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Abstract

Objectives: To compare paramedics' ability to minimize cervical spine motion during patient transfer onto a vacuum mattress with two stabilization techniques (Head Squeeze vs. Trap Squeeze) and two transfer methods (log roll with one assistant (LR_2) vs. 3 assistants (LR_4)).

Methods: We used a cross-over design to minimize bias. Each lead paramedic performed 10 LR_2 transfers and 10 LR_4 transfers. For each of the 10 LR_2 and 10 LR_4 transfers, the lead paramedic stabilized the cervical spine using the Head Squeeze technique five times and the Trap Squeeze technique five times. We randomized the order of the stabilization techniques and LR_2 / LR_4 across lead paramedics to avoid a practice or fatigue effect with repeated trials. We measured relative cervical spine motion between the head and trunk using Inertial Measurement Units placed on the forehead and sternum.

Results: On average, total motion was 3.9° less with three assistants compared to one assistant (p=0.0002), and 2.8° less with the Trap Squeeze compared to the Head Squeeze (p=0.002). There was no interaction between the transfer method and stabilization technique. When examining specific motions in the six directions, the Trap Squeeze generally produced less lateral flexion and rotation motion but allowed more extension. Examining within paramedic differences, some paramedics were clearly more proficient with the Trap Squeeze technique and others were clearly more proficient with the Head Squeeze technique.

Conclusion: Paramedics performing a log roll with three assistants created less motion compared to a log roll with only one assistant, and using the Trap Squeeze stabilization technique resulted in less motion than the Head Squeeze technique. However, the clinical relevance of the magnitude remains unclear. However, large individual differences suggest future paramedic training should incorporate both best evidence practice as well as recognition that there may be individual differences between paramedics.

Introduction

The majority of spinal cord injuries occur at the cervical level [1-3] as a consequence of trauma related to road accidents, sport and leisure activities.[4] Trauma accounts for 20% of pre-hospital paramedic calls,[5] with approximately 3% of these victims having spinal fractures. Spinal cord damage occurs in 12% of trauma victims with spinal fractures,[6] although such damage can also occur in unstable spine injuries without fracture.[2, 3] To minimize spinal cord damage, current guidelines for pre-hospital management of cervical spine injured patients dictate they should be stabilized prior to transport to a medical facility.[7-9] Further, cervical spine stabilization is recognized as a research priority in both adult and pediatric pre-hospital research.[10, 11]

During pre-hospital management, patients with suspected cervical spine injuries are transferred and secured onto a stable surface (e.g. vacuum mattress, spine board[9]) by a team of rescuers. Although a spine board is used for transfer to hospital in most of North America, the vacuum mattress is often used within Quebec and Europe.[12] Vacuum splints (small cushions) were originally developed in 1970 for use during surgery [13] and peripheral fractures,[14, 15] and later enlarged to allow stabilization of the entire patient. In general, a vacuum mattresses is associated with 30%-85% reduced motion compared to a spine board in simulated experiments,[16, 17] and provide for more patient comfort.[12, 18]

The two main methods of transferring a patient onto a stable surface are the log roll (LR) and the lift-and slide. Although the lift-and-slide results in less motion compared to the LR [19-23], the current standard of care in the paramedic context is to transfer a patient onto a spine board using a standard LR technique [9] conducted with 1-3 assistants depending on availability.[9] This is because the lift-and-slide is often not feasible given it requires 6-8+ persons, and several feet of space around the patient on all sides [9, 22]. With the vacuum mattress, an additional step (compared to the spine board) is required to position the patient into the middle of the semi-rigid mattress (Figure 1). In Quebec, prior to the LR, a bed sheet is placed on the vacuum mattress. When the patient is log rolled back into the supine position, they are lying on the bed sheet, which is partly on the vacuum mattress. The patient is then slid into the centre of the mattress by pulling the bed sheet, just as one would move a patient from one stretcher to another stretcher in the hospital.

While the patient is log rolled, the lead paramedic attempts to limit cervical spine motion using a manual stabilization technique. There are two published accepted techniques. In the "Head Squeeze" technique, the lead paramedic holds the sides of the head with both hands and tries to minimize cervical spine motion by matching head motion with trunk motion.[24, 25] In the "Trap Squeeze" technique,[19, 26, 27] the lead paramedic grabs the patient's upper shoulders and muscles on either side of the neck (trapezius muscle) and firmly squeezes the head between the forearms. In this way, the lead paramedic limits cervical spine motion by stabilizing the head (via the forearms) to the trunk (via the grip on the trapezius).

Although the Trap Squeeze is superior compared to the Head Squeeze (<10° vs >20°) when a patient is agitated,[19] it was only slightly superior to the Head Squeeze for a cooperative patient during a LR conducted with 3 assistants.[19] These results may not be generalizable to paramedic pre-hospital care conditions where paramedics work in pairs, and there is often only one assistant immediately available. Therefore, the primary objective of this study was to compare paramedics' ability to limit overall cervical spine motion with two cervical spine stabilization techniques (Head Squeeze vs. Trap Squeeze) and two transfer methods (LR with one assistant (LR_2) vs. LR with 3 assistants (LR_4)). Our secondary objective was to compare the intra-paramedic variability of performance when using the Trap Squeeze vs. Head Squeeze under the different transfer methods.

Methods

We recruited paramedics with at least one-year experience from Montreal, Canada and the surrounding areas through 1) email notifications to potential participants identified by Urgences-santé, the ambulance system for Montreal and Laval, and 2) conducted on-site visits to Urgences-santé operational centres. The Research Ethics Committee of the Jewish General Hospital in Montreal Quebec approved the study.

Procedures

After providing consent, paramedics underwent a standardized training session lasting between 20 min and 45 min depending on the number of paramedics and their previous experience with the different transfer methods and stabilization techniques. In brief, we standardized processes so all paramedics used the same methods to LR and slide the patient into the centre of the vacuum mattress. Although participating paramedics had some knowledge of the Trap Squeeze, many had never used it in the field. We reviewed common errors leading to excessive extension or lateral flexion. Training continued until paramedics felt comfortable using the techniques (range ~20-50 min). Following the standardization session, paramedics completed a short demographic questionnaire.

Study Design

As in previous studies by our group and others,[19, 23, 28] we used a standard epidemiological crossover design to minimize confounding bias and variability. In this design, the paramedic responsible for cervical spine stabilization at the head (lead paramedic) performed each of the "interventions" (i.e. the combination of transfer method and stabilization technique) on the same standardized patient (SP). In the analysis, the cervical spine motion of the SP is the unit of analysis, and we only compare results of each lead paramedic to themselves (i.e. within lead paramedic comparisons) to minimize confounding bias due to lead paramedics' personal characteristics. In addition, to eliminate bias due to variability in different SP characteristics, each lead paramedic used the same SP across all methods and techniques.

Each lead paramedic transferred a supine SP from the ground to a vacuum mattress 10 times using LR_2 and 10 times using LR_4. For each of the 10 trials in LR_2 and LR_4, the lead paramedic used the Head Squeeze technique five times and the Trap Squeeze technique five times. We randomized the order of the stabilization techniques and LR_2 / LR_4 across lead paramedics to avoid a practice effect or a fatigue effect with repeated trials. The lead paramedic was assisted by other paramedics attending the same data collection session, or persons specifically trained in the LR_2 and LR_4 transfer method.

Transfer Methods (Figure 1)

LR_2: The fully cooperative SP lay supine (head / neck in the neutral position) with a cervical collar, and the mattress placed to their right side. The lead paramedic manually stabilized the cervical spine at the head, with the assistant rescuer placed at the patient's left side (approximately at the abdominal level). The assistant reached over and placed his or her hands at the patient's right shoulder and pelvis. At the count of the lead paramedic (1-2-3-Roll), the body was rolled 90° until it faced the side, the vacuum mattress was slid into position, the bed sheet was tucked under the SP, and the patient was rolled back onto the bed sheet and vacuum mattress. The end of the bed sheet was rolled over the SP encircling the SP's body. The assistant then moved to the right side of the SP, took the two ends of the bed sheet below and above the SP, and on the count of the lead paramedic, slid the patient into the centre of the vacuum mattress.

LR_4: This is similar to the LR_2, but there are 3 assistants[9] positioned on the patient's left at the chest, abdomen and mid-thigh level. Each assistant reaches over and places their hands on the right side of the patient, ensuring that their arms cross with the assistant next to them. The log roll and placement into the vacuum mattress are the same as LR_2.

Manual Stabilization Techniques

Head Squeeze:[25] The lead paramedic firmly holds the SP's occiput in their own palms. The ulnar fingers are on the mastoid process so the 2nd and 3rd fingers can apply a jaw thrust if necessary. If the body slips during the transfer or the patient initiates movement, the lead paramedic tries to maintain the cervical spine in a neutral position by matching head to body movement

Trap Squeeze:[19, 26, 27] The hands of the lead paramedic are placed with the thumb anterior to patient's trapezius muscle, the 2nd / 3rd fingers posterior to the trapezius muscle and the forearms squeeze the head firmly. If a patient moves, the head is held still with the forearms, and lead rescuer applies pressure to the clavicles and trapezius muscles to prevent trunk movement. The forearm placement is approximately at ear level. Theoretically, the Trap Squeeze should be superior to the Head Squeeze because it connects the head to the trunk through the lead paramedic's forearms thereby stabilizing above and below the fracture site. If the forearms are too far posterior, the head may slip anteriorly (neck flexion). If the forearms are too far anterior, the head may slip posteriorly (neck extension). Our experience also suggests the risk of forcing the cervical spine into lateral flexion during the LR is decreased if the rescuer's forearms are placed parallel to the floor (i.e. elbow and wrist the same distance from the floor).

Main Outcome: Measures of Cervical spine Motion (Figure 2)

We assessed total cervical spine angular motion (in degrees) by measuring changes in orientation of the head relative to the trunk motion using inertial measuring units (IMUs) placed on the forehead and sternum of each SP.[19] IMUs are comprised of a triad of sensors (accelerometers, gyrometers and magnetometers) and a fusion algorithm that estimate the orientation of the module, and hence the orientation of the body segment it is attached to, in a global reference frame based on gravity and magnetic north. IMUs are used in aerospace, marine and automotive fields and are now increasingly used for human motion tracking in several clinical applications.[29-43] We used IMUs from Xsens Technologies (XSens MTx, www.xsens.com). Under controlled conditions of motion using a Gimbal table, the Xsens MTx IMUs have demonstrated an absolute mean precision of 0.3° to 1.0° depending on the axis of rotation under slow conditions of motion when compared to an optical motion tracking system (Optotrak).[44]

Our primary outcome was peak change in angular motion (degrees) of the head relative to the trunk from an initial neutral position, calculated directly from data provided by the IMUs (Figure 2, top). Our secondary outcome (to understand where paramedic technique could be improved) was again peak angular motion of the head relative to the trunk, now expressed in each of the six anatomical directions (flexion, extension, right and left lateral flexion, right and left rotation) relative to the initial position of the SP (Figure 2, bottom).

Analysis

The data on demographics and experience were highly skewed so we report median and ranges. We used standard analytical methods for crossover designs that provided answers to similar questions in our previous study.[19, 23] For total angular motion (primary outcome), we used a multi-level regression model with the main techniques (Head Squeeze vs. Trap Squeeze) and transfer methods (LR_4 and LR_2) as fixed effects, and the lead paramedic as a random effect variable (to account for repeated measures on paramedics). We also included an interaction term in the statistical model to test if the amount of cervical spine motion with Trap Squeeze vs. Head Squeeze is dependent on the type of transfer method used (e.g. Trap Squeeze superior to Head Squeeze for LR_4 but inferior for LR_2). We conducted a similar secondary analysis comparing angular motion in each of the six individual directions.

We used the methods described in our previous publication[19] to explore whether some paramedics are more proficient at the Trap Squeeze and others less so. For each paramedic, we plotted the mean of the five trials for Trap Squeeze against the mean of the five trials for Head Squeeze, along with the line of identity to easily visualize the number of paramedics more proficient at one method versus the other. We conducted a similar analysis examining the sd, and maximum motion that occurred, across each set of five trials.

Sample Size Calculations

In our original protocol, our calculations suggested we needed a sample size of 40 paramedics to determine a minimal important difference (MID) of 3° between transfer methods or stabilization techniques for the total motion, and for 4/6 anatomical direction motions. This was based on the multi-level design / analysis of our study [45] with 5 trials per lead rescuer per transfer method/stabilization technique combination.[46] We estimated the variances as 10% higher (increase in sd by 30%) than our previous study because 1) one LR would now be performed with only one assistant, and 2) we previously used lead rescuers with more than six months experience with both the Head Squeeze and Trap Squeeze techniques. Because we were forced to drop a third transfer method from the protocol (a lift-and-slide transfer using four rescuers was not studied because the vacuum mattresses were too wide),[9] we re-calculated the sample size using the observed variances after 19 paramedics, and determined that 20 paramedics would provide over 97% power for each of our outcomes. Even using the lower 95% confidence interval for our variance estimate, our power would still be greater than 95%.

Results

The mean age of the 21 paramedics studied was 37 (range: 22 to 62) and 52% were female. The demographic information of the paramedics is described in Table 1. Paramedics were experienced in cervical spine management (median of 8 years) with both transfer methods. All paramedics had used the Head Squeeze technique at work. Only eight paramedics used the Trap Squeeze at work, although all had learned it at some point in their career. Almost all paramedics preferred LR_4 vs. LR_2, and just over half preferred the Head Squeeze to the Trap Squeeze, likely due to experience and previous training with these methods.

Our main results are shown in Table 2. Overall, the Trap Squeeze resulted in two to three degrees less motion than the Head Squeeze, and the LR_4 resulted in approximately three degrees less motion than the LR_2; the effectiveness of the Trap Squeeze was independent of the transfer method (p=0.42 for the interaction term). Compared to the Head Squeeze, the Trap Squeeze resulted in less left lateral flexion and left rotation but more extension. Compared to LR_2, LR_4 resulted in less flexion, right lateral flexion, and both left and right rotation. There was no significant interaction between transfer method and stabilization technique for any of the individual motions.

Figure 3 is a plot of the sd during the five Trap Squeeze trials versus the five Head Squeeze trials for both LR_2 and LR_4 in each of the six directions of motion. By visual inspection, there was little difference for most paramedics but several paramedics had much greater sd during the Head Squeeze and LR_2 trials. Similarly, in Figure 4, the maximum motion among the five trials was generally similar between stabilization techniques and transfer methods, except that some paramedics had much larger motion for right and left lateral flexion and rotation with Head Squeeze, but much larger motion for extension with Trap Squeeze.

Discussion

Our results suggest that on average, paramedics are slightly better at minimizing total cervical spine motion during transfer onto a vacuum mattress when using the Trap Squeeze stabilization technique compared to the Head Squeeze, and when using the LR_4 transfer method compared to the LR_2. The clinical relevance of the magnitude of these differences remains unclear. Similarly, the variability among trials was generally less with the Trap Squeeze. When examining specific motions in the six directions, the Trap Squeeze generally produced less motion for lateral flexion and rotation but allowed more extension. Although there is no consensus on what is considered a safe amount of motion and less motion is always considered better,[9] these differences were small compared to the overall motion.

The finding that the Trap Squeeze results in slightly less motion than the Head Squeeze except for extension under the ideal conditions of our experiment are consistent with theory. In brief, the technique should improve synchronization between the lead rescuer and assistants because it connects the body to the trunk. We believe the observed increased extension occurred because the forearms of the lead paramedic were placed too anteriorly on the head due to the limited training available during the study. Although all paramedics had once been taught the technique, only a minority of them ever used it. Within our training session, they spent 15-20 min specifically learning the technique for both a confused patient and during the LR. In our previous study using sport therapists experienced with the technique for more than six months, we did not observe increased extension.[19] That said, we studied paramedics under ideal conditions and the relative effectiveness of the Trap Squeeze under non-ideal conditions (e.g. head is wet, helmeted athlete, assistant slips and patient suddenly shifts) remains to be determined.

Our results suggested the LR_4 is only slightly superior to the LR_2. However, paramedics commented that our SPs were fit young men (~20 years old, 75-85 kg) and easy to LR. The effect of different size SPs should be explored in future studies.

The overall motion during the transfer onto the vacuum mattress was generally similar to our previous study using sport therapists as rescuers, although there was slightly more extension in the current study for both the Head Squeeze and Trap Squeeze. When rescuers place a patient onto a spine board, the board is clearly flat and one can easily slightly elevate the occiput with an occiput pad. Although a vacuum mattress has several advantages over a spine board that include less motion during the types of sudden shifts that would occur during ambulance transport, one disadvantage is that the beads within the mattress cannot be easily molded into a flat surface like a spine board.

Examining the mean results and variability of individual lead paramedics, clearly some paramedics were superior with the Head Squeeze and others were superior with the Trap Squeeze. Although more training might increase the number of paramedics being superior with one technique, we believe individual differences would remain. First, further training with the Head Squeeze is unlikely to affect results because all paramedics had extensive experience with this technique. Second, LR with the Trap Squeeze requires a certain level of agility for the lead paramedic or the cervical spine will be forced into right lateral flexion. Therefore, although further training would improve placement of the paramedic's forearms during the Trap Squeeze and almost certainly decrease extension (extension was less with Trap Squeeze compared to Head Squeeze with trained therapists[19]), we believe the Trap Squeeze will simply be too difficult for some paramedics based on their anatomical and physiological characteristics. Therefore, it would seem prudent to allow paramedics to use whichever technique is best for themselves rather than have one policy that requires paramedics to use a technique for which they might not be proficient. However, training protocols that stress a best-evidence practice should look to the Trap Squeeze as the preferred method for most paramedics due to the lower amount of movement.

Limitations

Published cervical spine stabilization studies have been performed with either conscious simulated patients [19, 47, 48], or cadavers with surgically induced cervical spine lesions [20, 49] using different types of motion capture systems and environments. Each approach has its merits and limitations depending on the research question studied and the scope of the investigation targeted. The use of cadavers with surgically induced cervical spine instability offer better mechanistic insights into inter-vertebral motion induced during cervical spine management for well constrained conditions (ex: airway management) but represents only a worst-case clinical scenario when there is an unconscious patient where active muscle stabilization of the spine is eliminated; the protective muscle tone present in conscious patients cannot be reproduced in this model. Variations in the cadaver's conditions and the surgical induced instability can also affect the conditions of measurements. Alternatively, the use of simulated patients allows one to study more complex clinical scenarios performed under less constrained conditions, but has its own limitations. The principal outcome for this study was cervical spine angular motions measured with IMUs placed on the forehead and sternum of each SP and expressed as changes in orientation of the head relative to the trunk (total range of motion and motion expressed anatomically). While IMUs offer multiple advantages over traditional optical or magnetic based motion capture systems for studying cervical spine stabilization in the scenario tested (i.e. bigger and less constrained capture volume, not sensitive to visual obstructions, more robust to magnetic perturbations) they only provide measures of orientation and can't be used to measure translational motions. Translational motions could play an important role in secondary injuries occurring during cervical spine management. However, optical or magnetic based motion tracking system could not be used reliability in the scenarios we tested. We decomposed total range of motion into anatomical plane of motion by modeling cervical spine motion as rotations of the head around a pivot point using calibration motion performed in each anatomical plane of motion. Although flexion and extension are relatively simple to model with IMUs, the results for lateral flexion and rotation should not be interpreted literally but rather as a combined motion.

We used a MID similar to previous studies of 3°.[19, 50] Although this magnitude has face validity, establishing a true MID is difficult because measurements during cervical spine stabilization of real patients are limited by their accuracy, and extrapolation from cadaveric normative data may not be applicable to live humans.

Our results evaluated the placement of the standardized patient onto a vacuum mattress. Whether the same results would be obtained using a spine board remains to be determined.

Conclusion

Our results suggest that there is statistically significant but small reduction in motion when the log roll is conducted with three assistants compared with only one assistant, and when conducted with the Trap Squeeze compared to the Head Squeeze stabilization technique. However, there were large individual differences between lead paramedics. Future paramedic training should incorporate best-evidence practices as well as recognition that there may be individual differences between paramedics.

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Figure Legends

Figure 1: The procedures used to log roll the supine patient onto the vacuum mattress with one assistant are illustrated in panels A-F. The patient is log rolled while maintaining cervical spine stabilization (A-B), the mattress with the overlying bed sheet are pulled close to the patient (C), and the patient is then log rolled back onto the bed sheet / mattress (D). The bed sheet is then wrapped over the patient and the patient slid into the centre of the mattress (E-F). In A and F the inertial measurement unit on the forehead is visible.

Figure 2: The top panel shows the total motion of the forehead Inertial Measurement Unit (IMU) relative to the sternal IMU over time for one Log Roll trial. The bottom panel decomposes the total motion into anatomical directions of flexion, extension, left and right rotation, and left and right lateral flexion. The shaded areas illustrate (from left to right) the time spent log rolling the supine patient towards the assistants to 90°, log rolling the patient back to the supine position, and sliding the patient into the middle of the vacuum mattress. The white sections represent time periods where the patient is held stationary.

Figure 3: The standard deviation (sd) of motion across the five Trap Squeeze trials for each lead paramedic is plotted against the sd of motion for the five Head Squeeze trials for the same lead paramedic, in each of the six directions of motion. Data are provided separately when the log roll was conducted with one assistant helping the lead paramedic (Log Roll-2), or with three assistants helping the lead paramedic (Log Roll-4).

Figure 4: The maximum motion across all the five Trap Squeeze trials for each lead paramedic is plotted against the maximum motion for the five Head Squeeze trials for the same lead paramedic, in each of the six directions of motion. Data are provided separately when the log roll was conducted with one assistant helping the lead paramedic (Log Roll-2), or with three assistants helping the lead paramedic (Log Roll-4).

Table 1: Demographics of Experience and Preferences

Experience	**Median (range)**
Cervical spine management experience (yrs)	8 (1 to 36)
2-person Log Roll experience (yrs)	8 (1 to 38)
Competence* 2 person Log Roll (10=max)	7 (4 to 10)
≥4-person Log Roll experience (yrs)	8 (0 to 38)
Competence* ≥4 person Log Roll (10=max)	8 (0 to 10)
Head Squeeze experience (yrs)	8 (1 to 38)
Competence* Head Squeeze (10=max)	8 (6 to 10)
Trap Squeeze experience (yrs)	0 (0 to 8)
Competence* Trap Squeeze (10=max)	4 (0 to 10)

Preferences	**Percent**
4-person Log Roll (vs. 2 person Log Roll)	95%
Head Squeeze (vs. Trap Squeeze) for 2 person Log Roll	57%
Head Squeeze (vs. Trap Squeeze) for 4 person Log Roll	57%

* Competance is based on a self-reported numerical rating scale from 0-10

Table 2: Mean of five trials for total motion, and in each of the six directions. P-values for Head Squeeze (HS) vs. Trap Squeeze (TS), and 2-Person Log Roll (LR_2) vs. 4-Person Log Roll (LR_4) are provided. Interaction p-values ranged 0.2 to 0.9 (not shown).

	LR_2		LR_4	
	Head Squeeze	Trap Squeeze	Head Squeeze	Trap Squeeze
Total Motion HS vs. TS: p=0.002 LR_2 vs. LR_4: p=0.0002	24.2 (22.0 to 26.4)	21.4 (19.2 to 23.7)	20.2 (18.0 to 22.5)	18.3 (16.1 to 20.5)
Flexion HS vs. TS: p=0.40 LR_2 vs. LR_4: p=0.015	6.2 (5 to 7.4)	5.8 (4.5 to 7.0)	4.7 (3.5 to 6.0)	4.8 (3.5 to 6.0)
Extension HS vs. TS: p=0.001 LR_2 vs. LR_4: p=0.31	11.0 (8.7 to 13.4)	13.9 (11.5 to 16.2)	10.4 (8.0 to 12.7)	12 (9.7 to 14.4)
Left Lateral Flexion HS vs. TS: p=0.001 LR_2 vs. LR_4: p=0.24	12.4 (11 to 13.8)	9.6 (8.2 to 11)	11.7 (10.3 to 13.1)	9.3 (7.9 to 10.7)
Right Lateral Flexion HS vs. TS: p=0.33 LR_2 vs. LR_4: p=0.02	5.5 (4.3 to 6.8)	5.0 (3.7 to 6.3)	4.0 (2.7 to 5.3)	4.5 (3.2 to 5.8)
Left Rotation HS vs. TS: p=0.002 LR_2 vs. LR_4: p=0.008	18 (15.4 to 20.6)	15 (12.4 to 17.7)	15.6 (13 to 18.3)	12.9 (10.3 to 15.5)

Figure 1

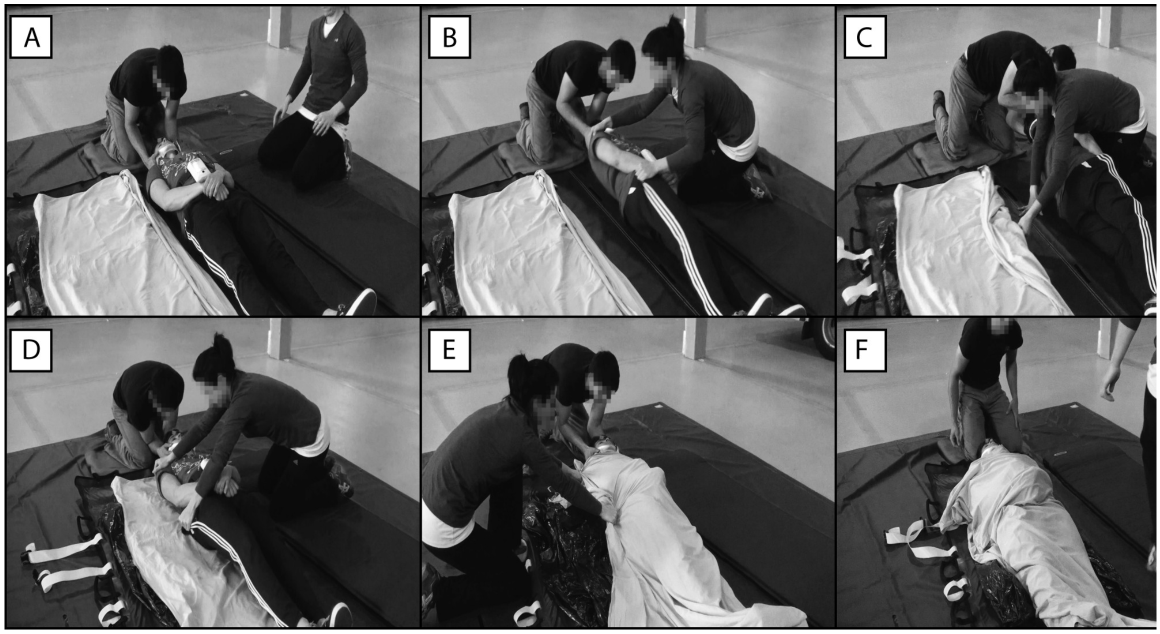


Figure 2

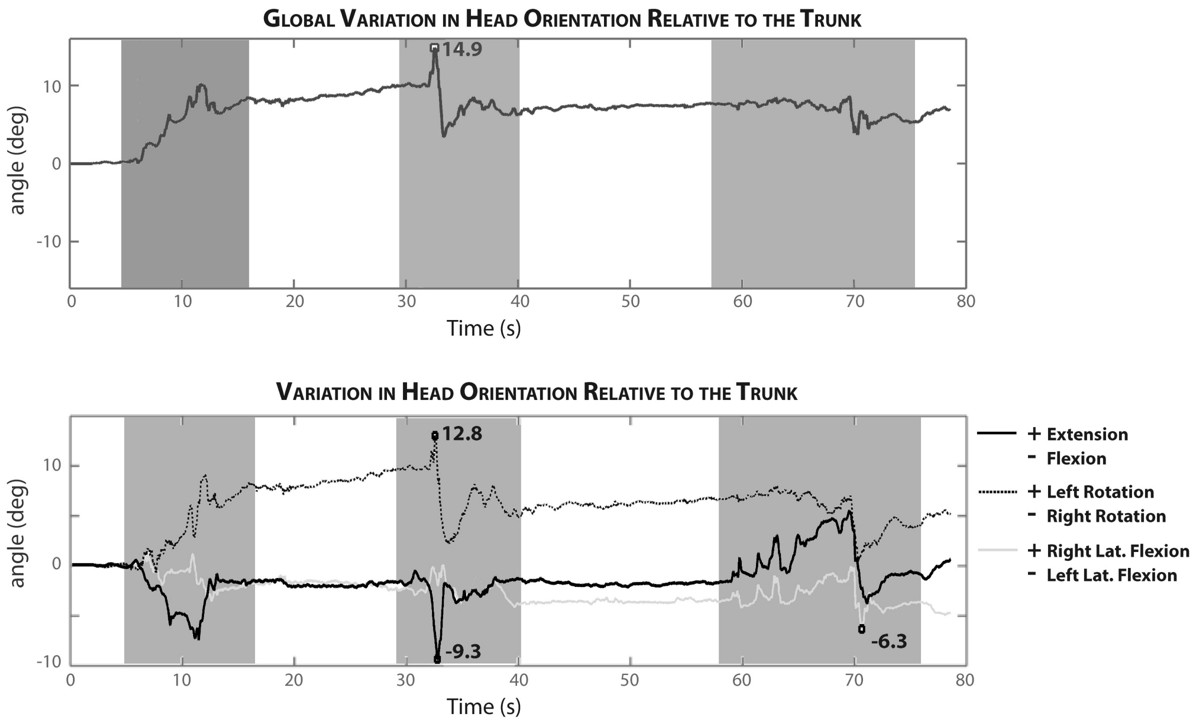

GLOBAL VARIATION IN HEAD ORIENTATION RELATIVE TO THE TRUNK
14.9
angle (deg)
Time (s)
VARIATION IN HEAD ORIENTATION RELATIVE TO THE TRUNK
12.8
-9.3
-6.3
angle (deg)
Time (s)
+ Extension
- Flexion
+ Left Rotation
- Right Rotation
+ Right Lat. Flexion
- Left Lat. Flexion

Figure 3

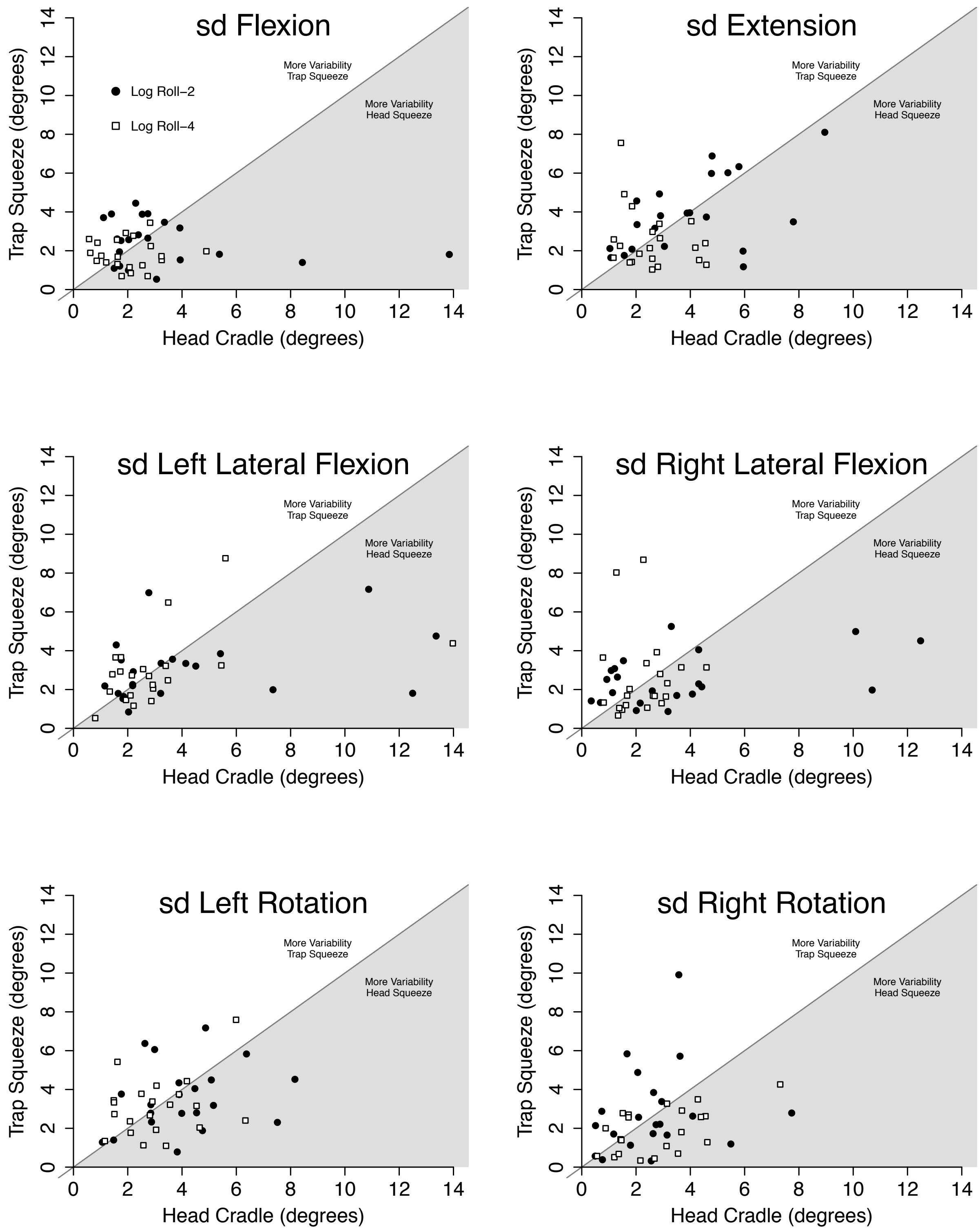
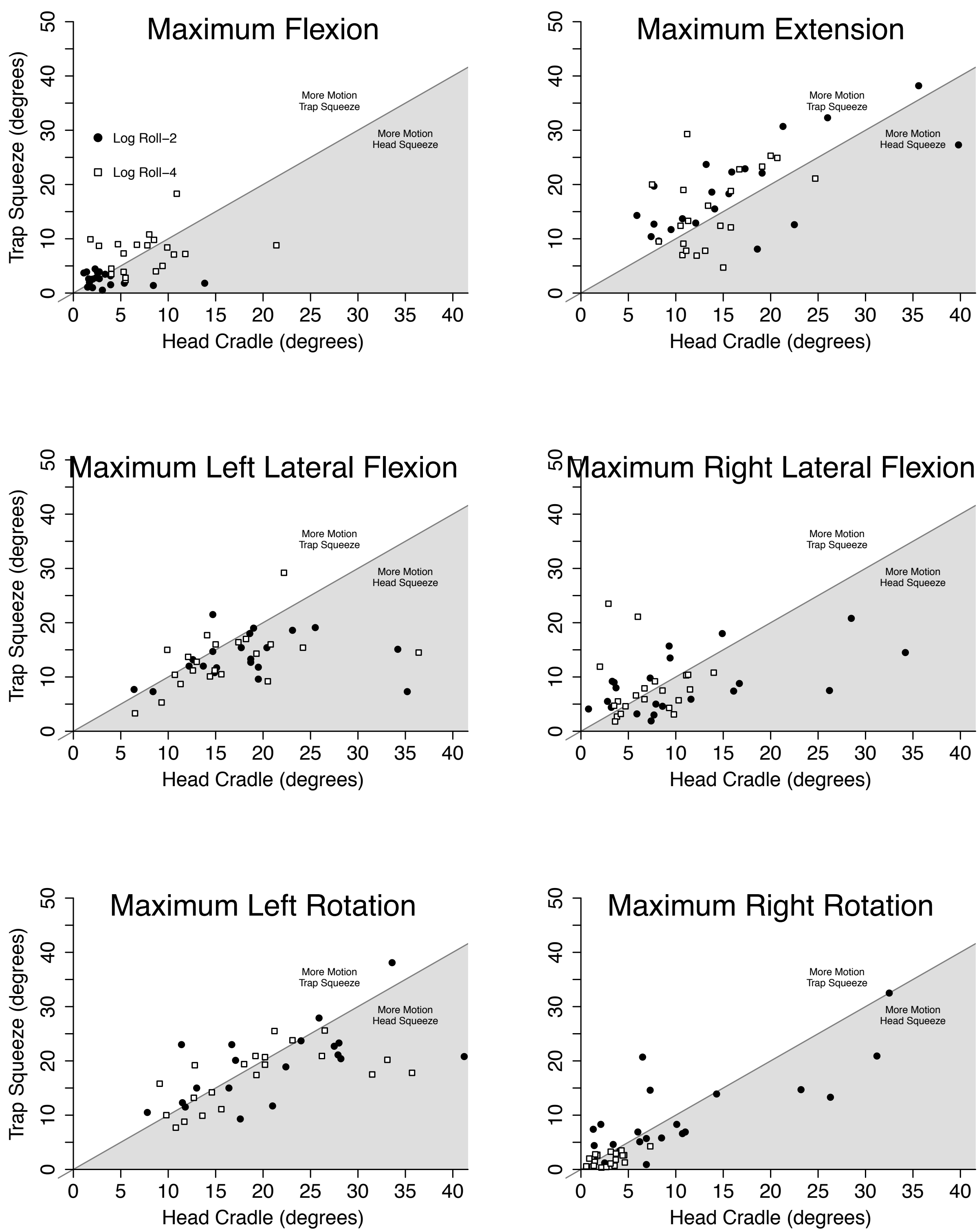

sd Flexion
sd Extension
sd Left Lateral Flexion
sd Right Lateral Flexion
sd Left Rotation
sd Right Rotation
Log Roll−2
Log Roll−4
More Variability Trap Squeeze
More Variability Head Squeeze
Trap Squeeze (degrees)
Head Cradle (degrees)

Figure 4


Maximum Flexion
Maximum Extension
Maximum Left Lateral Flexion
Maximum Right Lateral Flexion
Maximum Left Rotation
Maximum Right Rotation
Trap Squeeze (degrees)
Head Cradle (degrees)
More Motion
Trap Squeeze
More Motion
Head Squeeze
Log Roll−2
Log Roll−4
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40