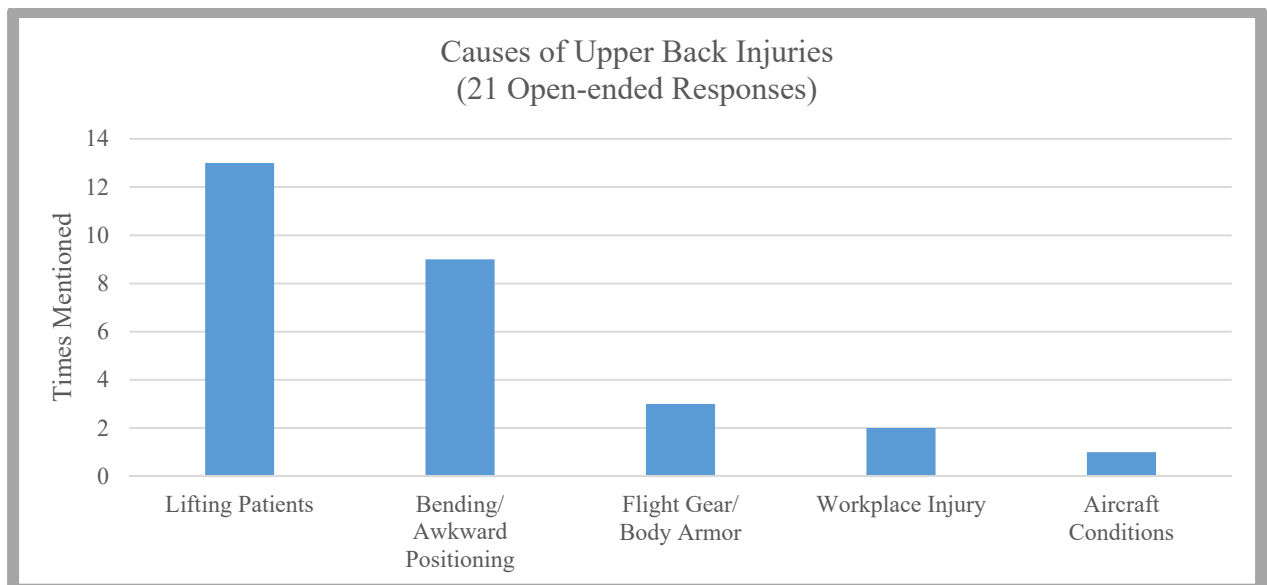


Figure 58. Causes of upper back injuries.

The most commonly cited cause of upper back injuries among respondents was “Lifting Patients.” Here is a breakdown of the responses to Q39 ranked in order of number of times mentioned from most to least:

- o Lifting Patients – 13 mentions
- o Bending/Awkward Positions – 9 mentions
- o Flight Gear/Body Armor – 3 mentions
- o Workplace Injuries – 2 mentions
- o Aircraft Conditions – 1 mention

Q40. What caused your (un)reported lower back injury/discomfort?

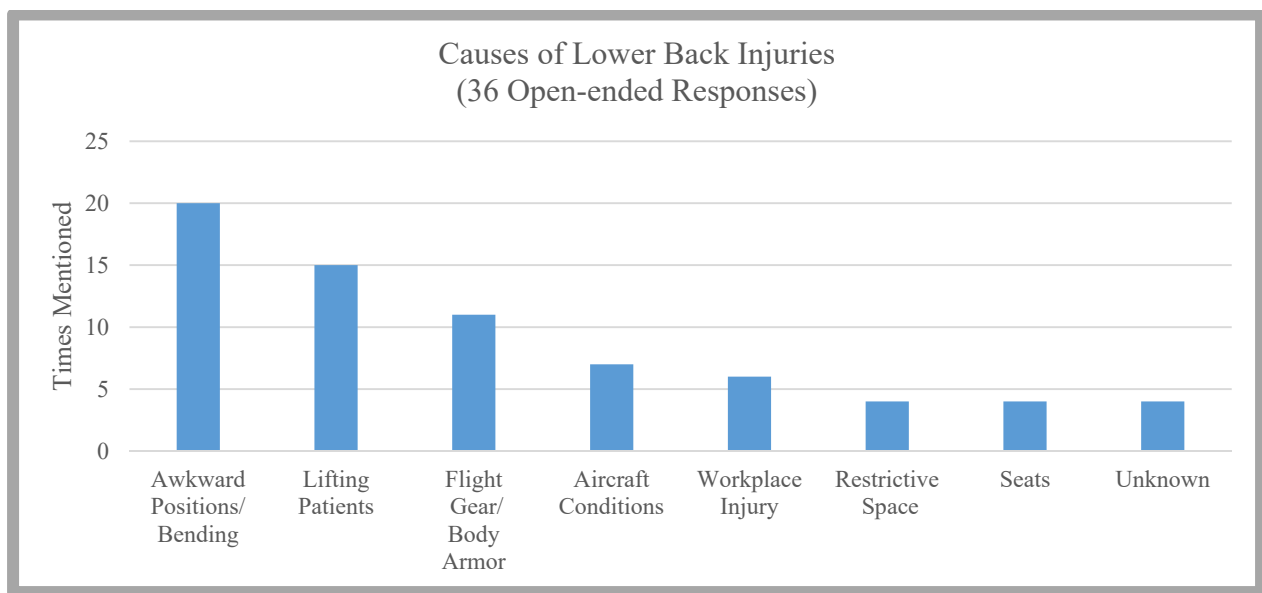


Figure 59. Causes of lower back injuries.

The most commonly cited cause of lower back injuries among respondents was “Awkward Positions/Bending.” Here is a breakdown of the responses to Q40 ranked in order of number of times mentioned from most to least:

- o Awkward Positions/Bending – 20 mentions
- o Lifting Patients – 15 mentions
- o Flight Gear/Body Armor – 11 mentions
- o Aircraft Conditions – 7 mentions
- o Workplace Injury – 6 mentions
- o Restrictive Space – 4 mentions
- o Seats – 4 mentions
- o Unknown – 4 mentions

Q41. You chose “Other” injury. What was this injury/discomfort and what caused it?

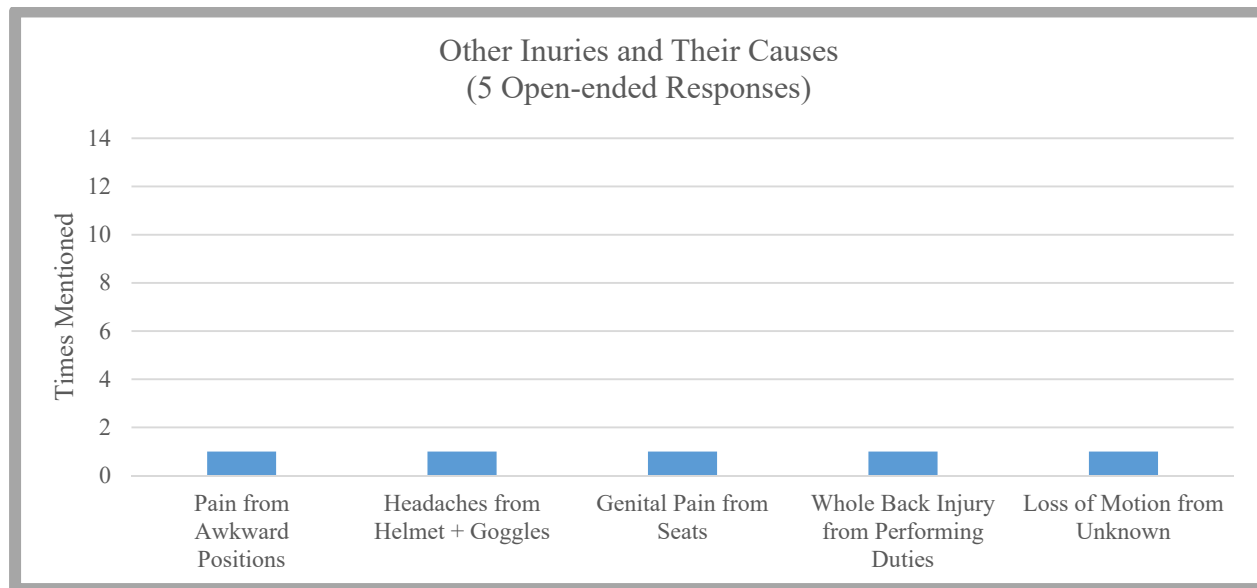


Figure 60. Types and causes of other injuries.

All “Other” injuries were mentioned one time each, and vary in their nature and causes. One commenter had pain from awkward positions, location was not specified. Commenters also had headaches from wearing their helmets and NVGs, genital pain from sitting on the stiff seats for lengths of time, whole back injury from performing crewmember duties, and loss of range of motion from an unspecified cause and in an unspecified location.

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Section 7: Reasons for Not Reporting and Primary Sources of Pain

All graphs in this section are based on all valid responses, complete and incomplete.

Q42. For injuries that you did not report, what were your reasons for not reporting?

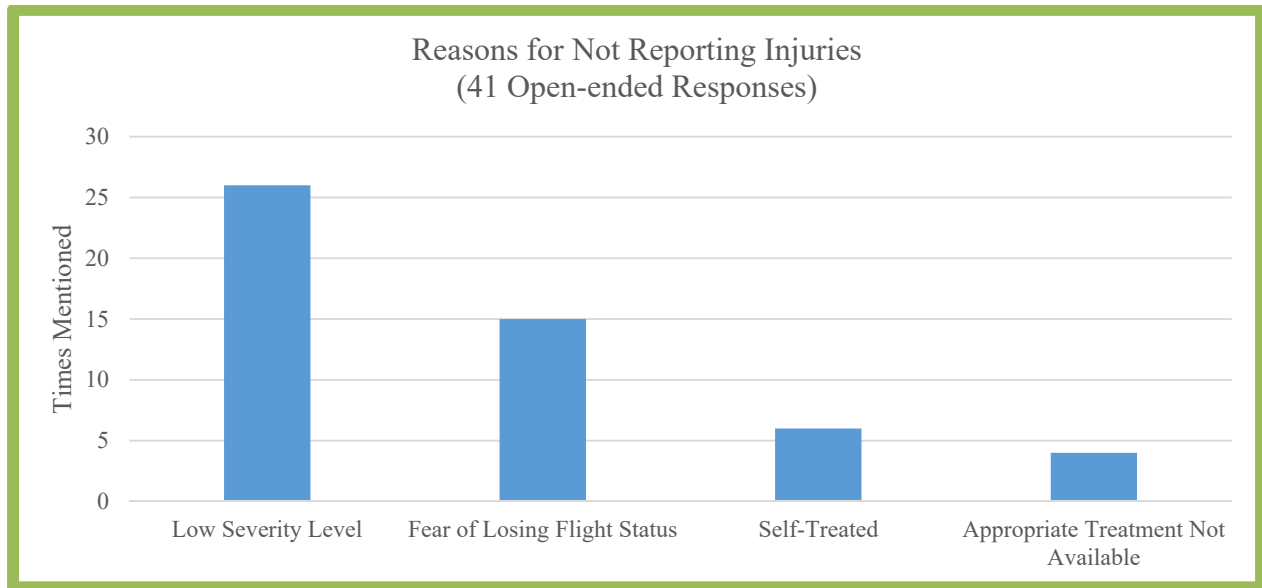


Figure 61. Reasons that respondents chose not to report their injuries.

The most common reason that respondents chose not to report injuries was “Low Severity Level.” Here is a breakdown of the responses to Q42 ranked in order of number of times mentioned from most to least:

- o Low Severity Level – 26 mentions
- o Fear of Losing Flight Status – 15 mentions
- o Self-Treated – 6 mentions
- o Appropriate Treatment not Available – 2 mentions

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Q43. Do any specific postures or tasks cause your primary source of pain? Please explain.

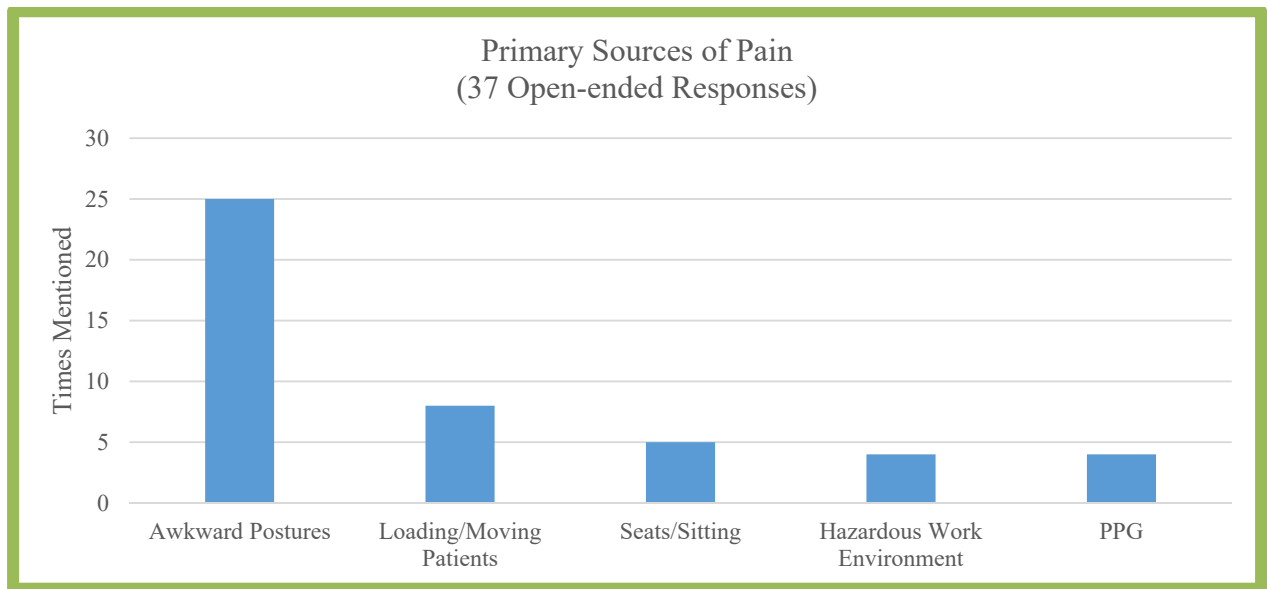


Figure 62. Primary sources of pain.

The most common primary source of pain among respondents was “Awkward Postures.” Here is a breakdown of the responses to Q43 ranked in order of number of times mentioned from most to least:

- o Awkward Postures – 25 mentions
- o Loading/Moving Patients – 8 mentions
- o Seats/Sitting – 5 mentions
- o Hazardous Work Environment – 4 mentions
- o PPG – 4 mentions

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Q44. Please discuss any other injuries you may have experienced related to patient care/loading.

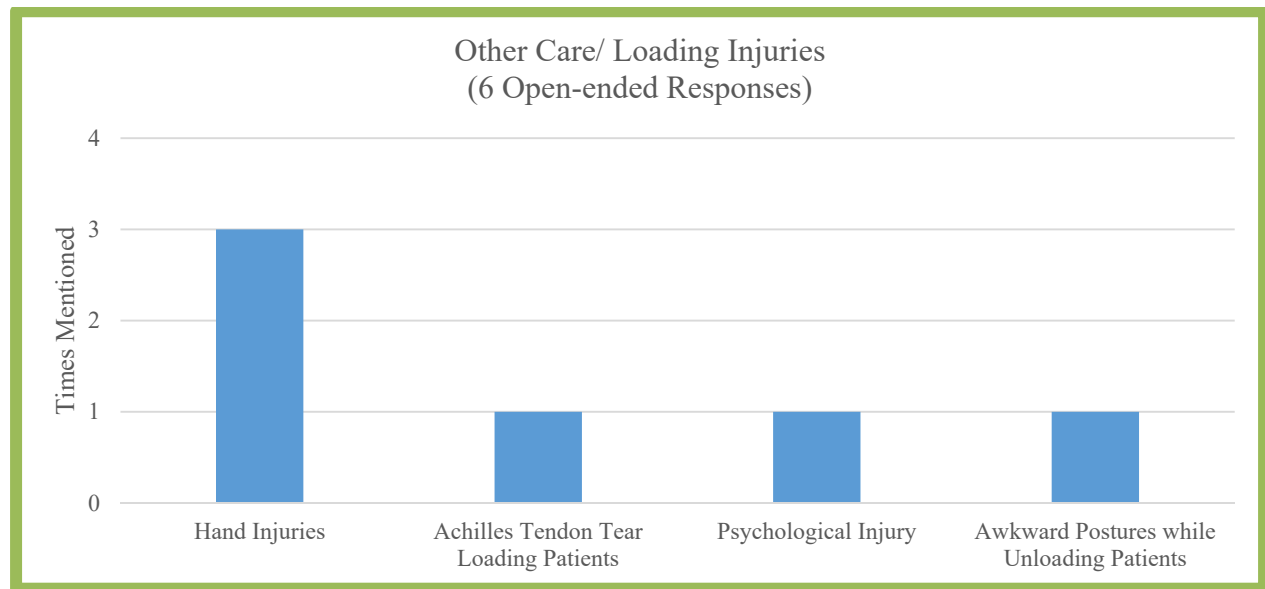


Figure 63. Injuries not listed previously in the survey.

The most common injury that respondents did not mention earlier in the survey was “Hand Injuries.” Here is a breakdown of the responses to Q44 ranked in order of number of times mentioned from most to least:

- o Hand Injuries – 3 mentions
- o Achilles Tendon Tear Loading Patients – 1 mention
- o Psychological Injury – 1 mention
- o Awkward Postures while Unloading Patients – 1 mention

ANOVA Analysis

ANOVA analyses were performed by using Excel’s filter tables to sort the data into categories and then performing single-factor ANOVA analysis using Excel’s Data Analysis ToolPak add-in to obtain the *P*-values. RStudio was then used to obtain the power of the sample using the pwr pack function `pwr.t2n.test` with the following parameters.

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Table 27. Parameters Used for RStudio's Pwr.t2n.test Function

Parameter	Value
<i>N1</i>	Number of observations in the first group
<i>N2</i>	Number of observations in the second group
Significance Level	.05
<i>d</i>	Calculated

The *d*-value in Table 27 is the observed effect size according to Cohen (1988) and is calculated using the following equation:

$$d = \frac{N1 - N2}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}}$$

Where SD_1 and SD_2 are the standard deviations of the first and second group, respectively.

The *P*-values that resulted from ANOVA analyses indicate whether or not there is a statistically significant difference between the means of two groups. If the resulting *P*-value is less than the significance level used (0.05 in this survey) then there is a statistically significant difference between the groups being analyzed.

Power analyses were run on the ANOVA results after the *P*-values were calculated. The power value that results from power analysis is equal to 1 – (probability of making a type II error), and indicates whether or not the sample size being analyzed possesses sufficient power to yield true results. A power of $P = 0.8$ is typically considered sufficient power (Cohen, 1992).

The confidence intervals were calculated in Excel using the following equations:

$$\text{Confidence Interval Limits} = \bar{x}_1 - \bar{x}_2 \pm t * S_p * \left(\frac{1}{n_1} - \frac{1}{n_2}\right)$$

$$\text{Where } S_p = \sqrt{\frac{(n_1-1)*s_1^2 + (n_2-1)*s_2^2}{n_1+n_2-2}}$$

$\bar{x}_1$ is the mean of group 1

$\bar{x}_2$ is the mean of group 2

t was taken from the 95% confidence value on a standard *t*-table using $n_1 + n_2 - 2$ degrees of freedom.

n_1 is the number of samples in group 1

n_2 is the number of samples in group 2

The *P*-values, power values, and confidence interval (CI) limits related to the ANOVA analyses performed are recorded in Tables 28 through 31.

Table 28. ANOVA Results Comparing Heights of Respondents that Had Injuries vs. Those that Did Not

Results Relating Injury to Height, Complete Valid Surveys									
	Neck	Knee	Hip	Shoulder	Ankle	Elbow	Wrist	Upper Back	Lower Back
P-Value	0.90	0.61	0.44	0.10	0.03	0.12	0.09	0.18	0.65
Power	0.052	0.088	0.125	0.365	0.644	0.399	0.478	0.259	0.081
Upper CI Limit	1.88	1.72	1.32	0.29	-0.23	0.47	0.31	0.60	2.11
Lower CI Limit	-2.12	-2.91	-2.97	-3.34	-4.10	-3.87	-3.88	-3.02	-3.35

The respondent's heights were divided into groups based on whether or not the respondent was injured in each location. A statistically significant relation was found between ankle injuries (highlighted in Table 28) and care provider height, but the power value was below .8, so the result does not have sufficient power to detect significance. The comparisons in this category all possess too little power to detect a statistical significance.

Table 29. ANOVA Results Comparing Weights of Respondents that Had Injuries vs. Those that Did Not

Results Relating Injury to Weight, Complete Valid Surveys									
	Neck	Knee	Hip	Shoulder	Ankle	Elbow	Wrist	Upper Back	Lower Back
P-Value	0.90	0.87	0.76	0.75	0.44	0.51	0.31	0.57	0.89
Power	0.052	0.053	0.059	0.061	0.118	0.101	0.187	0.087	0.053
Upper CI Limit	17.68	20.82	20.63	13.04	10.30	12.42	8.73	10.95	24.27
Lower CI Limit	-15.56	-17.73	-15.19	-17.99	-23.44	-24.49	-26.71	-19.57	-21.15

The respondent's weights were divided into groups based on whether or not the respondent was injured in each location. No statistically significant results were produced by this analysis.

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Table 30. ANOVA Results Comparing the Minimum Number of Times a Posture was Required of Respondents that Had Injuries vs. Those that Did Not

Results Relating Injuries to Repetitions of Postures, Complete Valid Surveys										
Posture	Value	Neck	Knee	Hip	Shoulder	Ankle	Elbow	Wrist	Upper Back	Lower Back
Bending	P-Value	0.16	0.07	0.66	0.31	0.65	0.52	0.74	0.72	0.19
	Power	0.284	0.428	0.072	0.170	0.073	0.096	0.062	0.065	0.236
	Upper CI Limit	12.94	16.50	10.15	10.74	9.67	11.35	9.68	8.39	17.23
	Lower CI Limit	-2.15	-0.77	-6.47	-3.53	-6.08	-5.80	-6.96	-5.81	-3.45
Kneeling	P-Value	0.13	0.03	0.78	0.87	0.85	0.63	0.88	0.96	0.19
	Power	0.308	0.530	0.072	0.053	0.054	0.072	0.053	0.050	0.257
	Upper CI Limit	11.71	15.57	6.29	6.85	7.60	5.77	6.77	6.40	15.17
	Lower CI Limit	-1.54	0.58	-8.37	-5.85	-6.29	-9.37	-7.90	-6.12	-3.04
Squatting	P-Value	0.08	0.03	0.25	0.07	0.05	0.13	0.07	0.24	0.07
	Power	0.418	0.622	0.207	0.441	0.499	0.323	0.450	0.216	0.602
	Upper CI Limit	13.78	17.41	12.67	13.02	14.64	14.53	15.00	10.91	19.12
	Lower CI Limit	-0.81	0.78	-3.39	-0.58	-0.16	-1.88	-0.71	-2.78	-0.75
Overex-tending	P-Value	0.16	0.12	0.57	0.02	0.26	0.27	0.47	0.37	0.04
	Power	0.280	0.355	0.092	0.633	0.208	0.208	0.112	0.146	0.747
	Upper CI Limit	12.19	14.70	10.13	13.93	11.59	12.55	10.71	9.72	19.45
	Lower CI Limit	-2.14	-1.84	-5.62	1.02	-3.16	-3.56	-5.00	-3.66	0.36
Reaching Behind You	P-Value	0.24	0.02	0.60	0.09	0.22	0.29	0.36	0.42	0.04
	Power	0.212	0.735	0.081	0.400	0.228	0.173	0.147	0.124	0.785
	Upper CI Limit	10.94	16.55	9.55	11.76	11.41	11.79	10.93	8.99	18.91
	Lower CI Limit	-2.87	1.19	-5.54	-0.93	-2.68	-3.67	-4.06	-3.84	0.69
Straining to Lift a Heavy Weight	P-Value	0.06	0.02	0.40	0.08	0.17	0.33	0.42	0.17	0.06
	Power	0.537	0.782	0.133	0.432	0.268	0.162	0.126	0.280	0.684
	Upper CI Limit	12.06	14.86	9.68	10.86	10.77	10.48	9.57	9.75	16.23
	Lower CI Limit	-0.15	0.88	-3.95	-0.64	-1.98	-3.58	-4.07	-1.73	-0.51

A statistically significant relation was found between knee injuries and the frequency at which care providers utilized the postures kneeling, squatting, reaching behind themselves, and straining to lift a heavy weight. Statistically significant relations were also found between

shoulder injuries and overextending, and between lower back injuries and the postures overextending and reaching behind themselves. All statistically significant values are highlighted in Table 30. None of the relations found in Table 30 can be substantiated, as none of the relations possess sufficient power.

Table 31. ANOVA Results and Power Comparing the Minimum Number of Times a Posture was Required of Respondents ≤ 69.09 in. vs. Those > 69.09 in. Tall

Results Relating Awkward Postures to Height, Complete Valid Surveys						
	Bending	Kneeling	Squatting	Overextending	Reaching Behind You	Lifting
<i>P</i> -Value	0.43	0.22	0.80	0.48	0.05	0.97
Power	0.122	0.217	0.057	0.106	0.560	0.050
Upper CI Limit	4.63	2.52	6.61	4.72	0.01	6.47
Lower CI Limit	-10.70	-10.84	-8.49	-9.85	-13.42	-6.27

There were no statistically significant relations found between the care provider's height and the awkward postures that they had to assume.

Fisher's Exact Analysis

The Fisher's exact analysis was performed in Excel. Fisher's exact for two-by-two tables examines two non-overlapping groups that fit into dichotomous categories and returns a *P*-value that indicates whether or not there is a statistically significant difference between the means of the two groups' answers. Similarly to the ANOVA results, a *P*-value of less than .05 indicates a statistically significant difference between the groups. The results of the Fisher's exact analyses are recorded in Tables 32 through 36.

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Table 32. Fisher's Exact Results Comparing Significant and Insignificant Platform Design Features Between Two Height Groups Complete Valid Surveys

Fisher's Exact Analysis of Groups of Height > 69.09 in. vs. ≤ 69.09 in., Platform Design Characteristics, Complete Valid Surveys				
Platform Design Feature	P-Values	95% Confidence Interval (CI) Lower Limit	95% CI Upper Limit	Odds Ratio
Crew Seats	0.03	0.07	0.94	0.27
Env. Control System	0.04	0.01	1.18	0.16
O ₂ System	0.04	0.03	1.22	0.19
Seat Belts	0.10	0.06	1.29	0.30
Compartment Size	0.33	0.07	2.26	0.46
Communication System	0.50	0.12	2.41	0.53
Patient Loading Capability	0.52	0.11	2.65	0.59
Compartment Configurability	0.70	0.05	3.86	0.60
Lighting System	0.72	0.33	11.22	1.65
Windows	0.75	0.16	2.93	0.69
PPG	0.75	0.28	5.32	1.24
Cabin Ergonomics	1.00	0.22	4.65	1.06
Hoist	1.00	0.19	7.30	1.03
Suction System	1.00	0.17	4.69	0.84
Litter System	1.00	0.14	3.51	0.77
Lack of Litter System	1.00	0.17	4.69	0.84

The Fisher's exact analysis was performed on two groups: care providers above the average height for males in the U.S. Army, and care providers average height or below. The two categories were divided based on whether or not the group found each platform design feature to significantly and negatively affect the mission. A statistical significance was found between these two height groups and whether or not the O₂ system, environmental control system, and crew seats affected the mission negatively. The reference category for this analysis was the group > 69.09 in., so based off of the odds ratios, taller care providers were 73% less likely to find the crew sets to significantly and negatively affect the mission than care providers average height or below, 84% less likely to find the environmental control system to be a negative feature, and 81% less likely to find the O₂ system to be a negative feature.

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Table 33. Fisher's Exact Results Comparing Significant and Insignificant Platform Design Features Between Two Height Groups All Valid Surveys

Fisher's Exact Analysis of Groups of Height > 69.09 in. vs. ≤ 69.09 in., Platform Design Characteristics, All Valid Surveys				
Platform Design Feature	P-Values	95% CI Lower Limit	95% CI Upper Limit	Odds Ratio
Patient Loading Capability	0.04	0.00	1.08	0.14
Lighting System	0.13	0.75	20.45	3.27
O ₂ System	0.16	0.08	1.63	0.36
Seat Belts	0.40	0.16	2.09	0.60
Compartment Size	0.54	0.12	2.45	0.60
PPG	0.56	0.41	5.31	1.48
Litter System	0.75	0.13	2.78	0.67
Cabin Ergonomics	0.76	0.32	5.03	1.31
Env. Control System	0.76	0.20	3.11	0.76
Communication System	0.77	0.21	2.89	0.76
Hoist	0.77	0.32	5.45	1.25
Windows	0.78	0.21	2.62	0.74
Compartment Configurability	1.00	0.14	4.89	0.94
Suction System	1.00	0.21	3.91	0.87
Lack of Litter System	1.00	0.28	4.90	1.11
Crew Seats	1.00	0.26	3.19	0.91

A statistical significance was found between the two groups' answers regarding whether or not they found patient loading to significantly and negatively affect the mission when examining all valid surveys, but not when examining only the complete valid surveys. The crew seats, O₂ system, environmental control system were no longer found to be significant when all valid surveys were examined. Once again, the group > 69.09 in. was the reference group, so based on the odds ratio, tall care providers were 86% less likely to find patient loading capability to be a negative feature that significantly and negatively affected the mission.

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The Fisher's Analysis in Table 34 was performed on male respondents versus female respondents and whether or not they found platform features to significantly and negatively affect missions. No statistically significant differences were found. It is important to keep in mind, however, that the ratio of female to male respondents was quite far from the national ratio.

Table 34. Fisher's Exact Results of Two-by-Two Tables Comparing Significant and Insignificant Platform Design Features Between Males and Females

Fisher's Exact Analysis of Males Vs. Females, Platform Design Characteristics, Complete Valid Surveys				
Platform Design Feature	P-Values	95% CI Lower Limit	95% CI Upper Limit	Odds Ratio
O ₂ System	0.07	0.00	1.94	0.09
Env. Control System	0.19	0.00	3.77	0.18
Windows	0.25	0.32	Impossible to Calculate	Impossible to Calculate
Cabin Ergonomics	0.27	0.19	252.20	4.01
Compartment Configurability	0.49	0.03	46.14	2.14
Hoist	0.53	0.03	34.67	0.54
Communication System	0.54	0.20	Impossible to Calculate	Impossible to Calculate
PPG	0.55	0.16	206.05	3.28
Lack of Litter System	0.56	0.14	Impossible to Calculate	Impossible to Calculate
Seat Belts	0.57	0.01	7.58	0.37
Patient Loading Capability	1.00	0.01	17.49	0.85
Suction System	1.00	0.03	44.21	0.69
Lighting System	1.00	0.04	49.44	0.78
Litter System	1.00	0.02	21.50	1.03
Compartment Size	1.00	0.02	21.50	1.03
Crew Seats	1.00	0.09	117.82	1.88

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The Fisher's Analysis in Table 35 was performed on male respondents versus female respondents. No statistically significant differences were found. Again, the ratio of female to male respondents was quite far from the national ratio.

Table 35. Fisher's Exact Results of Two-by-Two Tables Comparing Significant and Insignificant Platform Design Features Between Males and Females

Fisher's Exact Analysis of Males Vs. Females, Platform Design Characteristics, All Valid Surveys				
Platform Design Feature	P-Values	95% CI Lower Limit	95% CI Upper Limit	Odds Ratio
O ₂ System	0.11	0.00	2.45	0.12
Cabin Ergonomics	0.20	0.25	321.57	5.16
Env. Control System	0.20	0.00	3.98	0.19
Windows	0.25	0.34	Impossible to Calculate	Impossible to Calculate
Compartment Configurability	0.44	0.04	53.04	2.50
Communication System	0.54	0.22	Impossible to Calculate	Impossible to Calculate
Lack of Litter System	0.55	0.17	Impossible to Calculate	Impossible to Calculate
PPG	0.55	0.17	211.96	3.42
Seat Belts	0.59	0.01	8.57	0.42
Patient Loading Capability	1.00	0.02	22.82	1.12
Hoist	1.00	0.04	55.84	0.90
Suction System	1.00	0.03	43.14	0.69
Lighting System	1.00	0.05	60.53	0.97
Litter System	1.00	0.02	27.27	1.33
Compartment Size	1.00	0.02	24.90	1.21
Crew Seats	1.00	0.09	117.84	1.91

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The Fisher's Analysis in Table 36 was performed on male respondents versus female respondents. No statistically significant differences were found. Again, the ratio of female to male respondents was quite far from the national ratio.

Table 36. Fisher's Exact Results of Two-by-Two Tables Comparing Injury Frequency Between Males and Females

Fisher's Exact Analysis of Injuries in Males Vs. Females, Complete Valid Surveys				
Injury Location	P-Values	95% CI Lower Limit	95% CI Upper Limit	Odds Ratio
Neck	1.00	0.02	23.97	1.15
Knee	1.00	0.00	10.44	0.00
Hip	0.14	0.00	2.97	0.14
Shoulder	0.26	0.00	3.60	0.00
Ankle	0.19	0.00	3.77	0.18
Elbow	0.11	0.00	2.61	0.12
Wrist	0.14	0.00	2.97	0.14
Upper Back	0.60	0.01	9.10	0.44
Lower Back	1.00	0.00	17.32	0.00

Skipped Questions Analysis

The skipped sections were also analyzed to check if there were any noticeable trends. The results are displayed in Tables 37 through 38 and Figure 64.

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Table 37. Tally of Respondents that Skipped Each Section and the Number of Respondents that Skipped the Rest of the Survey After Skipping Each Section

Section Content	Number of Respondents that Skipped the Entire Section	Number of Respondents that Skipped Through to End
Basic Information and Demographics	0	0
Platform Design Characteristics that Negatively Impacted Mission Performance	2	2
Items in the Current Aeromedical or Ground Evacuation Medical Equipment Sets Caused Awkward or Painful Postures	8	8
Relation Between Number of Patients and Number of Postures, and Usual Number of Patients	9	9
Frequency of Awkward Posture During Tasks	13	13
Occupational Injuries or Discomfort Associated with Postures During Patient Loading and Patient Care	14	14
Primary Source of Pain and Reasons for not Reporting	14	14

Once a respondent skipped a section, all sections were skipped afterwards, no respondents skipped a single section and continued.

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Table 38. Average Experience Level of Respondents that Skipped Each Section

	Vehicle Design Effects	Equipment	Usual Number of Patients + Increasing Number	Frequency of Awkward Postures	Occupational Injuries	Primary Source of Pain + Reasons for Not Reporting
Average Experience (Years) of Respondents Who Skipped the Section	3.42	6.48	7.09	8.35	7.97	7.97

Note. The sections are ordered sequentially left to right.

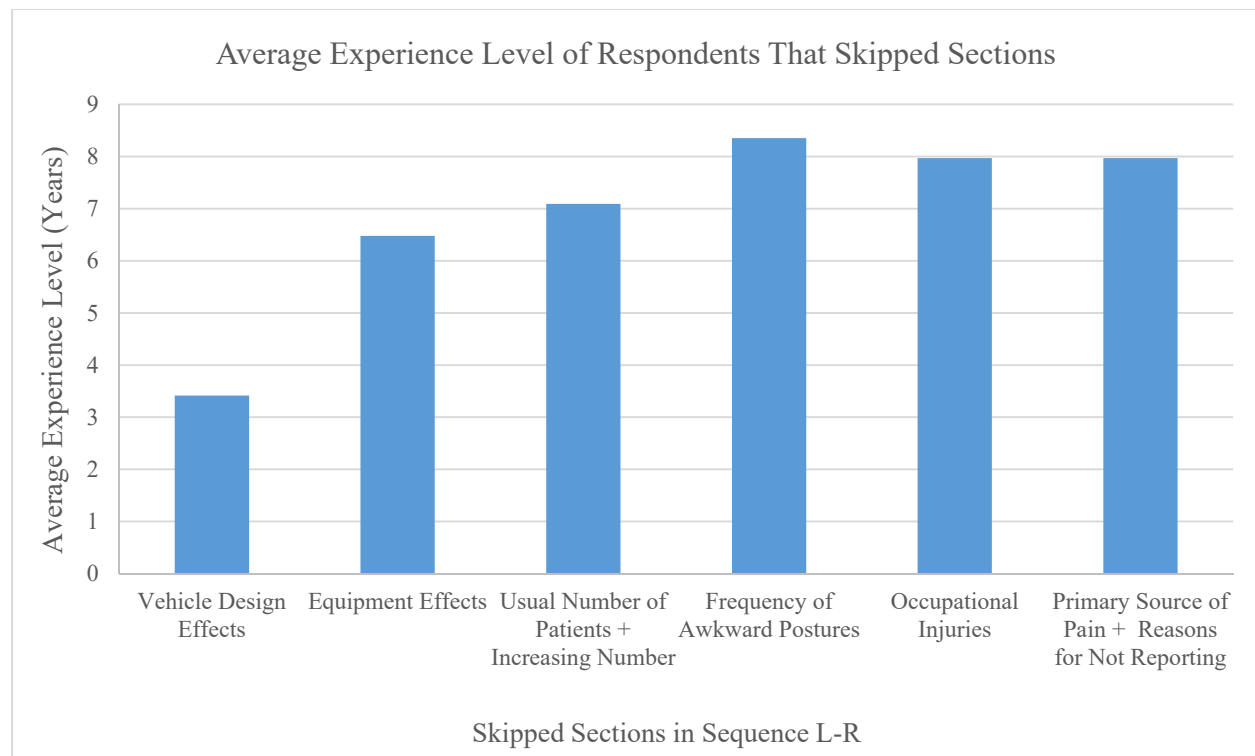


Figure 64. Average experience level of respondents that skipped sections, ordered sequentially from left to right.

As seen in Table 38 and Figure 64, the experience level increased somewhat as the survey continued, meaning the less experienced medics quit responding to the survey earlier.

An ANOVA analysis was performed on the group of complete surveys versus incompletes comparing the number of vehicle design characteristics that the respondents found significant in order to see if those who found more issues with the platforms were willing to complete more of the survey. The result was a P -Value of $P = 0.342$, meaning that there is not a statistically significant difference between the groups.

Discussion

In Section 2, Compartment Configurability, the Litter System, Cabin Ergonomics, Compartment Size, Patient Loading Capability, and PPG were all found to negatively affect mission by over 60% of respondents. Out of those six features, four of them (Compartment Configurability, the Litter System, Cabin Ergonomics, and Patient Loading Capability) had the litter pan system or lifting littered patients as one of the main problems with the feature.

In Section 3, most of the respondents did not find the medical equipment to cause awkward or painful postures. The piece of equipment that caused the most painful postures was the litter, which was cited by 34.8% of respondents when analyzing all valid surveys. The patient monitor, defibrillator, O₂ bottle with regulator, trauma panel, and Sked[®] BRS were all cited as causing painful postures by 21% to 26% of respondents. The factors that all of these items shared that negatively affected the mission was that they caused painful postures, were cumbersome or difficult to use, and were difficult to store properly (the last factor applies to all but the litter).

In Section 4.1, 94% of respondents agreed that an increasing number of patients increases the amount of painful postures that must be utilized by care providers, and in Section 4.2 almost half (49%) of respondents reported usually caring for one patient at a time. The results of this survey indicate that awkward positions, especially bending, are the leading causes of lower back injuries, which 87% of respondents had sustained. Even though almost half of the respondents only care for one patient at a time, the majority of respondents have suffered lower back injuries.

In Section 5, Load/Unload Littered Patients was among the top causes of awkward postures such as bending, overextending, kneeling, and squatting. The majority of participants responded to this section in detail, however it is possible that some participants may have copied their answers across all actions. Four participants provided the same postures required for all actions, and there is no means of telling if those were genuine answers, or if they were simply copied across all actions.

In Section 6, every type of injury had more counts of being unreported than reported. Lower back, knee, neck, shoulder, and upper back injuries were prevalent among respondents. Lower back injuries were the most common among respondents, suffered by 87% of respondents. Awkward positions, especially bending, lifting patients, and flight gear/body armor were the leading causes of lower back injuries among respondents. The leading cause of knee injuries was kneeling/crawling. The leading causes of neck injuries were NVGs and helmets, and many comments cited the combination to be particularly painful. The leading causes of shoulder

injuries were workplace injuries and moving patients. The leading causes of upper back injuries were lifting patients and bending/awkward positions.

Comparing the results of this study to the results of the previously mentioned civilian EMS study (Maguire et al., 2005), the most common occupational injury among survey respondents was to the lower back (87%), similar to the civilian EMS study where the back was also the most injured location. In the civilian EMS study, many injuries were related to the stretcher, and in the survey responses the litters were the second most cited issue, after awkward positioning/bending. Many respondents cited more than one reason for their injuries and some respondents did not give an explanation of the cause of their injuries, so the following percentages are based on the frequency at which an issue was mentioned by the respondents with respect to the total number of reasons for that injury given by all respondents. For lower back injuries among respondents, 30.0% of the cited issues were related to lifting patients and 37.5% were related to awkward positions/bending.

Analysis was not performed to relate platform or job title to injuries or postures used because there was too much data overlap. Since 93.47% of respondents were CCFPs and four of the job title categories only represented approximately 2% to 4% of respondents each, the imbalance was not conducive to obtaining any results related to job title.

Analysis between male and female participants was conducted to see if any correlations could be found and perhaps explored in the future to substantiate them, but those analyses cannot be representative of the entire population due to the low percentage of female respondents.

Note that this survey was not presented to all 68Ws, so it cannot represent the entire population, but rather the subset who responded to it. It is still valuable information that provides insight, but the entire population cannot be accurately represented by the information provided.

Recommendations

Since the studies are in agreement that back injuries are the most prevalent among care providers, it would be prudent to focus on solving issues that cause back problems. According to survey results, finding a way to minimize the stress placed on the care providers while lifting and loading patients would contribute significantly to reducing the amount of back injuries. Also, the current cabin area necessitates that care providers bend and kneel frequently to care for patients. Designing cabin areas and litter pan systems with the intention of minimizing these awkward postures would significantly reduce the amount of back and knee injuries suffered by care providers.

Some recommendations regarding the survey method itself and analyzing the responses are as follows:

- 1) Do not have blanks as possible negatives, request that all respondents clearly state a negative answer so that blanks may be interpreted as a skipped question.

- 2) Put the information that is most valuable at the beginning of the survey so if the respondent grows tired and quits, there is a greater chance that the most important information was collected.
- 3) Have the analysis plan put together at the same time as the survey so the format is best for analysis.
- 4) It may be best to have incentives for longer surveys to encourage complete data sets.
- 5) Technical errors in data recording software and/or presentation of questions led to occasional missing data points, which needs to be further evaluated before selecting a platform for web surveys.

Conclusion

The results of this study may be used in conjunction with other studies to develop mitigation plans in order to reduce the stress factors in the MEDEVAC environment which contribute to injuries and MSDs in care providers.

Lower and upper back injuries sustained from lifting and loading patients are an apparent area of interest for developing mitigation plans, especially since these can be seen in U.S. Army and civilian EMS care providers and could provide opportunity for joint efforts between researchers on both sides.

A frequent issue among respondents was the necessity of kneeling or squatting while caring for patients, which were reported as the leading causes of knee injuries. Mitigation plans which reduce the need for kneeling or squatting, or at least implement knee pads as a standard provision in MEDEVAC platforms, may be able to reduce the number of knee injuries among MEDEVAC care providers.

There are numerous results in this study which could inform future research into mitigation plans, from the combined effects of night vision goggles/head supported mass and helmets in causing neck injuries to the effect of the cabin interior of MEDEVAC platforms in causing painful postures.

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Appendix

Medical Provider Posture and Injury Survey

This questionnaire is anonymous and voluntary. No information about your identity is collected and there is no way for anyone to link you to participation in the study. The purpose of this research is to gather information from U.S. Army en route medical care providers (air and ground transport) on their experiences related to occupational stressors such as awkward postures, strain, and fatigue. The survey addresses the question, "Do awkward postures and lifting demands associated with confined space medical interiors cause occupational injuries?" Results will be used to identify stressors and injuries, recognize their sources, and recommend solutions to the U.S. Army medical community. U.S. Army Soldiers and their families will benefit from this study.

The survey is mostly comprised of fixed questions and short open-ended responses. Please answer to the best of your ability. The survey will take approximately 10 minutes to complete and gives you a unique opportunity to have your voice heard. We are seeking open and honest feedback.

If you are completing the survey online, your answers will be saved each time you move forward to the next page. Once you have completed the last question, your full survey will be saved when you see a "thank you" message. If completing this survey on paper, please insert it in the envelope included with the survey and mail without your name on the envelope. If you are completing the survey on paper with a study team member, place your survey in the blank envelope and drop it in the designated box located in the room. None of the envelopes will be opened until the research team is in a secure location at USAARL. If you have questions about the research at any time, you should contact Rachel Kinsler at 334-255-6982.

You may decline to participate now, or stop taking part in this research at any time, without any penalty or loss of benefits to which you are entitled. If you are completing the survey online, just close the browser window. If you do not want questions you answered before closing the window to be used in the study, please contact Rachel Kinsler at 334-255-6982. If you are taking the survey on paper, just destroy your survey or insert the survey back into the envelope and drop it in the designated box.

We appreciate your assistance in completing this important study.

Figure A1. Page 1 of the Medical Provider Posture and Injury Survey.

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1. What is your gender?
☐ Male ☐ Female

2. What is your height in inches?

3. What is your age?

3. What is your weight in pounds?

4. In the blanks below, please provide your job position and general platform/location when you performed the majority of your duties as a medical care provider in addition to the length of time you were in that position?

Job Position as Medical Care Provider	Platform/Location	Length of Time You Performed This Job Position

Job position examples: Critical Care Flight Paramedic (CCFP), Flight Nurse (FN), Ground Medic (GM), etc. Please feel free to abbreviate.
Platform/Location examples: hospital or clinic, on an HH-60M, UH-72, UH-1, in a field hospital, in an FLA, Stryker, etc. Specific names of clinics, tail numbers, etc. are not needed.

5. Please select aircraft/vehicle/gear design characteristics from this list that negatively affected your mission performance or caused you to perform your mission as a care provider in awkward or painful postures and discuss the negative impacts.

	Design Characteristic	How This Negatively Impacted You or The Mission
☐	Patient loading capability	
☐	Cabin ergonomics (i.e., crew comfort)	
☐	Cabin/patient compartment configurability	
☐	Hoist	
☐	O ₂ system	
☐	Environmental control system	
☐	Suction system	
☐	Lighting system	
☐	Seat belts	
☐	Litter systems	
☐	Lack of litter system	
☐	Cabin/patient compartment size (dimensions-length, width, height)	
☐	Windows (SMART, etc.)	
☐	Crew seats (please be specific)	
☐	Communication system	
☐	Personal protective gear (body armor/helmet)	
☐	Other:	

Figure A2. Page 2 of the Medical Provider Posture and Injury Survey.

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6. Which of the following items in the current Aeromedical or Ground Evacuation Medical Equipment Sets caused you to use an awkward or painful posture? Use the blank provided to list the posture, such as squatting, kneeling, bending at the waist, twisting, reaching behind you, over-reaching, etc. The blank will expand as you type.

	Item	Awkward/Painful Posture
☐	Monitor	
☐	Defibrillator	
☐	Ventilator	
☐	I.V. pump	
☐	Suction	
☐	EZ-IO kit	
☐	SMEED	
☐	Medical aid bag	
☐	Medication box	
☐	Fluid warmer	
☐	Oxygen bottle with regulator	
☐	Traction splint	
☐	Spine board	
☐	Trauma panel	
☐	SKEDCO	
☐		
☐	Spine splint	
☐	Thermometer	
☐	Glucometer	
☐	Litter	
☐	Litter straps	
☐	Other	

7. Assuming the average transport time will be approximately 30 minutes, would the number of patients cared for increase the likelihood of awkward or painful postures for the care provider?

☐ YES ☐ NO

8. On average, how many patients do you typically provide care for at one time?

Figure A3. Page 3 of the Medical Provider Posture and Injury Survey.

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9. Please read each task and rate the frequency you have experienced each awkward posture during each task listed.

Write in "1" for once per patient

Write in "2" for multiple times per patient per flight

Leave the space blank for never

You may add additional answers at the end

	Bending at waist	Kneeling	Squatting	Overextending arms, legs, or torso	Reaching behind you	Straining to lift heavy weights
Load/Unload patients on a litter						
Loading patients NOT on a litter						
Assessment requiring full patient exposure						
Initiate peripheral IV						
Administer blood / blood products						
Provide care for a suspected spinal injury						
Ventilate a patient with a bag-valve-mask system						
Perform oral suctioning / endotracheal suctioning						
Inserting an endotracheal tube						
Initiate treatment for an open abdominal wound						
Application of tourniquet						
Initiate an EZ Intraosseous device						
Applying splint						
Perform intubation						
Perform a surgical cricothyroidotomy						
Perform a needle chest decompression						
Insert a King LT						
Insert and manage a chest tube						
Initiate treatment for a head injury						
Immobilize the pelvis						
Apply pressure dressing to axillary/femoral wounds						
Using monitor, ventilator, suction, pleurovac together						
Performing a log roll						
Administering CPR						
Dressing wounds						
Utilize warming equipment (such as fluid warmer)						
Apply warming blankets						
Other:						
Other:						

Figure A4. Page 4 of the Medical Provider Posture and Injury Survey.

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Please remember answers about injuries are anonymous and will not be reported or recorded into your records.		
10. Complete the questions below if you have experienced occupational injuries or discomfort associated with any postures during patient loading and patient care.		
	Injury was not reported	Reported/Treated by a physician
Neck		
What caused this injury/discomfort?		
Knee		
What caused this injury/discomfort?		
Hip		
What caused this injury/discomfort?		
Shoulder		
What caused this injury/discomfort?		
Ankle		
What caused this injury/discomfort?		
Elbow		
What caused this injury/discomfort?		
Wrist		
What caused this injury/discomfort?		
Upper back		
What caused this injury/discomfort?		
Lower back		
What caused this injury/discomfort?		
Other:		
What caused this injury?		
11. For injuries that you did not report, what were your reasons for not reporting?		
12. Do any specific postures or tasks cause your primary source of pain? Please explain.		
13. Please discuss any other injuries you may have experienced related to patient care/loading.		
Thank you for contributing to our study. We appreciate your support.		

Figure A5. Page 5 of the Medical Provider Posture and Injury Survey.

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Acronym/Abbreviation List

ANOVA – Analysis of Variance
BAM – Blackhawk Advanced Medevac
CI – Confidence Interval
EMS – Emergency Management System
ICS – Integrated Communication System
In. – Inches
Lbs. – Pounds
MEDEVAC - Medical Evacuation
MES – Medical Equipment Set
MSD – Musculoskeletal Disorder
USAARL – U.S. Army Aeromedical Research Lab



Department of the Army
U.S. Army Aeromedical Research Laboratory
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Appendix C. Quad Chart.

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En Route Care in Confined Spaces: Impact of Transport, Immobilization Practices, Space Constraints and Medical Awareness Enhancements

DM167047 Joint En Route Care Award - Intramural



PI: Rachel Kinsler

Org: U.S. Army Aeromedical Research Laboratory

Award Amount: \$3,724K

Study/Product Aim(s)

- Project 1: Evaluate the effect of patient weight as a factor under two immobilization conditions including litter with no board and litter with board.
- Project 2: Administer survey of En Route Care providers regarding posture
- Project 3: Evaluate incorporation of audio medical alarms into Integrated Communications System (ICS)
- Project 4: Quantify forces/motions and Medic postures during patient handling to include litter dropping and loading/unloading.
- Project 5: Evaluate effects of patient strapping protocols and the amount of tension applied using current strapping protocol to determine the transmitted forces and pressure points on the body during transport. Forces transmitted to the supine human body under whole-body vibration and repeated shock will be quantified.

Approach

Protocols will be written for each Project. Volunteers will be used for data collection. The team will use USAARL's Multi-Axis Ride Simulator (MARS) platform and the research JUH-60A for aircraft data collection.



Project 1 and Project 2 data collection is complete. Data has been analyzed. Technical reports for both projects have been written. Pictured: example of subject secured in immobilization equipment from medical equipment set (Project 1) and example of awkward Medic posture during a litter loading exercise (Project 2).

Timeline and Cost

Activities	FY	17	18	19	20	21
Evaluate patient weight with board vs no board						
Administer survey of En Route Care providers regarding posture						
Incorporation of medical alarms into ICS						
Quantify forces during patient handling and Medic posture assessment						
Effect of strapping configuration, transmitted forces, pressure points						
Estimated Budget (\$3.724M)		\$746K	\$742K	\$750K	\$749K	\$737K

Goals/Milestones

FY17 Goal

- ☒ Draft protocols for Projects 1, 2, and 3

FY18 Goals

- ☒ Submit protocols for approval
- ☒ Draft protocol for Project 4
- ☒ Begin data collection

FY19 Goals

- ☒ Complete data collection for Projects 1 and 2
- ☒ Analyze collected data

FY20 Goals

- ☐ Complete data collection for Project 4
- ☐ Draft protocol for Project 5

FY21 Goals

- ☐ Complete data collection for Projects 3 and 5

Comments/Challenges/Issues/Concerns

N/A

Budget Expenditure to Date

Projected Expenditure: \$2,200K

Actual Expenditure: \$2,200K

Updated: 15 October 2019