Effectiveness of Cervical Spine Stabilization Techniques

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Objective: To compare head motions that occur when trained professionals perform the head squeeze (HS) and trap squeeze (TS) C-spine stabilization techniques.

Design: Cross-over design.

Participants: Twelve experienced lead rescuers.

Main Outcome Measures: Peak head motion with respect to initial conditions using inertial measurement units attached to the forehead and trunk of the simulated patient. We compared both HS and TS during lift-and-slide (L&S) and log-roll (LR) placement on spinal board, and agitated patient trying to sit up (AGIT-$_{\mathrm{Sit}}$) or rotate his head (AGIT-$_{\mathrm{Rot}}$). The a priori minimal important difference (MID) was 5 degrees for flexion or extension and 3 degrees for rotation or lateral flexion.

Results: The L&S technique was statistically superior to the LR technique. The only differences to exceed the MID were extension and rotation during LR (HS > TS). In the AGIT-$_{\mathrm{Sit}}$ test scenario, differences in motion exceeded MID (HS > TS) for flexion, rotation, and lateral flexion. In the AGIT-$_{\mathrm{Rot}}$ scenario, differences in motion exceeded MID for rotation only (HS >TS). There was similar intertrial variability of motion for HS and TS during L&S and LR but significantly more variability with HS compared with TS in the agitated patient.

Conclusions: The L&S is preferable to the LR when possible for minimizing unwanted C-spine motion. There is little overall difference between HS and TS in a cooperative patient. When a patient is confused, the HS is much worse than the TS at minimizing C-spine motion.

Key Words: head squeeze, trap squeeze, spine board placement, head motion, inertial measurements

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INTRODUCTION

The incidence of spinal cord injuries in developed countries is estimated at 11.5 to 53.4 per million of inhabitants.[1] The majority of these spine injuries occur at the cervical level[2,3] due to road accidents, falls, and sport and leisure activities.[4] Current guidelines recommend that patients with suspected spine fractures be stabilized in the field before transport to a medical facility. Patients are secured onto a rigid board by a team of rescuers who must attempt to minimize movement of the patient's cervical spine (C-spine) through stabilization techniques.[5,6] Some studies have reported on the effectiveness of stabilization using different devices such as collars, backboards, splints, body strapping, motorized spine board,[7,8] or the relative effectiveness of the lift and slide (L&S) versus log roll (LR) to place the body on the spinal board.[9–11] However, no studies have yet compared different techniques of manual stabilization of the C-spine itself. There are 2 commonly used techniques to stabilize the C-spine.

- Head squeeze (HS): The lead rescuer lets the patient's head rest in the palms, hands on both sides of the head with fingers placed so that the ulnar fingers can grab the mastoid process below and the second and third fingers can apply a jaw thrust if necessary.[12,13]
- Trap squeeze (TS): The rescuer grabs the patient's trapezius muscles on either side of the head with his/her hands (thumbs anterior to the trapezius muscle) and firmly squeezes the head between the forearms with the forearms placed approximately at the level of the ears.[5]

Although the HS technique is easy to apply with an unconscious or cooperative patient, it does not stabilize the joints above and below the fracture site. Therefore, there may be considerable head motions if the patient attempts to move.[14] Even though the TS technique is theoretically better at limiting movement, it has never been formally studied. Because of the limited published evidence on the effectiveness of these techniques, and no direct comparison of them,[7] the objectives of this study are to characterize and compare head motion with both HS and TS techniques, recorded during L&S placement on spine board, LR placement on spine board, and under simulated conditions where the patient is confused.

METHODS

Study Design and Participants

We used a cross-over design with 12 lead rescuers (rescuer controlling the head) performing C-spine stabilization techniques under different test scenarios. Two men (64 and 77 kg, respectively) with "Regular Size" neck lengths (according to the Stifneck Select collar; Laerdal Medical, Toronto, Ontario, Canada) were used as simulated patients. The same patient was used across all scenarios for each lead rescuer. Lead rescuers were recruited among certified athletic therapists, athletic trainers, and physiotherapists with specific training in C-spine stabilization. Inclusion criterion included prior training for both HS and TS in the past 6 months. The Ethics Review Board of the Health and Social Services Centre, University Institute of Geriatrics of Sherbrooke (CSSS-IUGS) approved the study, and all participants gave informed consent.

C-Spine Stabilization Techniques and Test Scenarios

The HS and TS were compared during 4 test scenarios and were performed according to accepted recommendations (Figure 1).[5,15] We used the 6-person L&S with the lead rescuer at the head, the patient being cooperative and wearing a Stifneck Select collar, 2 assistant rescuers at either side, and a sixth rescuer to place the spine board under the patient.[16] We used the 5-person LR[11] with the lead rescuer at the head, the patient being cooperative and wearing a Stifneck Select collar, 3 assistant rescuers at the side of the patient, and a fifth rescuer to place the spine board in position. We also simulated the condition early in the stabilization process before a collar is applied when a rescuer attempts to stabilize the C-spine in a confused patient who tries to sit up (AGIT-$_{Sit}$) or rotate his head (AGIT-$_{Rot}$). For the AGIT-$_{Rot}$ and AGIT-$_{Sit}$ scenarios, we randomized (and blinded the lead rescuer to) the sequence of movements to ensure that the lead rescuer did not know what movement or direction the patient was about to do. We conducted 5 trials for HS and 5 trials for TS under each of the 4 scenarios. Lead rescuers were allowed for practice trials with

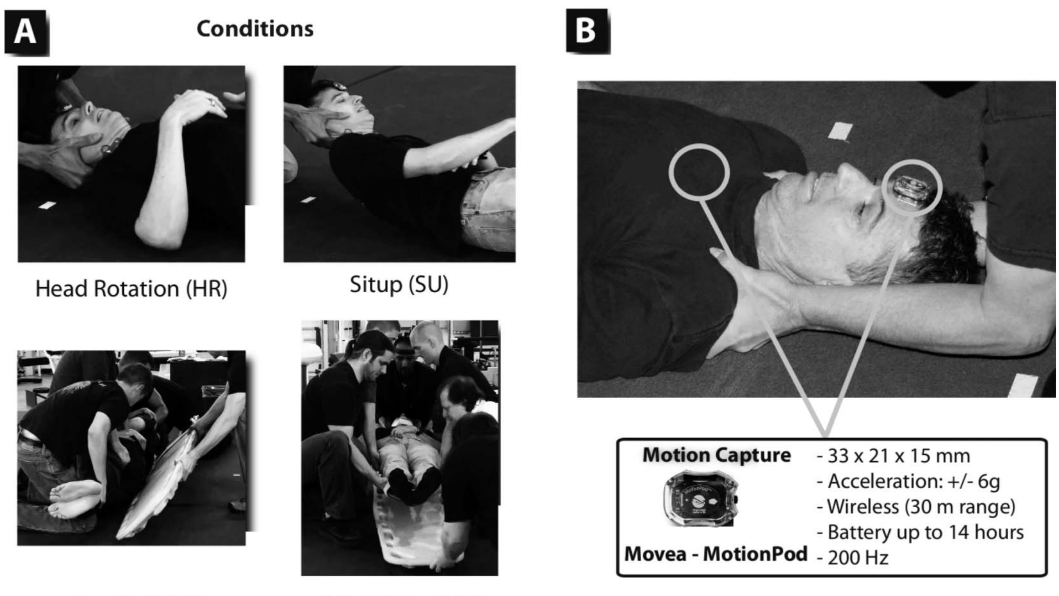

FIGURE 1. Overview of test scenarios and measures of head and trunk motions. A, Still pictures illustrating the 4 scenarios tested: 6-person lift and slide technique to place a cooperative patient with a stiff cervical collar on the spine board (bottom right), 5-person log roll technique to place a cooperative patient with a stiff cervical collar on the spine board (bottom left), confused patient trying to rotate the head (AGIT-$_{Rot}$) before the collar could be placed (top left), and confused patient trying to sit up (AGIT-$_{Sit}$) before the collar could be placed (top right). During AGIT-$_{Rot}$ or AGIT-$_{Sit}$, the patient initially lay quiet and supine with the head/neck in the neutral position. The lead rescuer immobilizes the patient's head using the head squeeze (HS) or trap squeeze (TS) technique. Within a 45-second window, the patient suddenly tried to rotate the head to the left or the right side or to sit up to the left or right side (timing and direction of movement chosen by the simulated patient). The lead rescuer attempted to maintain the head in the neutral position without any motion in the sagittal, coronal, or frontal planes. During HS for the AGIT-$_{Sit}$ test scenario, the lead rescuer limits motion by trying to match head movement to body movement. During the TS for the AGIT-$_{Sit}$ test scenario, the lead rescuer firmly holds the head in place with the forearms and holds the shoulders down by applying pressure with the thumbs. B, Overview of the equipment used for the Outcomes measures. Head motion was measured using wireless IMUs (MotionPod, Movea Inc, Grenoble, France) attached to the forehead and the manubrium–sternal junction.

the same team of trained individuals acting as assistants during the experimental recording. The order of use of the C-spine stabilization techniques for each test scenario was counterbalanced across lead rescuers.

Outcome Measures

Effectiveness of stabilization was characterized as peak head motion with respect to initial conditions (head position before stabilization efforts) in the transverse plane (right

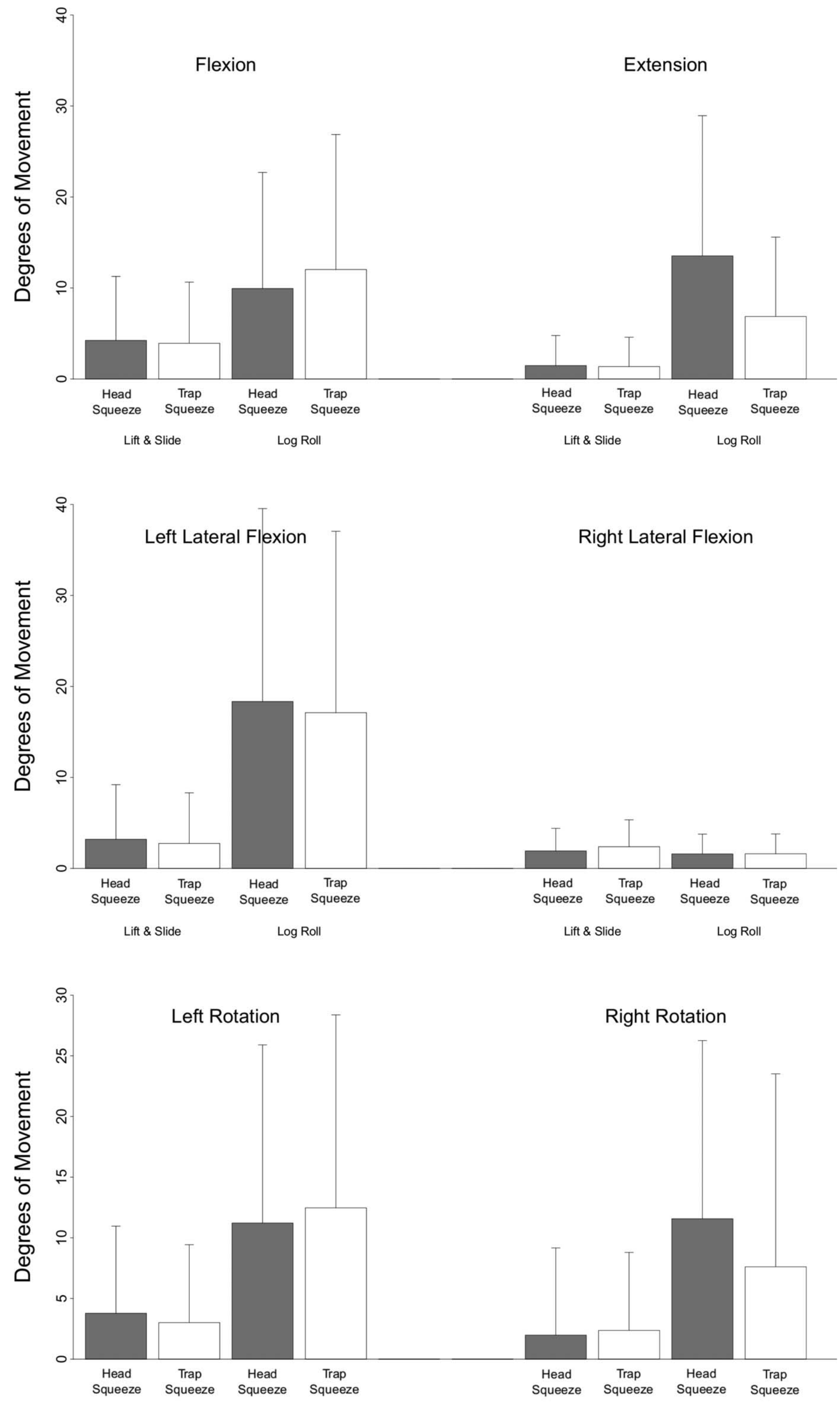

FIGURE 2. Mean head motion and 95% confidence interval in each direction for both lift and slide and log roll scenarios, using both head squeeze and trap squeeze techniques to stabilize the cervical spine.

rotation and left rotation), sagittal plane (flexion and extension), and coronal plane (right lateral flexion and left lateral flexion). Head motion relative to the trunk was measured using inertial measurement units (IMUs) attached to the forehead and trunk of the individual (Figure 2). Inertial measurement units are electronic devices with sensors (accelerometers, gyroscopes, and magnetometers) that can measure the orientation of an object or body segment through fusion of data from these sensors (for more detail, refer to articles by Luinge and Veltink[17] and Sabatini[18]). We used MotionPod IMUs from Movea, Inc (Grenoble, France). Data from the MotionPod modules were wirelessly transmitted to a computer using proprietary software (MotionDevTool, Movea, Grenoble, France). Orientation data (Euler angles of each module) were used to compute relative motion of one module with respect to the other using Matlab (Mathworks, Natick, Massachusetts). Before the experiment, we established the accuracy of the angles measured by the MotionPod module under static and dynamic test conditions using an optoelectronic motion capture system (Optotrak Certus; Northern Digital, Waterloo, Ontario, Canada) as a reference. We fixed the MotionPod module to the center of a rectangular plastic assembly on which 19 active markers were linked together as a rigid body. The module's reference system was set to be the same as the rigid body created with the motion capture reference system. Marker data and IMU data were collected at 100 Hz and synchronized in post-processing using cross-correlation techniques. We measured static accuracy (moving the assembly from 0 to 90 degrees in 5-degree increments in each orthogonal axis) and dynamic accuracy (rotating the assembly around each orthogonal axis for 30 seconds) with no magnetic perturbations present. The mean errors (differences expressed in the same reference planes of the stabilization trials between orthogonal angles measured by Optotrak Certus and MotionPod) during static accuracy tests (n = 19 values) were 0.34 degrees for rotation (transverse plane), 0.56 degrees for flexion-extension (sagittal plane), and 0.39 degrees for lateral flexion (coronal plane). The mean errors during dynamic accuracy tests were 0.44 degrees for rotation, 0.51 degrees for flexion-extension, and 4.16 degrees for lateral flexion. The average speed of rotation calculated a posteriori from the Optotrak data during these tests was 59.2 degrees per second.

Data Reduction and Statistical Analysis

Peak motions per trial in all planes (main outcome) were extracted for each scenario (L&S, LR, AGIT-$_{Sit}$, and AGIT-$_{Rot}$) using each technique (HS and TS). We used a random effects multiple linear regression model to account for repeated measures across the rescuers. For the L&S and LR trials, we first compared L&S with LR. In addition, we compared HS with TS under both L&S and LR (using an interaction term in the model). For the AGIT-$_{Sit}$ and AGIT-$_{Rot}$ scenarios, we compared peak motions using HS and TS within each scenario only.

We also calculated whether the differences between groups exceeded an a priori minimal important difference (MID) for movement in each direction. Our MID was based on the mean motion values obtained from a previous study on human subjects during L&R[8]: 5 degrees for flexion and extension and 3 degrees for each of right/left rotation and right/left lateral flexion. All analyses were carried out using an open-source statistical software (R Statistical Package 2.9.1, R Foundation for Statistical Computing, Vienna, Austria). We report 95% confidence intervals and accepted $P \leq 0.05$ as statistically significant.

RESULTS

All lead rescuers were certified as emergency responders and had professional certifications as physiotherapist, athletic therapist, or athletic trainer (Table). C-spine trauma management experience ranged from 4 to 42 years; rescuers were more experienced with the HS technique versus the TS technique.

Comparison of Head Motions

Lift and Slide and Log Roll

Overall, the L&S technique was superior to the LR technique for all motions ($P < 0.0001$ for each) except right lateral flexion ($P = 0.22$) (Figure 2). For L&S, the difference in head motion between HS and TS never exceeded the MID. For LR, depending on the particular motion, there were minimal and nonsignificant differences in magnitude of movement with HS and TS; however, the only differences that exceeded the MID were increased extension with HS versus TS technique (6 degrees; $P < 0.0001$) and right rotation (3.9-degree difference; $P < 0.007$).

AGIT-$_{Sit}$ and AGIT-$_{Rot}$

Overall, rescuers were unable to stabilize the C-spine using the HS technique during the AGIT-$_{Sit}$ scenario, and the differences between HS and TS exceeded the MID for flexion, lateral flexion, and rotation ($P < 0.00001$ for each) but was less than the MID for extension (2.4 degrees; $P = 0.004$) (Figure 3). For the AGIT-$_{Rot}$ scenario, motion with HS versus TS exceeded the MID only for rotation (6.4 degrees less motion with TS; $P < 0.0001$) but was less than the MID for all other directions (range of differences, 1.7 to 2.3 degrees for the others; $P \leq 0.002$ for each direction).

TABLE. Rescuer Demographics

Categorical Variables	n (total = 12)
Profession	
Physiotherapist	3
Athletic therapist/trainer	9
Certification	
Emergency responder	12
Strength and conditioning	3
Prefer HS	
L&S	2
LR	8
Confused patient	5
Continuous Variables	**Mean (Range)**
Experience	
Years managing C-spine	14.9 (4-42)
Years using HS	15.5 (7-42)
Years using TS	6.8 (1-35)

HS, head squeeze; L&S, lift-and-slide; LR, log-roll; TS, trap squeeze.

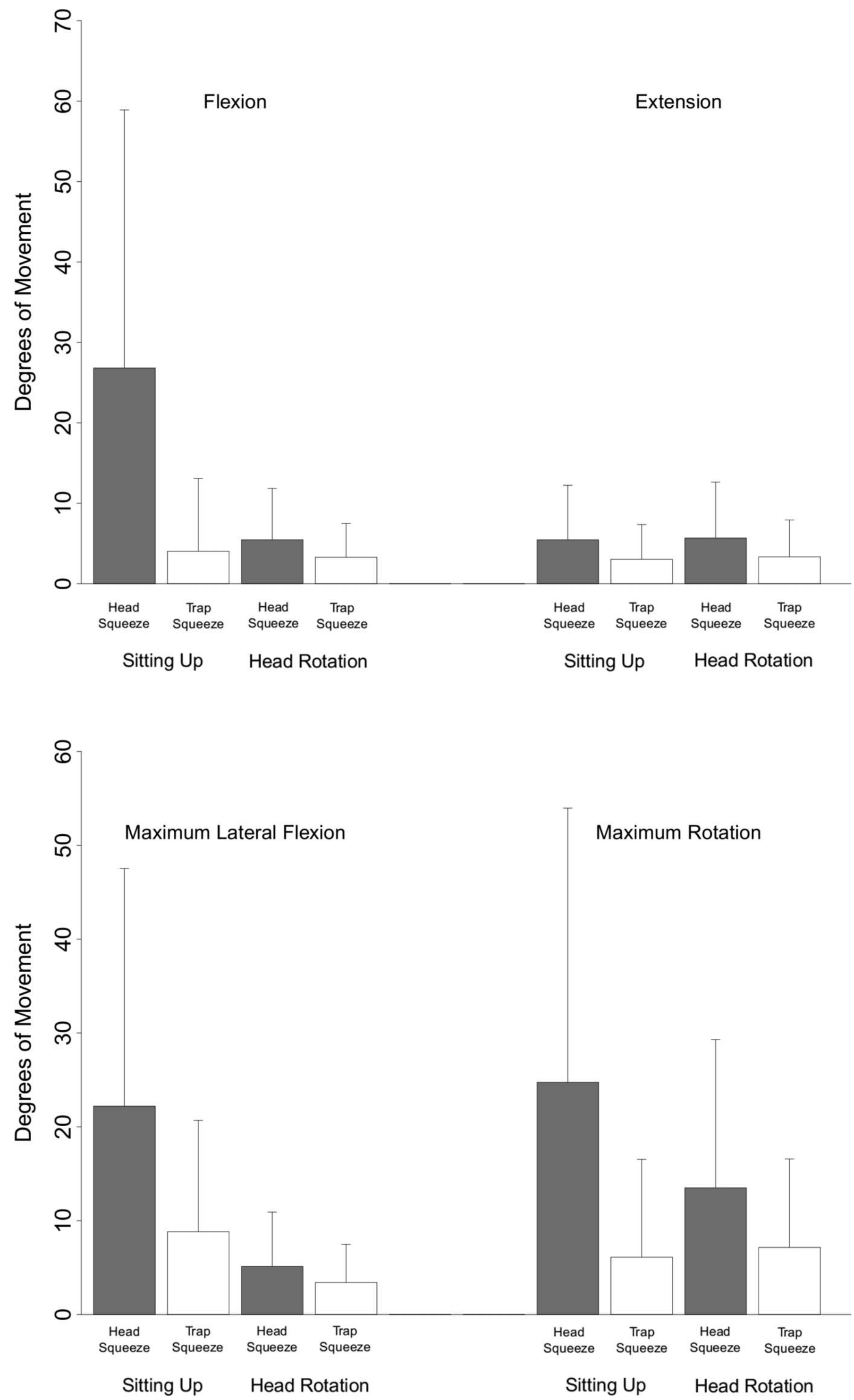

FIGURE 3. Mean head motion and 95% confidence interval in each direction for both sit-up (AGIT-$_{\text{Sit}}$) and head rotation (AGIT-$_{\text{Rot}}$) scenarios in the confused patient, using both head squeeze and trap squeeze techniques to stabilize the cervical spine. Because the patient sometimes rotated/sat up to the right and sometimes to the left to ensure that the rescuer did not know what was going to happen, we averaged the maximum lateral flexion and rotation movement in either direction for these results.

Variability Between Rescuers and Between Trials of Each Rescuer

For the same mean motion, a technique that produces more consistent results (ie, has less variable responses) should be considered superior. We explored variability using scatter plots with identity lines superimposed during HS and TS for each scenario in Figures 4 to 7 (L&S, LR, AGIT-$_{\text{Sit}}$, and AGIT-$_{\text{Rot}}$, respectively). Points below the identity line indicate greater motion (or greater variability) with HS compared with TS.

During L&S (Figure 4), rescuers performed well with both techniques, most movements were less than the MID, and

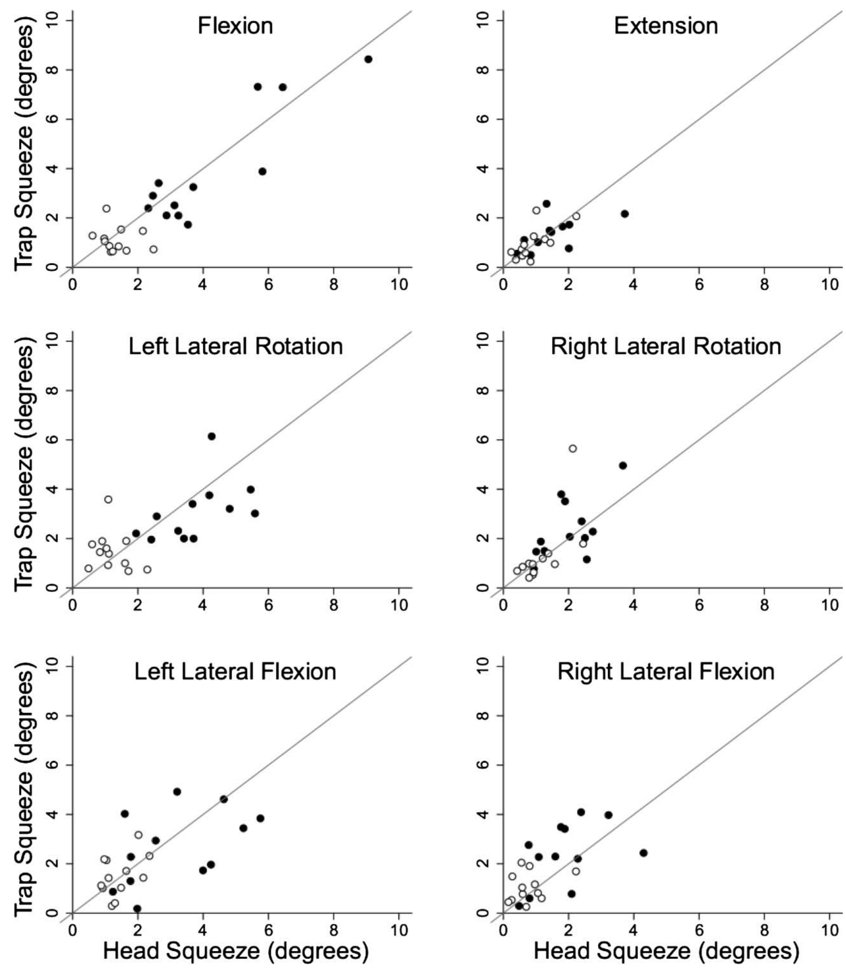

FIGURE 4. Within-rescuer and within-trial variability of head motions during lift and slide (L&S). Each rescuer's mean result across trials (filled circles) and SD across the trials (open circles) are plotted for the trap squeeze (TS) technique (*y* axis) against the HS technique (*x* axis), for each direction of movement during the L&S scenario. The diagonal line represents the line of identity. The mean motion (open circles) for TS across recorded trials for a given direction of a given lead rescuer is plotted against the mean motion for head squeeze (HS). The filled circles represent a plot of the variability of TS across recorded trials (SD) against the variability across HS trials. If a filled circle is above the line, the rescuer had more motion with the TS versus the HS. Similarly, if an open circle is above the line, the rescuer had more variability across trials with the TS versus the HS.

both the mean and variability across all trials are equally scattered across the line of identity. This suggests no advantage for HS or TS. During the LR scenario (Figure 5), although the points are equally scattered across the line of identity for flexion, left rotation, and left/right lateral flexion, all but 1 rescuer had increased extension with HS, and all but 2 rescuers had increased right rotation with HS. In addition, the variability between trials conducted by each rescuer was greater with the HS for these 2 movements.

During AGIT-$_{\mathrm{Sit}}$ (Figure 6), every rescuer except 1 was able to stabilize the C-spine much better with the TS. Overall, almost all rescuers created more motion in each direction (greatly exceeding the MID, except for extension) and had more variability in each direction, when they used the HS. Similarly, during AGIT-$_{\mathrm{Rot}}$ (Figure 7), there was much greater movement during HS for rotation for every rescuer except 1 and generally increased variability as well. These differences were 2 to 5 times larger than the MID.

DISCUSSION

Our results suggest that there is limited motion with both the HS and TS techniques for the L&S, some increased motion with HS compared with TS for the LR, and much greater motion for HS versus TS for the confused patient scenarios. In addition, more variability is noted in some scenarios with HS compared with TS.

Comparing the L&S with the LR, the mean motion was less than 5 degrees in all planes of motion for L&S and less than 15 degrees in most planes of motion during LR. Although our sample size was limited, the magnitudes of the motions under each scenario, and greater motion with LR versus L&S, are consistent with the conclusions of others studies.[8–11] This was evident using either TS or HS for all motions with the exception of right lateral flexion. Although the LR may be necessary when there are only a few assistants available, or when it is not possible to conduct an L&S because of the position of the patient, the findings of our study and others present strong arguments to use the L&S technique whenever possible. Future studies should examine the relative effectiveness of other L&S methods (eg, 5-person straddle[16]) and LR methods (3-person, prone-to-supine push versus prone-to-supine pull[16]).

When we compared the HS with TS during L&S, the difference in motion never exceeded the MID, and the variability in motion was very small. In addition, both techniques are easy to learn and apply, suggesting that under our ideal conditions, there are no clear advantages in using one over the other.

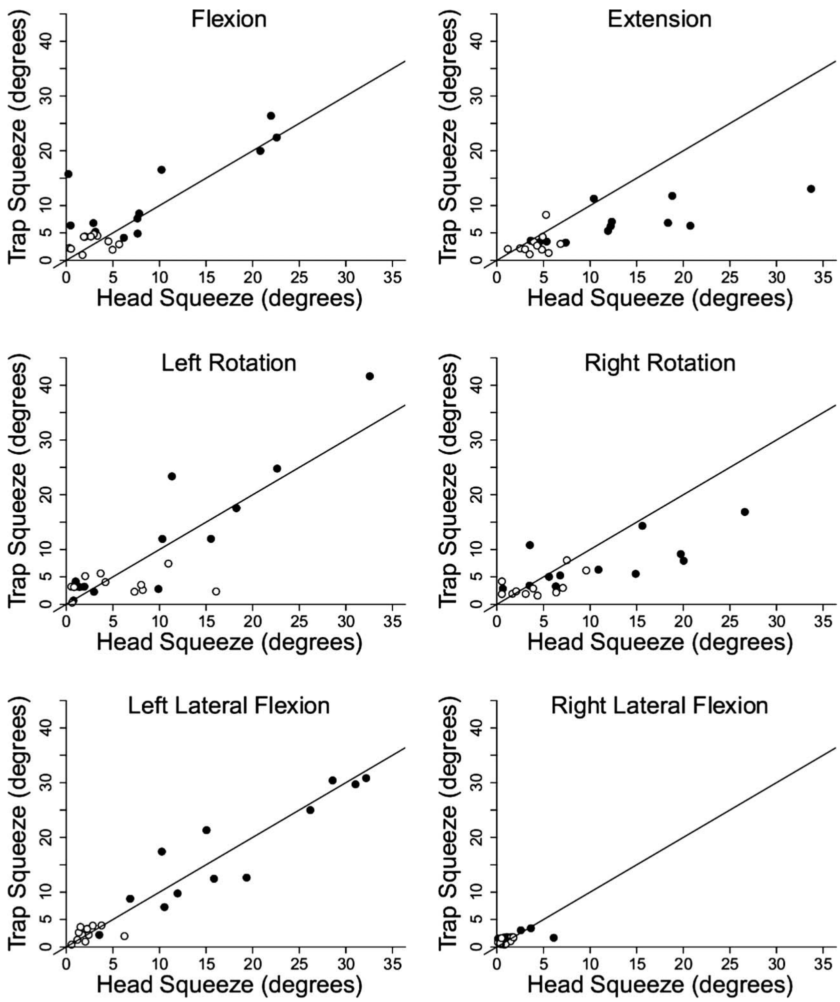

FIGURE 5. Within-rescuer and within-trial variability of head motions during log roll. Each rescuer's mean result across trials (filled circles) and SD across the trials (open circles) are plotted for the trap squeeze (TS) technique (*y* axis) against the head squeeze (HS) technique (*x* axis), for each direction of movement during the LR scenario. The diagonal line represents the line of identity. The mean motion (open circles) for TS across recorded trials for a given direction of a given lead rescuer is plotted against the mean motion for HS. The filled circles represent a plot of the variability of TS across recorded trials (SD) against the variability across HS trials. If a filled circle is above the line, the rescuer had more motion with the TS versus the HS. Similarly, if an open circle is above the line, the rescuer had more variability across trials with the TS versus the HS.

For the LR scenario, similar amounts of motion were recorded using HS and TS. However, in this scenario, the TS is theoretically more difficult because the lead rescuer has to roll his/her body to avoid pushing the head into lateral flexion with the forearm on the side of the roll (ie, right forearm can push the C-spine into left lateral flexion during an LR to the right). Despite this, we observed that the variability in head motion recorded across trials during an LR was slightly lower with TS compared with HS. Therefore, lateral flexion does not seem to be a practical concern for experienced rescuers. Whether the TS can be used for the LR in the prone or semiprone patient remains to be studied. In addition, the difficulty of the maneuver with patients of different size necks for rescuers with different arm lengths is unknown.

For the AGIT-$_{Rot}$ scenario (agitated patient), there was greater peak rotation and variability of motion with the HS. In the AGIT-$_{Sit}$ scenario, there was greater motion and variability in all directions with the HS. Although resisting movement with the TS for AGIT-$_{Sit}$ (compared with after motion with the HS) is a theoretical disadvantage because of the potential for an increased force across an injured segment, accepting the magnitude of motion that occurred with the HS (5 rescuers had a *mean value* $>$ 30 degrees) is practically equivalent to not stabilizing the C-spine at all. These results suggest that the TS technique should be used over the HS technique in the agitated patient. However, several other factors should also be considered. First, one may quickly need to LR a supine nonintubated patient who suddenly needs to vomit. Although our results show that the TS and HS are equally effective in experienced rescuers when the LR is conducted in a controlled manner, we do not know if one technique is superior when the LR must be performed urgently. Second, only the HS allows rescuers to apply a jaw thrust in an unconscious patient whose airway becomes occluded because of poor muscle tone. However, it is easy enough for a rescuer to switch to the HS when this situation occurs. Furthermore, if an unconscious patient begins to regain consciousness, the first indication might be sudden movement; hence, using the HS would likely result in an increased motion that could have been prevented with the TS.

Limitations

Our study was conducted under ideal circumstances. In the real world, the head of the patient may be wet from water (water rescue) or perspiration (sport rescue). Under these conditions, the ability to maintain a firm grip between the

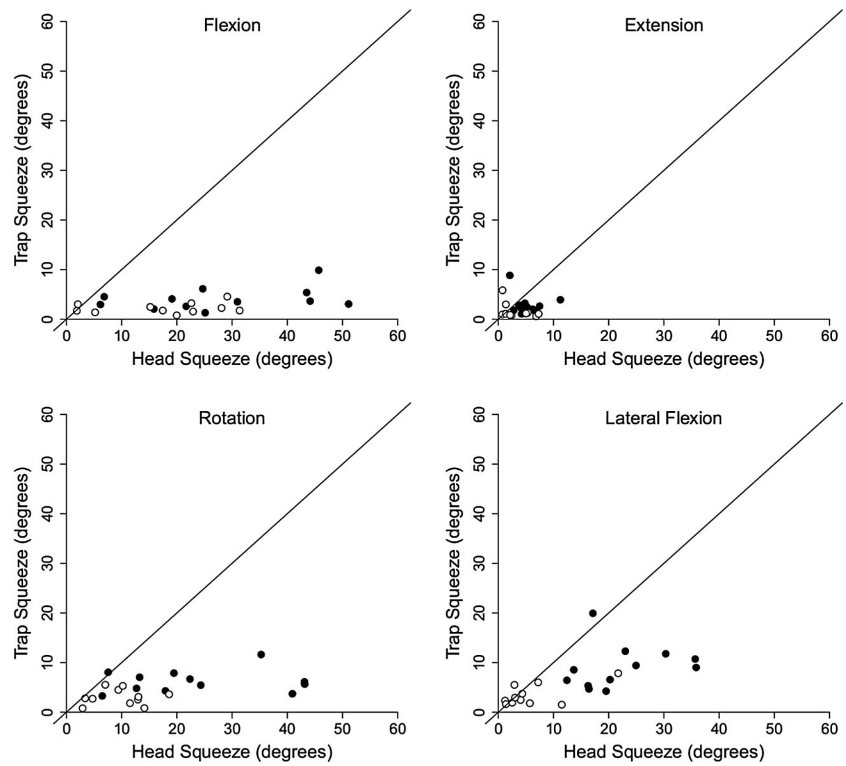

FIGURE 6. Within-rescuer and within-trial variability of head motions during sit-up (AGIT-$_{Sit}$). Each rescuer's mean result across trials (filled circles) and SD across the trials (open circles) are plotted for the trap squeeze technique (*y* axis) against the head squeeze technique (*x* axis), for each direction of movement during the AGIT-$_{Sit}$ scenario. The diagonal line represents the line of identity.

forearms with the TS may or may not be compromised. Alternatively, an assistant may sometimes slip during the lifting of L&S or rotation of the LR. Under these conditions, the rescuer using the HS might take longer to react than a rescuer using the TS (ie, more motion with HS) because the TS theoretically maintains the head and trunk as 1 unit. Further studies should assess the relative benefits of using TS and HS under these and other conditions. In the meanwhile, rescuers

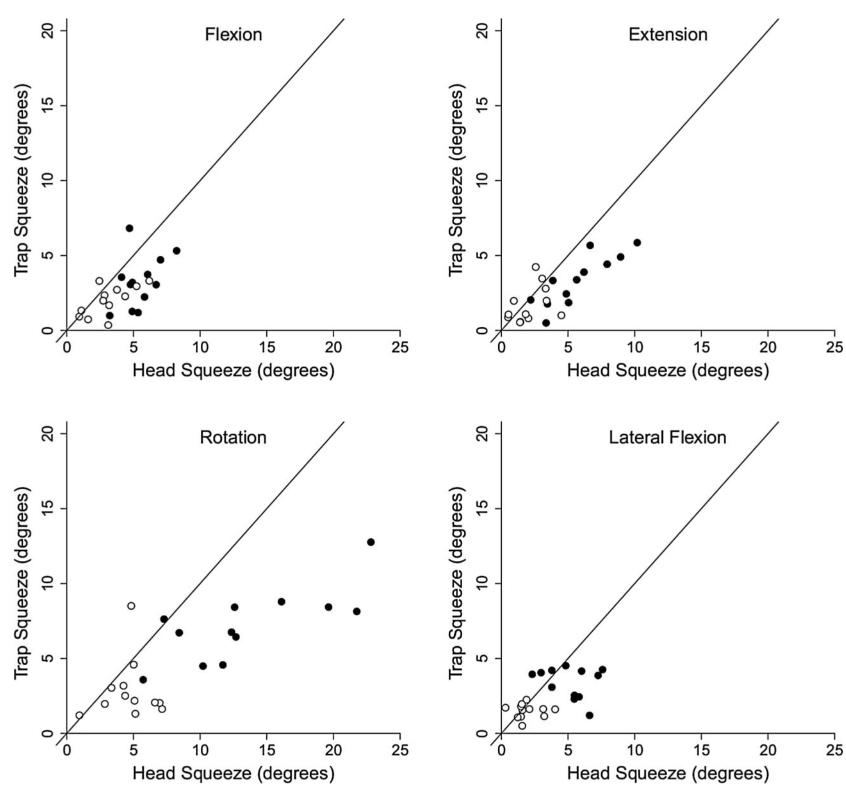

FIGURE 7. Within-rescuer and within-trial variability of head motions during rotation (AGIT-$_{Rot}$). Each rescuer's mean result across trials (filled circles) and SD across the trials (open circles) are plotted for the trap squeeze technique (*y* axis) against the head squeeze technique (*x* axis), for each direction of movement during the head rotation (AGIT-$_{Rot}$) scenario. The diagonal line represents the line of identity.

are encouraged to learn and practice different techniques under different scenarios.

We chose to compare the effectiveness of C-spine stabilization techniques using a MID based on mean data published from another study[8] that compared the amount of 3-dimensional head movements measured with an optical motion analysis system during the LR and motorized spine board stabilizations. Although the MID has face validity, it has not been clinically validated and should be interpreted with caution. Unfortunately, establishing a true MID is difficult because extrapolation from cadaveric normative data may not be applicable to live humans, and measurements during C-spine stabilization of real patients are limited either by their accuracy or by their application.

We measured head motions during C-spine stabilization techniques using IMUs, which do not measure translational motions and traditionally offer less accuracy than traditional laboratory-based optical motion capture systems. As such, head motions reported during $\text{AGIT-}_{\text{Rot}}$ and $\text{AGIT-}_{\text{Sit}}$ scenarios may have included translations that were not recorded. However, traditional laboratory-based optical motion capture systems have important limitations in our context because markers can be blocked from cameras during the 6-person L&S or when the body is rotated 90 degrees with 3 assistants to the side in the LR. Nonetheless, the average static accuracy of our measurement method was <1 degree. In addition, we had an excellent accuracy (<1 degree) for dynamic measures of rotation (transverse plane) and flexion-extension (sagittal plane) and adequate accuracy (4.16 degrees) for lateral flexion (coronal plane). The lower accuracy for lateral flexion (coronal plane) reflects limitations specific to the IMU used (ie, the MotionPod does not incorporate a gyroscope and thus relies on magnetometer data to compute heading), which can introduce bias under certain conditions. Innovations in IMU design and tuning of the fusion algorithm used to compute orientation have been shown to substantially reduce this bias and improve the accuracy.[19–21]

CONCLUSIONS

Results of this study confirm that the L&S technique is preferable to the LR when possible. There is little overall difference between the HS and TS when a patient is cooperative. When a patient is confused and trying to move, the HS is much worse at controlling movement compared with the TS. Further studies should assess the relative benefits of using TS instead of HS in conditions where there are inherent risks of instability of the head or trunk during transfers.

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