Save Your Back: Comparison of the Compressive Force on the Lower Back Based on Differences in the Training Techniques

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Contribution to Emergency Nursing Practice

- Current literature related to safe patient handling often excludes the emergency care areas or lacks consistency in educational methods. A dearth of knowledge exists related to emergency nurses, specifically in safe lifting methods.
- This article contributes to the knowledge in the reduction of 1 risk factor for low back injury in the emergency setting.
- Key implications for emergency nurses found in this article are that with a safer lifting strategy, the force on the lumbar spine is reduced.

Abstract

Introduction: Musculoskeletal injury prevention for nurses is aimed at removing the need to manually position patients. In the ED, this is not always possible or practical. The purpose of this study is to compare the calculated estimated compressive force on the lumbar spine between recommended lifting techniques and the SHAPE lifting method during the horizontal transfer of a patient.

Methods: Twenty-one student nurses completed the horizontal transfer of a simulated patient while motion was collected using inertial measurement units. Motion data were analyzed to calculate an estimated compressive force on the lumbar spine while completing the movement based on current recommended lifting methods and while using the SHAPE lifting method.

Results: A significant reduction in estimated peak and average compressive force at the lumbar spine was found during both the push and the pull portions ($P < .001$) of the horizontal transfer.

Discussion: While the optimal way to limit musculoskeletal injury among nurses is to eliminate the need for manual handling of a patient, this is not always possible in the ED. It is critical that when emergency nurses must reposition a patient, they perform the movement in the most biomechanically sound method while using a friction reduction. These findings, coupled with the previous biomechanical risk factor reduction related to the SHAPE lifting intervention, gives promise to a safer lifting strategy for emergency nurses moving forward.

Key words: Emergency nurse; Musculoskeletal injury; Repetition strain injury; Biomechanics

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Introduction

Wellness in the workplace can be defined as the ability of workers to realize their highest potential while addressing their normal stressors and working productively.[1] A common theme among emergency nurses is to place the safety and wellbeing of the patient over the safety and wellbeing of themself.[2] This practice often leads to the bypassing of safety procedures while providing lifesaving care at the expense of their own safety. For an emergency nurse to achieve wellness they must address the physical[3-5] and psychological[6-9] demands that they will face in the highly unpredictable emergency environment. Despite decades of research and millions of dollars invested, nurses remain 1 of the most injured occupations in the country, with musculoskeletal injury related to overexertion being a leading cause.[10]

In 2020, over 10,500 nurses were injured, resulting in days away from work due to overexertion,[11,12] with the back being the most frequently injured part of the body.[10] Low back pain has been reported in as many as 84.7% of nurses ($n = 569$) in a recent survey study.[13] While little is known about the current injury rates among emergency nurses specifically, a prior survey of the members of the Emergency Nurses Association (ENA) found that 1 in 4 emergency nurses reported non-violence-related injury in the workplace.[14] Given that the overall injury rate among nurses has not seen a significant reduction since the publication of the ENA study, it is assumed that the injury rates among emergency nurses have remained similar. It is imperative that a better approach to the preparation of emergency nurses to handle the rigors of the emergency department be developed to maintain the workforce while limiting the distraction of injury and pain,[15,16] allowing them to continue to perform at the high level required.[17]

Current strategies to minimize musculoskeletal injury focus on the environment surrounding the nurse and remove the need to manually handle patients and equipment.[18-21] While this is an ideal method for injury prevention in most industrial settings, it is not always practical or available in the health care environment, specifically the emergency department. Lifting devices require a harness to be placed under the patient to be used. While some facilities will place these harnesses on all beds in some critical care units, it is not feasible to have these placed on all emergency medical services (EMS) stretchers on which patients arrive. Without a harness being pre-placed under the patient, the nursing team must roll the patient onto their side, place the harness, and then roll them to their other side to finish placement of the harness. With an average wheelbase ranging from 22 to 26 inches[22] for EMS stretchers, this movement is not safe to perform on our arriving patients due to potential tipping,[23] thus leaving no option but to manually perform the horizontal transfer of the patient from the EMS stretcher to the hospital bed.

Lavendar et al[24] utilized a 47 kg (103 lb) mannequin to complete several movements performed by firefighter/ paramedic 2-person teams. The team identified the horizontal transfer of a patient as being a high-risk movement for musculoskeletal injury among this population. The force pressing down on the spine during the movement, or the spine compressive force identified during the horizontal transfer, averaged 2147 N on the stretcher side and 3,350 N on the hospital gurney side. While the recommendation is to not allow compressive force to exceed 3.4 kN,[25,26] this level is often exceeded during patient movement.[27,28] It was also estimated that only 86% of the firefighter/ paramedic population tested in the study had an adequate amount of back strength to pull the patient from the stretcher to the hospital gurney.[24] The NIOSH lifting equation estimates the allowable compressive force to be representative of moving a weight acceptable for 99% of the male population and 75% of the female population to be able to handle the weight.[27] Given that a large portion of the patients presenting to the emergency department weigh more than the 47 kg used in this study,[24] it can be assumed the compressive forces on the lumbar spine would be greater when transferring heavier patients requiring a larger expenditure of strength to complete the move.

Current recommendations for the movement of a patient are to utilize a mechanical lifting device when lifting or moving a patient.[29,30] When this is not possible, the nurse is recommended to raise the bed to hip height and lift with their leg muscles rather than those of their backs.[29] When performing the horizontal transfer of a patient with the bed at this height, the use of the leg muscles to perform the movement is limited due to the pelvis being locked in place, requiring a majority of the strength necessary to complete this movement to be generated by increasing the velocity of the trunk or by relying on the muscles of the lower back and shoulder regions.[3] Current evidence identifies an average strength differential based on biological sex that is more pronounced in the upper body.[31,32] The SHAPE lifting method[4] demonstrated an increase in the muscle activation of the muscles of the legs when completing the horizontal transfer.[3] This increased incorporation of the more pronounced muscles of the legs, specifically in the emergency setting where mechanical lifting devices are not practical, is critical in helping to reduce the risk of low back injury among emergency nurses.

Prior research has identified the need for safe patient handling policies, equipment, training, and adequate staffing in the emergency department.[14] While contextual

TABLE 1
Participant demographic data

Participant	Age	Sex	Height	Weight
1	21	M	69	180
2	20	M	69	175
3	23	M	71	192
4	21	F	58	110
5	20	F	69	210
6	21	F	66	132
7	21	F	67	130
8	20	F	64	125
9	20	F	66	130
10	20	M	67	150
11	20	M	70	175
12	21	F	68	129
13	21	F	67	128
14	20	F	67	140
15	20	F	66	145
16	20	F	64	137
17	21	M	70	175
18*	22	F	64	125
19*	21	F	69	150
20*	23	M	71	210
21*	22	F	66	130

Note:
* Indicates participation in study 2

training demonstrates better results than classroom-based education,[33] little is known about the biomechanical efficacy of the current techniques being taught. The purpose of this study was to compare the current practice recommendations for repositioning a patient[29,34,35] to the Safe Handling and Applied Efficiency (SHAPE) training model[3,4] utilizing an estimation of compressive force in the lumbar spine equation.[36]

Methods

Two prior studies examined risk factors for a back injury during the horizontal transfer of a patient using biomechanical analysis during the movements among a convenience sample of nursing students[3,4] who had completed the initial patient handling training. Demographic data can be found in Table 1. Inertial measurement units were attached to each lifter (17 units from head to foot) to track their motion while performing the push and pull portions of the horizontal transfer of a simulated patient. A pre-test/ post-test (quasi-experimental) method was used in each study with biomechanical analysis of the movements performed comparing the recommended lifting technique[29,35] to the SHAPE lifting intervention (Table 2). Data were collected in the skills practice laboratory within the College of Nursing and lasted approximately 30-60 minutes. Both studies were quasi-experimental in nature, with a pre-post biomechanical analysis of each movement following delivery of the SHAPE lifting education. IRB approval was obtained from the University of Alabama IRB for the initial collection of the research data (18-OR-456-A, and 21-03-4434-A).

Participants in both studies[3,4] presented to the skills practice lab and were fitted with the motion capture system. Participants were guided on completion of the horizontal transfer of a simulated patient (34 kg and 75 kg, respectively), both the push and the pull portions, for a total of 3 repetitions utilizing the recommended lifting methods (Table 2 and Figure 1). Participants then received the SHAPE lifting intervention training and completed the movement again while biomechanical data were obtained. Comparison of the data between lifting techniques was utilized for this study.

The biomechanical risk factors of lever arm distance,[4] trunk velocity, and angle of the lumbar spine[3] were the primary variables of concern in the 2 prior studies; however, the compressive force experienced at the lumbar spine was not examined. For this study, a secondary analysis was conducted while applying the revised back compressive force estimation model.[36,37] The following equation was applied to all participant data with BW being the weight of the participant (lb), H being the height of the participant (inches), θ the angle of the lumbar spine (degrees), L being the load of the patient (lb), and HB being the distance from the lumbar spine to the load (inches):

$$F_c = .045(BW)(H)\cos\theta + \frac{L(HB)}{2} + 0.8\left(\frac{BW}{2} + L\right)$$

The primary outcome of lever arm distance (LAD) was calculated by creating a virtual marker at the level of L5S1 that tracked with the right hand and is represented as HB in the equation. The angle of the lumbar spine was collected during both studies and is applied to this equation. During previous testing of the formula, the angle of the lumbar spine was rounded to the nearest 10 degrees.[37] For this analysis, actual values of the angle of the lumbar spine were used. Accuracy of the model indicates an average error of 9.3 ± 8.2% with the addition of the height of the participant to account for the length of the torso in the equation.[37]

TABLE 2
Movement instructions for textbook method and Safe Handling and Applied Efficiency (SHAPE) method

Movement	Textbook[29,34,35]	SHAPE
Core activation	No recommendation	Core activation must be utilized throughout each of the movement patterns. To practice this skill, participants are instructed to stand up straight with feet shoulder width apart, shoulders back, and chest pushed forward. Then, they contract gluteal muscles fully and take a deep breath. On the exhale of the breath, they contract the abdominal muscles, and while maintaining contraction of the abdominal muscles, relax the gluteal muscles.
Horizontal transfer of patient (push and pull)	A slide board is recommended for this movement Step 1: Position the participant to the side of the bed that the patient will be moving to and another nurse on the opposite side. Step 2: Fan fold the sheet on both sides against patient Step 3: Stand with feet spread widely with 1 foot slightly in front of the other and grasp the draw sheet. Step 4: On count of 3, pull the patient to the new desired position.	One member of the team will be on either side of the patient, who is on a slide board. The bed will be positioned at the mid-thigh position of the shortest member of the team such that each participant can grasp the draw sheet under the patient with knees slightly bent and spine in a neutral position. In a coordinated effort, the participant on the push side of the patient will push through their heel, extending their arms as they push the patient across the slide board. The participant receiving the patient will push through their heels, standing upright, pulling their elbows back, and squeezing their scapula together.

FIGURE 1
Initial setup for the horizontal transfer based on the SHAPE lifting method with bed at midthigh position of the shortest lifter (top) compared to recommended height of the bed at hip height (bottom). Participant completing the pull is 4'11", the push is 5'8".

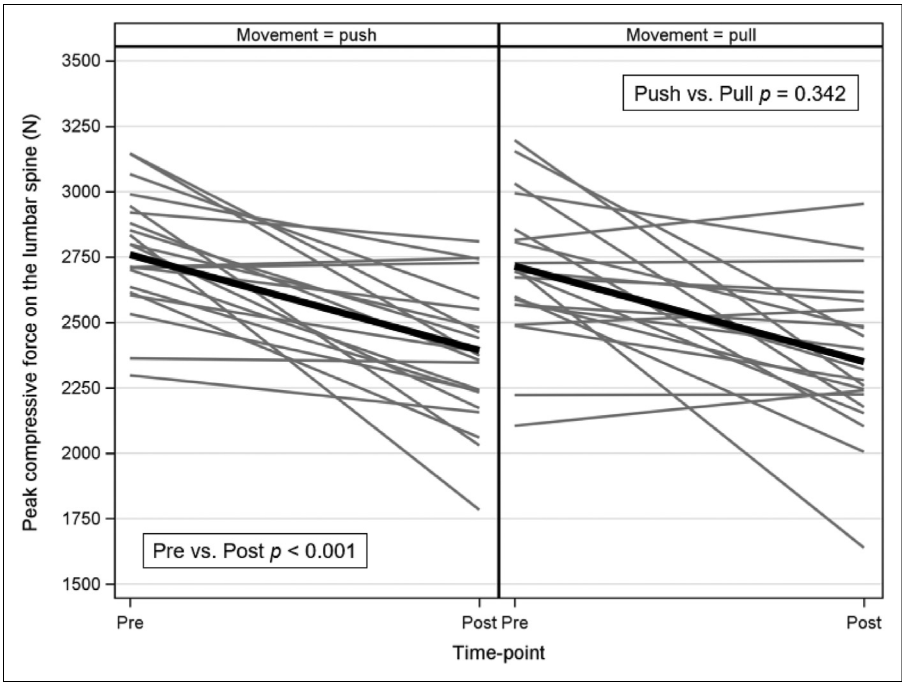

FIGURE 2

Peak compressive force (N) by movement and time-point. **Note*. Gray lines represent trends for individuals while the black line is the linear mixed-effects modeling estimated average trend across individuals.

For data analysis, back compressive force (force) was first examined for the presence of outliers using boxplots and normality assumptions using *Q-Q* plotting and Shapiro-Wilk testing separately for peak and average force. No extreme outliers were present, and plotting and non-significant tests suggested normality assumptions were reasonable. Linear mixed-effects modeling was performed to test if the peak and average forces were different post-test compared to the pre-test. A random intercept for participants was specified to account for repeated measures. Kenward-Roger degrees of freedom were specified for this modelling,[38,39] and least square means were estimated for movements (push, pull) and time-points along with their mean differences (*md*). All analyses were performed using SPSS v28.0 (IBM Statistics, Aurora, IL) and SAS v9.4 (SAS Institute, Cary, NC). A 2-sided *P*-value $< .05$ was considered statistically significant.

Results

A total of 21 participants participated in the intervention and pre- and post-data collection time-points with no missing data. Participants in the 2 studies identified as female (67%) with an average age of 20.9 (SD = 1.0) years, with an average height of 67.1 inches (SD = 3.0) and an average weight of 151.3 pounds (SD = 29.4). All participants were nursing students who had completed their initial training in patient movements offered in the fundamentals course of their bachelor's level nursing education.

Estimated peak and average compressive force for all participants can be seen in the Supplementary Table and visually in Figures 2 and 3 (for peak and average force, respectively). The mean peak and average compressive force for the push movement were 2774 N (SD = 226.4) and 2275.5 N (SD = 293.5) when completing the movements per recommendations and 2377.5 N (SD = 264.5) and 1862.7 N (SD = 242.5) per the SHAPE method. The average peak and average compressive force for the pull movement were 2699.8 N (SD = 267.3) and 2117.4 N (SD = 303.8) for the recommended lifting techniques and 2365.2 N (SD = 292.4) and 1868.2 N (SD = 243.6) when using the SHAPE lifting method.

For peak back compressive force, the difference between pre- and post-intervention average force did not significantly depend upon which movement it was (push vs. pull; Interaction $F[1,60] = 0.46$, $P = .498$). In a subsequent main effects-only model, there was not a significant

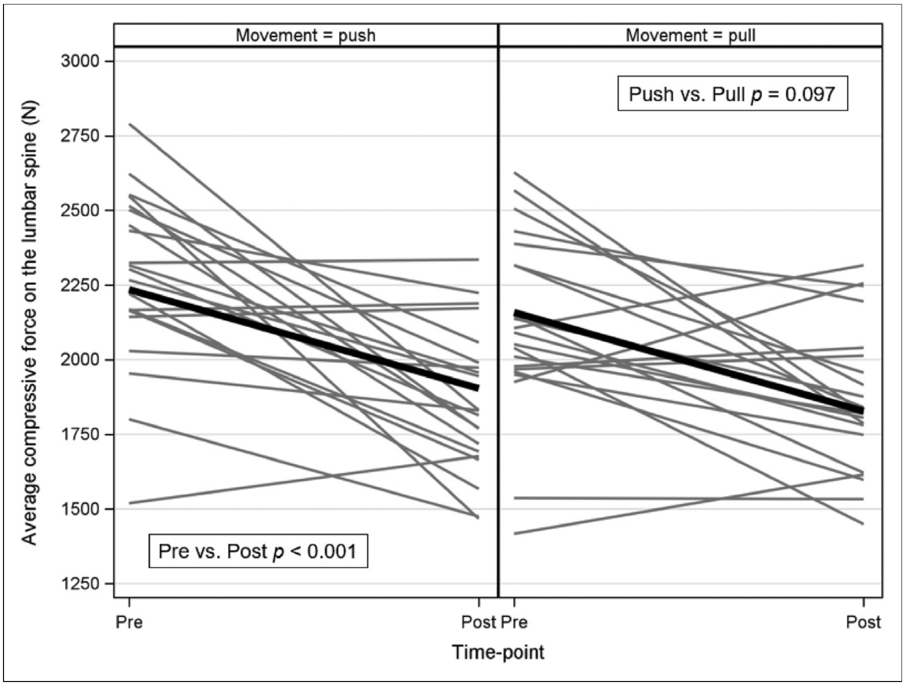

FIGURE 3

Average compressive force (N) by movement and time-point. **Note*. Gray lines represent trends for individuals while the black line is the linear mixed-effects modeling estimated average trend across individuals.

difference in peak force for push versus pull movements ($t = -0.96$, $P = .342$), but there was a significantly lower estimated peak back compressive force at post-intervention relative to pre-intervention (post – pre $md = -365.5$ N, $t = -8.09$, $P < .001$). Similarly, for average back compressive force, the difference between pre- and post-intervention average force did not depend upon the movement (F [1,60] = 3.40, $P = .070$). Again, there was not a significant difference in average force for push versus pull movements ($t = -1.69$, $P = .097$), but there was a significantly lower estimated average back compressive force at post-intervention relative to pre-intervention (post – pre $md = -331.0$ N, $t = -7.32$, $P < .001$).

Discussion

Despite previous efforts aimed at injury prevention, back injury remains a major concern among the nursing profession worldwide.[2,11,13,18,19] The National Institute of Occupational Safety and Health (NIOSH) established a peak compressive force on the lumbar spine of 3.4 kN[26] in an effort to decrease the risk of lower back injury. This limit of 3.4 kN was established by linking compressive force data to the incidence rate of lower back injury[28], but the validity of this limit has been questioned[25,27] specifically for workers over the age of 40 years[25] and during movements requiring flexion of the spine.[25,27] While questions remain about the exact limit that should be in place for compressive force on the lumbar spine, it is accepted that an increased compressive force on the lumbar spine during flexion, as seen in the horizontal transfer, will result in an increased risk for injury.[40]

Our analysis demonstrated an average compressive force on the stretcher side (push) of 2276 N and the gurney side (pull) of 2117 N when utilizing the recommended lifting technique to complete the horizontal transfer. This finding is consistent with the findings of Lavender et al, with EMS workers demonstrating an average compressive force of 2147 N on the stretcher side and 3350 N on the gurney side.[24] A significant reduction in estimated force (1863 N stretcher and 1868 N gurney) was demonstrated when utilizing the SHAPE lifting technique,[3,4] lending merit to the SHAPE lifting method providing a reduction of musculoskeletal injury risk during the horizontal transfer of the patient compared to the current recommended method.

Educational offerings have demonstrated limited success in reducing injury rates, but few display an acceptable quality in their methodology, and large variation in educational approaches exists.[12] Improvement has been noted in safe lifting techniques secondary to educational offerings,[41] but there remains a lack of high-quality studies to explore the true effects of preventative strategies.[42] This study evaluated the effect of a new lifting intervention on the compressive force of the lumbar spine in comparison to current recommended practice.[29,35]

Although several studies have indicated a minimal impact of educational interventions on musculoskeletal injury,[20,43-45] the standard of raising the bed to hip height for patient movement[19] may be perpetuating the failure of this methodology. The use of the SHAPE lifting education method has demonstrated an improvement in the biomechanical risk factors of lever arm distance,[4] trunk flexion, trunk velocity, and improved muscle activation[3] during the horizontal transfer of a patient. The further analysis of this data has demonstrated that the use of the SHAPE lifting method provides a decrease in the estimated compressive force on the lumbar spine when compared to the accepted teaching practice.

Limitations

There are several limitations in this study. The homogenous sample size, including all healthy college students, does not allow for the findings of this study to be generalizable to the nursing population. The limited weight of the simulated patient (34 kg and 75 kg) does not consider the patients that exceed these weights in the emergency department. An increased weight of the patient would increase the force experienced at the lumbar spine; however, the comparison between the recommended lifting method and the SHAPE lifting method utilized the same weight patient for both movements. Another limitation of the study is the smaller sample size. In biomechanical research, a smaller sample size is not uncommon among biomechanical studies due to the large volume of data associated with motion capture (60 frames per second) and EMG (1200 frames per second) collections. Target power of 0.8 is often achieved with 5 to 40 participants when utilizing 1-dimensional (1D) analysis.[46] Given the sample size of 21 participants and the use of 3D motion analysis rather than 1D, the given sample size was adequate to achieve power but does not allow for generalizability to all nurses completing the task. Future research should include a larger sample size of emergency nurses and examine their perceived pain and fatigue related to patient handling activities.

Implications for Emergency Nurses

The positioning of the nurse when performing the horizontal transfer of a patient is critical to reduce the compressive force on the lumbar spine. While the primary preventative strategy for back injury among nurses is the use of lifting devices and eliminating the need for manual handling of a patient,[20,45] it is not always feasible to use these devices for a newly presenting patient to the emergency department from an EMS provider due to the narrow footprint of the EMS stretcher making it unsafe to place a lifting harness under the patient; thus the use of a slide board can be an effective addition while transferring the patient to the hospital gurney. Slide boards have demonstrated a reduction in the force required to be generated to move a patient to 26% of a patient's weight[47] and are often readily available in the emergency department. While upwards of 80% of the torque placed on the lower back during a patient's movement while using a slide board is related to body positioning,[47] the body position of the nurse during the horizontal transfer of the patient is critical in limiting the risk of lower back injury.

The horizontal transfer of a patient will require 2 people at minimum, 1 on the stretcher side (push) and 1 on the gurney side (pull). The bed should be positioned at the mid-thigh position of the shortest lifter, allowing all members assisting with the move to begin in a squat position with a neutral position of the spine while using the muscles of their legs to initiate the movement. Activation of the core[48] is critical to provide stability to the lumbar spine during the movement. Core activation and the SHAPE lifting technique are described in Table 2.

Conclusions

Emergency nurses face many physical and mental stressors in the performance of their everyday job. Through the proper use of assistive devices to reposition and move patients, the physical strain on the nurse can be reduced while transferring a patient from the EMS stretcher to the hospital gurney. The SHAPE lifting technique makes the adjustment in the bed height to the mid-thigh position rather than hip height to reduce the estimated compressive force on the lumbar spine. With safer lifting strategies through improved biomechanics, we can limit the incidence of musculoskeletal injuries in our emergency work force.

Author Disclosures

Conflicts of interest: none to report.

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Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jen.2023.12.009.

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