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May 2015

Abstract

OBJECTIVE: This study examined the forces exerted by caregivers while performing the patient-handling task of sliding a patient up in bed when using a variety of bed heights.

METHOD: Thirty-eight healthy adult participants from 20 to 58 years of age were recruited as "caregivers" in this study. Hand forces and lumbar compression, forward shear, and sagittal shear forces were calculated on the "caregivers" during the repositioning task.

RESULTS: Statistically significant differences between the bed heights in terms of compression forces at L4-L5 and sagittal shear forces at L4-L5 and L5-S1. In the case of the compression forces at L4-L5, the results showed that the highest bed position (51% of the caregiver's height) required statistically less force than the lowest bed position (41% of the caregiver's height). When considering the sagittal shear forces at L4-L5, the lowest bed position required statistically less force than the bed in the highest position. This trend was contrary to all other findings. In terms of sagittal shear forces at L5-S1, the middle bed position (46% of the caregiver's height) required statistically more force than either the low or high bed position. This finding mirrors the results of the hand forces, which showed that the middle bed position required statistically more peak force than either the low or high positions. While there was no statistical significance found in the compression forces at L5-S1 or the forward shear forces at L4-L5 or L5-S1, these results trended in the same direction of the compression forces at L4-L5 in that the highest bed position required the least amount of force and the lowest position required the most amount of force.

CONCLUSION: This study does support the adjustment of bed height based on the caregiver's height. In all but one finding, the higher, more upright bed position required the least amount of force of the caregiver in terms of lumbar forces. Future research should continue to investigate best safe patient handling techniques during a variety of repositioning and transfer tasks.

Introduction

Work related injuries, including musculoskeletal disorders, are prevalent in healthcare workers (Daynard et al., 2001; Nelson & Baptiste, 2004). The physically demanding nature of patient handling tasks leads to injuries and musculoskeletal disorders, especially among nursing aids, orderlies, and attendants. According to the Bureau of Labor Statistics, these three categories of personnel had the highest overall incidence of injury, as well as the most number of musculoskeletal disorders resulting from workplace injury (2012). More than 43,000 healthcare professionals reported musculoskeletal disorders in 2011 alone (Labor, 2012). This issue of safe patient handling is incredibly relevant to the healthcare field and is of great concern to the Occupational Safety and Health Administration (United States Department of Labor, 2012).

The most common of all musculoskeletal disorders in healthcare workers is low back injury (Kjellberg, Lagerström, & Hagberg, 2003). Much research has been done on the prevalence of low back pain as a result of work related injury in nursing staff (Gagnon, Chehade, Kemp, & Lortie, 1987; Marras, Davis, Kirking, & Bertsche, 1999; Mitchell et al., 2009; Owen & Garg, 1991; Yassi et al., 1995; Yingling & McGill, 1999). According to Knibbe and Friele (1996), between 35-80% of nurses will experience low back pain in a given year. The most common cause of low back pain and injury in nursing personal is the task of patient transfers (Knibbe & Friele, 1996; Marras et al., 1999; Yassi et al., 1995). According to Yassi et al., (1995), the top two reasons provided by nurses for the high incidence of low back injuries are insufficient training and inadequate staffing. As a result, nurses are using improper patient handling techniques and are attempting to bear too heavy of a load without assistance, resulting in low back pain (Kjellberg et al., 2003).

Occupational and physical therapists are also at risk of sustaining such injuries during patient handling (Darragh, Huddleston, & King, 2009). Darragh et al., (2009), found that incidence of both occupational and physical therapists experiencing work related musculoskeletal injuries is on the rise. In 2006, between 16 and 17% of occupational and physical therapists reported sustaining musculoskeletal injuries that year (Darragh et al., 2009). These injuries lead to days off of work, medical costs, job changes, and general discomfort, which can seriously impact job performance (Darragh et al., 2009). Recent studies have shown that about 64% of occupational therapists in the state of Ohio are involved in patient handling tasks as a part of their job duties (Rice, Dusseau, & Miller, 2011). With the large number of occupational therapists expected to perform patient lifting tasks and sustaining injuries as a result, it is important that these professional receive sufficient training in the most current safe patient handling (SPH) techniques (Slusser, Rice, & Miller, 2012).

There are studies that investigated the degree to which SPH is addressed in occupational therapy and occupational therapy assistant curricula (Frost & Barkley, 2012; Slusser et al., 2012). These survey studies have provided great insight into the current situation surrounding work related musculoskeletal injuries sustained by occupational therapists and occupational therapy assistants specifically. Frost and Barkley (2012) achieved a response from of 49.6%, receiving 118 completed surveys from educators across America, out of the 238 surveys that were sent out. They found that although limited safe patient handling techniques are being incorporated into OT and COTA curricula, the basis for teaching is still on traditional manual patient handling (TMPH). Even among programs that advertised an emphasis on proper biomechanics and patient handling techniques, it was found that 78% use TMPH as the standard of practice (Frost & Barkley, 2012).

Slusser et al., (2012), supported these findings and added that 98.2% and 96.4% of programs used sliding boards and gait belts respectively, as a part of their SPH instruction. In contrast, only 18% used a powered portable lift, 10.8% used a powered sit-to-stand lift, and a mere 2.7% used a powered ceiling lift as a part of their SPH instruction (Slusser et al., 2012). These results are based on 111 returned surveys, out of 285 surveys that were successfully sent, rendering a response rate of 39% (Slusser et al., 2012). These findings support the evidence that occupational therapy programs currently lack the awareness and equipment necessary to make the much-needed shift from manual patient handling to safe patient handling.

It has been shown that traditional manual patient handling techniques are unsafe, and have contributed to the current rate of injury in this field (Menzel, Hughes, Waters, Shores, & Nelson, 2007; Waters, Collins, Galinsky, & Caruso, 2006). In contrast, safe patient handling techniques have been found to be successful in transferring and positioning patients safely and, when used correctly, can prevent musculoskeletal injuries (Frost & Barkley, 2012; Menzel et al., 2007; Nelson & Baptiste, 2004; Waters et al., 2006). Currently there is a disconnect between emerging evidence against TMPH in favor of SPH and what is taught in occupational therapy curricula (Frost & Barkley, 2012). In light of the aforementioned findings, it is imperative for researchers to continue to add to the evidence for safe patient handling, as there is a need for more health related disciplines to shift their standards of practice from TMPH to SPH (Frost & Barkley, 2012; Slusser et al., 2012).

Because of their background and training in positioning patients using proper handling techniques, occupational therapists, they are considered to be leaders in the area of SPH (Rice et al., 2011). This is evidenced, in part, by the fact that occupational therapists are often in charge of providing in-service training on patient handling to other facility staff (Rice et al., 2011). In a survey sent out to all members of the Ohio Occupational Therapy Association (OOTA), an overwhelming 81% of respondents indicated that occupational therapists were responsible for the in-service training when manual patient transfers were involved (Rice et al., 2011). This statistic is based on 285 surveys that were returned, out of the 1,097 that were successfully sent, an overall response rate of 26% (Rice et al., 2011). Because they are so often counted on to provide training to other healthcare providers, occupational therapists have the responsibility to further investigate the most practical ways to prevent work related injuries due to improper handling techniques.

A variety of studies have investigated caregiver forces required during a range of handling tasks and even with different assistive devices and ergonomic approaches (Baptiste, Boda, Nelson, Lloyd, & Lee, 2006; Bartnik & Rice, 2013; Darragh et al., 2013; Daynard et al., 2001; Freitag, Ellegast, Dulon, & Nienhaus, 2007; Keir & MacDonell, 2004; Kjellberg et al., 2003; Marras et al., 1999; Rice, Woolley, & Waters, 2009; Yingling & McGill, 1999). Baptiste et al., (2006) studied the overall performance of a variety of lateral transfer devices, through surveys completed by the caregivers using the devices. Bartnik and Rice (Bartnik & Rice, 2013), studied the caregiver forces involved in sliding a patient up in bed, using a variety of slide sheets. Darrah et al., (2013) investigated the uses of SPH equipment in rehabilitation and the effects it has on therapists, patients, and practice. Daynard et al., (2001), analyzed the spinal loads involved in patient handling using patient handling techniques and existing equipment versus use of added mechanical and other assistive devices. Freitag et al., (2007) evaluated spinal column stress involved in all body postures and movements of nurses during a typical shift. Keir and MacDonell, (2004), studied the muscle activity patterns involved in manual patient transfers and also while using floor and ceiling lifts. Kjellberg et al., (2003), explored the techniques used by nursing personnel during transfers. Marras et al., (1999), analyzed the risk of low-back disorders in healthcare workers based on spinal loads during patient repositioning and transfers. Rice et al., (2009) investigated a variety of forces required during patient transfers using three different lifting devises. Finally, Yingling and McGill, (1999) studied the biomechanics involved in spinal motion segments during shear loading tasks.

As mentioned above, Bartnik and Rice (Bartnik & Rice, 2013) investigated the caregiver forces required when using a variety of slide sheets. This study assessed the hand forces, as well as lumbar compression and sheer forces necessary to slide a patient up in bed, utilizing three different kinds of commercially available sheets (Bartnik & Rice, 2013). There was a statistically significant difference in the lumbar forces required, such that the cotton sheets required the most force and the McAuley disposable sheet eliciting significantly less lumbar force (Bartnik & Rice, 2013). This study supports the use of friction-reducing slide sheets for healthcare professionals and encourages further study in hand and spinal forces during patient handling repositioning tasks (Bartnik & Rice, 2013).

With all of the studies that have been conducted on various aspects of safe patient handling, there are very few studies that investigated the effect of various bed heights on required caregiver forces specifically. The few studies that do address adjustable bed height and caregiver forces did not use specific percentages of body height as the independent variables (Caboor et al., 2000; De Looze et al., 1994; Gagnon et al., 1987). For instance, Caboor et al. (2000) used a sample size of 18 participants. The researchers choose a standard bed height of .515 meters for the first condition of the independent variable (Caboor et al., 2000). The second condition of the independent variable was left up to the participants, who either raised or lowered the bed height according to what they deemed best (Caboor et al., 2000). The researchers found that the overall quality of spinal movement was improved when caregivers were able to adjust bed height (Caboor et al., 2000). Caboor et al. (2000) also found that when caregivers adjusted the bed to a higher position that allowed for a more upright stance, the caregivers spent more time in what these authors considered to be a "safe zone," referring to a more upright, neutral posture.

Similarly, De Looze et al. (1994) used a sample size of 22 participants. A bed height of .715 meters, according to the standards of the academic hospital in Brussels (De Looze et al., 1994). Again, the participants were asked to choose the secondary bed height, which was the second condition of the independent variable (De Looze et al., 1994). The researchers in this study saw a significant decrease in compression forces and shear forces required of the caregiver when the bed was adjusted in either direction, though the vast majority of the participants selected a higher position (De Looze et al., 1994). However, De Looze et al., (1994) also pointed out that the study did not indicate an optimal bed height in relation to the caregiver because it did not compare imposed heights.

In yet another study, Gagnon et al. used a sample size of 15 participants to investigate five different independent variables, including: "direction of applied force, velocities, knee support, leg positions, heights of the bed" (1987). In this case the two conditions of the bed height variable were set at 6 and 16 centimeters from the participants forearm in 90 degrees of flexion (Gagnon et al., 1987). Of the five independent variables, the researchers found the bed heights had greatest impact on overall task excursion (Gagnon et al., 1987). This study found that when the bed was in the higher position (about hip level), the caregiver was in a more vertical position, which led to decreased maximal muscles moment in the low back, decreased maximal compression forces required (Gagnon et al., 1987). However, this study also failed to use a percentage of body height when determining optimal bed height. They instead used two positions measured in centimeters away from the caregivers' forearm in 90 degrees of flexion (Gagnon et al., 1987). This study and its important findings point to the need for researchers to conduct further studies in order to determine the most effective bed height, in relation to the caregiver's height, in order to reduce the amount of force needed to perform the task of sliding a patient up in bed.

Previous studies have indicated that utilizing a particular percentage of an individual's body height may be a practical method for adjusting bed-height to the position requiring the least amount of caregiver force (Bartnik & Rice, 2013; Lindbeck & Engkvist, 1993). These studies suggest that an adjustment to 46% of total body height may be the safest position for certain transferring and handling patients (Bartnik & Rice, 2013; Lindbeck & Engkvist, 1993). A bed at 46% of an individual's body height compared to a lower 41% creates a more upright posture in the caregiver and prevents unnecessary trunk flexion, which can lead to a reduction in lumbar force required during patient handling task (Bartnik & Rice, 2013; Caboor et al., 2000; Gagnon et al., 1987)

As noted in previous studies, a higher, more upright position may keep the caregivers in a safer, more natural position (Caboor et al., 2000; Gagnon et al., 1987). Also, Snook and Ciriello, (1991) provided data that suggested less force may be required when initiating the movement from a higher position. Based on the previous findings, this current study will adjust the bed to 41%, 46%, and 51% of the caregivers' height, in an effort to identify the safest positioning.

Previous studies have determined that using a variety of safe patient handling techniques and ergonomics, along with assistive equipment, is the best way to prevent musculoskeletal disorders as a result of patient handling (Daynard et al., 2001; Owen, 1988; Owen & Garg, 1991). As such, this study used a variety of slide sheets while investigating the forces required by caregivers at a variety of bed heights. It is clear from the research that the issue of safe patient handling is of utmost importance if the incidence of musculoskeletal disorders, especially low back pain, is to be reduced (Marras et al., 1999).

This current study seeks to provide evidence of using various bed heights upon healthcare workers when performing a repositioning task. Specifically, the purpose of this study is to examine the forces exerted by caregivers while performing the patient-handling task of moving a patient up in bed when using a variety of bed heights. It is hypothesized that there will be a significant difference in the forces (e.g., lower-back and hand) required by the caregiver when sliding a patient up in bed when using a variety of different bed heights.

Method

Participants

The participants of this study included 38 healthy adults, both male and female, between 20 and 58 years of age. Based upon data from Bartnik and Rice (Bartnik & Rice, 2013), it was estimated that this sample size would generate enough statistical power to yield a significant result with a mean difference of approximately 29 N, a standard deviation of 53.6 N , an $\alpha = .05$, and a $\beta = .8$ of the L4-L5 lateral shear forces between two different reduced friction slide sheets. Participant recruitment was completed using university email, informational flyers posted in various areas around a public university, and through "word of mouth." The "patient" throughout the entire data collection process was a 26-year-old male, weighing approximately 150 lbs.

Apparatus

A Motion Analysis system, using Cortex (version 6.403.3.1.1301) data acquisition software, coupled with eight Owl motion capture cameras provided 3D motion capture data throughout this study. This system was used in conjunction with two force places (Amti Model# OR6-5-1, 176 Waltham Street, Watertown, MA 02472 and Bertec Model# 2060A, 6171 Huntley Road, Suite J, Columbus, OH 43229) as well as two hand held Futek MTA 400 tri-axial load cells (Tri Axial Load Cell Model, 10 Thomas, Irvine CA 92618). The researchers used the 3D Static Strength Prediction Program (version 4.32, University of Michigan, 3003 S. State St. #20171, Ann Arbor, MI 48109-1280) to calculate the spinal loads. The compression and tension forces at the hand were measured using the Futek MTA 400 tri-axial load cells, while sliding the "patient" up in bed. The hospital bed used in this study was manufactured by Linak (Model# CB9140AE-3+A011F, No. 106). The three types of sheets used were a traditional cotton draw sheet, the McAuley Medical disposable fabric slide sheet, and the Arjo's Maxislide ™ sheet, produced in Roselle, IL.

Dependent Variables

This study analyzed the compression force involved at L4-L5 and L5-S1, and also anterior-posterior sheer force and lateral sheer force at these same joints. This study examined the forces at the hands. For the investigation of the spinal forces, motion capture data were collected during the repositioning motion. From that data, joint angles were ascertained using Visual 3D software version 5.01.6 (C-Motion, Germantown, MD). Then, this along with the force data from the Futek load cell force gauges were used by the 3D Static Strength Prediction Program (version 6.0.6, University of Michigan, Ann Arbor, MI) to calculate the low back forces. Data were smoothed using a dual pass Butterworth low pass filter using a 10Hz cutoff frequency.

Procedure

The Biomedical IRB from The University of Toledo approved this study. The researchers obtained informed consent from every participant prior to data collection, which occurred from August 2013 through February 2014. The participants in this study acted as the “caregivers,” and the investigator assistant (*n*=1) acted as the “patient.” The participant’s height and weight was recorded, and a series of 27 patient transfers (3 for each of the 9 conditions) was performed. The “patient” participant also signed an informed consent, was weighed, and was given instructions to lay supine in the hospital bed. The order of the presentation for the bed heights and sheet types was randomized into one of 9 possible combinations (41% of height with Sheet1, 41% of height with Sheet2, 41% of height with Sheet3, 46% of height with Sheet1, 46% of height with Sheet2, 46% of height with Sheet3, 51% of height with Sheet1, 51% of height with Sheet2, or 51% of height with Sheet3). This particular transfer technique has been termed “pulling patient up in bed” (Fragala, 2011).

The hospital bed was horizontal, and the two “caregivers” stood on either side of the bed throughout the transfers. The height of the bed was adjusted to either 41%, 46%, or 51% (based on the outcome of the randomization) of the height of the shorter of the two “caregivers” (Bartnik & Rice, 2013; Lindbeck & Engkvist, 1993). The “patient” began in a position with his arms across his chest and his heels approximately 4 inches from the foot of the mattress. Two markers were placed on the bed, 12 inches apart, in order to identify the distance of the repositioning based on the position of the “patient’s” head. The “caregiver” participants were standing on a force plate and were instructed to grasp the handles in forearm supination and prepare to slide the “patient” up the bed. The “caregivers” then moved to the Amti force plate and communicated with one another to count up to three, at which point the two “caregivers” slid the “patient” up the bed, about 12 inches.

Statistical Analysis

This study used a repeated measures design with a focus on bed height using a repeated measures ANOVA for each of the dependent variables. On those analyses where significance was found (alpha = 0.05), a post-hoc with repeated measures contrasts were used on every possible combination. A Bonferroni correction with alpha set at 0.016 for the contrast comparisons.

Results

There were no order effects for the dependent variables ($p > .05$). Data from 38 participants were included in the peak sum of hand force analysis. A summary of the means and standard deviations for the peak hand sum of the hand forces at the low, middle, and high bed heights are tabulated in Table 1.

During the caregiver task of sliding a patient up in bed, there was a significance difference between the hand forces required when the bed was in the low position and medium position. There was also a significant difference in the hand forces required between the medium and high positions. There was, however, no significant difference between the hand forces required at the low and high positions. See Table 2.

Data from one participant was unable to be used due to large marker gaps that made analysis unreliable, hence data from 37 participants were included in the analyses of the compression, forward sheer, and sagittal sheer forces at L4-L5 and also at L5-S1. There were no order effects for any of the dependent variables ($p > .05$). The means and standard deviations of the peak sum of the forward sheer, sagittal sheer, and compression forces at L4-L5 and L5-S1 are listed in Table 3.

The repeated measures analysis of variance with follow up contrasts compared the three bed positions (low, middle, and high) to each other. Statistically significant differences were found between the low and middle positions and the high and middle positions when analyzing the sagittal sheer forces at L5-S1. Statistical significance was also found when analyzing the compression forces at L4-L5 between the low and middle and also the low and high bed positions. Finally, statistically significant differences were found between the low and high bed positions when analyzing the sagittal sheer forces at L4-L5. The results of the Analysis of Variance can be seen in detail in Table 4.

Discussion

Statistical significance was found between the low and middle bed heights and the high and middle bed heights, but not between the low and high heights. The middle height (46% of the subjects' height) created the highest mean peak of sum hand forces at 66.4 pounds of force. Even though the low and high heights required statistically significantly less force at the hands, the force required was still 61 and 62 pounds respectively, dramatically over the recommended lifting limit of 35 pounds. See Table 1.

In terms of lumbar compression forces, statistically significant differences were seen between the low and middle and also the low and high bed positions at L4-L5, such that the compression force at the low position (41% of the subjects' height) was the highest, followed by the middle, with the high position (51% of the subjects' height) requiring the least amount of force. The compression force at L5-S1, however, while it did follow this same trend, did not result and any statistical significance between the 3 heights.

The forward sheer forces did not yield statistical significance between any of the bed heights at either L4-L5 or L5-S1; however, they did trend in the same way as the compression forces. At both L4-L5 and L5-S1, the highest bed height required the least amount of forward sheer force, with the lowest bed position requiring the most. Again, there was no statistical significance between the 3 heights in regards to the forward sheer forces.

Finally, and perhaps the most perplexing are the results of the sagittal sheer forces. At L5-L5, statistical significance was found between the low and high bed positions, in that the low position required the least amount of force and the high position requiring the most. This trend is contrary to the rest of the findings regarding the forces required at the lower back when sliding a patient up in bed.

Additionally, the sagittal sheer forces required at L5-S1 showed statistical significance between the low and middle and also the middle and high bed heights. In this case, the middle bed height required statistically significantly more sagittal sheer force at L5-S1 than at the low or high bed heights. This finding mirrors the forces required at the hands when sliding a patient up in bed, but also does not agree with any of the other trends in bed height regarding the forces required in the lower back with this specific safe patient handling task.

One reason for the varied findings could be that the “caregiver’s” elapsed time when sliding the patient up in bed was not controlled for in the statistical tests. If the caregiver slid the patient more quickly at a particular bed height, he or she may exert more peak force than if the sliding motion were performed more slowly. However, because each participant was compared to himself or herself, this variable may not have made as much of an impact on the study assuming that intra-subject variability is minimal.

Another set of factors to consider in the analysis of these results is the respective body positions and joint mobility of the “caregivers” in this study. No two participants are alike, therefore the force required at specific anatomic locations can vary greatly between the participants. For instance, two participants may be the exact same height, yet one participant's arms and torso may be several inches longer than the other. These differences, while seemingly small, can have a significant impact on the way the force of the movement affects the individual's joints and muscles. As such, it is very difficult for a software program to conclusively show the exact amount of force required at specific anatomical landmarks when the force is translated so differently to each of these body parts depending on the participants' unique stature.

When considering the results of the hand forces and the sagittal sheer forces at L5-S1, which were consistent with each other, one possibility is that the middle bed height is the most biomechanically favorable position for the caregiver to pull from during this specific transfer. It is presumed that the middle bed position, 46% of the caregiver's height, would be the most biomechanically sound position because the load presented by the patient is closest to the caregiver's center of mass. Because of this favorable body position, the pull of force vector is therefore more perpendicular to the caregiver's spine, making it more biomechanically efficient to perform the slide transfer. These specific results, which were both statistically significant, suggest that the middle height required significantly more peak force than either the low or high positions. If the middle position is the most biomechanically favorable position, then the transfer itself may have been the most efficient at this height, leading to the highest amount of peak force. Again, as time was not a factor taken into account in this analysis, it is difficult to say conclusively if this was the case.

All of the other results, except for the outlier of the lateral sheer forces at L4-L5 (which trended the exact opposite way), favored the highest bed position or the most upright body position. These results are more logically conclusive in that the lower bed positions cause more force to be exerted at the back, because this position requires caregivers to be in a more flexed position at the trunk and hips. This forward leaning, biomechanically unsound position results in gravity pulling on the upper body to a greater degree and requires tremendous spinal forces to maintain this forward flexed position. The pull transfers at the low positions could almost simulate more of a lift than a slide, which would also require more force at the back. While the hand forces don't corroborate this, it may be that the forces from the upper body moments are highest when the bed is at the lowest position.

These results, which support the higher bed position and more upright posture for the slide transfer, support previous results by a variety of researchers (Caboor et al., 2000; De Looze et al., 1994; Gagnon et al., 1987). Caboor et al., (2000) concluded that when caregivers selected their own bed height from which to transfer patients, they had an improvement in their spinal movements. Also, this study found that when the bed height was adjusted to a higher position, that the caregivers' were in a more "upright, neutral posture" that was considered a "safe zone" (Caboor et al., 2000). While this study did not adjust the bed positions specifically based on the caregivers height as this current study did, the results still support a higher bed position, that leads to the caregiver being in a more upright stance. The majority of the results of the present study do corroborate these findings.

In a similar study, De Looze et al., (1994) supported the idea that caregivers ought to be allowed to adjust the bed height before performing a transfer. This study showed a significant decrease in shear and compression forces during a slide transfer when the bed height was selected by the caregiver. In this study, the majority of the caregivers, when given the option, moved the bed into a higher position. Again, the variable bed heights were not imposed on the caregiver as they were in the current study. Also, in the De Looze et al. study some participants did select a lower bed height from the standard .715 meters; however, without knowing their respective heights it is difficult to determine if this study's findings do agree conclusively with the findings of the present study. However, the fact that most participants did raise the bed and did experience a decrease in compression and shear forces does support the general conclusions of the current study that a higher bed position in relation to the caregiver's height can be a more optimal position for safe patient handling.

Finally, Gagnon et al., (1987) found that of their five independent variables (listed above) the bed heights had the greatest impact on the task excursion of the participants. Similarly to the current study, this study by Gagnon et al. analyzed the compression forces at the lower back. Additionally, they investigated the maximal muscles moment in the lower back. Also, this study did use the anatomy of the study participants to adjust the bed height, using the distance from their forearms when in 90 degrees of flexion. Gagnon et al., (1987) did find that the higher bed position did allow the participants to be in a more vertical body position, therefore decreasing both the maximal muscles moment and the compression forces at the lower back. Again, the current study does support these findings in the results of the compression and forward shear forces required at both L4-L5 and L5-S1.

While this current study used different independent variables than any of the aforementioned studies, the results of all of them support the idea that a more upright posture is the safest biomechanical position for performing safe patient handling sliding tasks. As mentioned in detail above, there is a general lack of safe patient handling research that investigates the effects of bed height specifically. As such, this current study does help to add to the knowledge base while also pointing to the need for further studies to be done.

Limitations and Future Research

There are several limitations to address in this study. One of the more obvious limitations is the sample of participants. The majority (87%) of the participants were females from age 22 to 26. This sample is certainly not representative of the average caregivers involved in safe patient handling tasks in the work force. Also, none of the participants were actively involved in patient transfers or had much experience with such safe patient handling tasks. Also, the “patient” in the situation was approximately 155 pounds, which is not representative of the average adult patient in hospitals across America today.

Another limitation to note in this study is the artificiality of the lab setting these transfers were conducted in. While for the purposes of this study, it was necessary to use a laboratory setting, it does not accurately reflect the variables that are often present in the hospital setting where many safe patient handling tasks occur. For instance, in the hospital setting, patients who require a maximum assistance transfer often have a variety of tubes and lines (e.g., urinary catheters, intravenous lines, hemovac drains) connected to various parts of their body. These obstacles can cause the caregivers to assume awkward positions during transfers in an attempt to move the patient safely without disrupting any of the equipment. Also, in the hospital setting, caregivers are often sliding the patients by gripping the sheets or the mattress pads with their hands. In this study, tri-axial force gauges were attached to the sheets with handles that the “caregivers” gripped to slide the patient. Again, while this artificial setting was necessary for the completion of this study, future research could be conducted in a more naturalistic setting, using participants who are experienced in safe patient handling tasks.

Another limitation is that while two “caregivers” were involved in the repositioning tasks in this study, data were only collected on one of them. One of the researchers involved in this study acted as one of the caregivers in every trial, though data were never collected from that individual. It would be noteworthy to analyze the data from both caregivers involved in the transfer, in order to be able to compare the two. While this is not presumed to have affected the existing data significantly, it would be an interesting addition to future research studies.

Conclusion

In light of the vast evidence of manual patient handling tasks leading to injuries to healthcare workers (Menzel et al., 2007; Waters et al., 2006), it is critical to investigate the effectiveness of various safe patient handling techniques. While some of the finding of this study were inconclusive, the trends showed that a higher bed height can lead to reduced compression and forward shear forces required at L4-L5 and L5-S1. Because of the important role occupational therapists play in increasing and dispersing knowledge regarding safe patient handling (Rice et al., 2011), the current study contributes to the ever-important body of evidence-based research.

Researchers in this study concluded that the highest bed height (51% of the participants' height) required the least amount of peak compression and forward sheer forces in the lower back, with significant results in compression forces at L4-L5. It was also determined that the sagittal sheer forces at L5-S1 were significantly higher at the middle bed height than at either the higher or lower heights. The only result that did not point toward the high bed height requiring the least amount of force was the sagittal shear forces at L4-L5, which showed the lowest bed position as requiring the statistically lowest amount of force. Because standard hospital beds are adjustable, raising the bed height is a simple, cost-effective way to reduce stress on the lower back for caregivers. While this study does help to build an evidence base, further research is necessary to establish best practices for safe patient handling techniques.

Future research should continue to investigate the effects of bed heights on required caregiver forces. Additional independent variables such as friction reducing slide sheets in combination with adjustable bed heights could also be investigated. More evidence is needed to determine safe and unsafe peak force amounts that caregivers should be allowed to exert safely. Without restrictions on how much weight caregivers can safely handle and without more concrete safe patient handling guidelines, caregiver injury will continue to be a pervasive problem. With more studies investigating similar safe patient handling tasks, the evidence-base of safe patient handling research will continue to grow, hopefully resulting in fewer work related muscular skeletal injuries for healthcare workers.

Acknowledgements

I would like to thank so many who have helped to make this research study a success over the past two years. First and foremost, I would like to thank my research advisor Dr. Martin Rice, for all of the advice, support, encouragement, and patience through this lengthy process. Thank you for lending your expertise in the construction of the research lab equipment, for completing the statistical analyses, and for allowing me time to be thorough in the arduous data analysis process. Thank you for giving of your time to help build in me an appreciation for research, safe patient handling, and the role of occupational therapists in this incredibly important effort. Thank you also to my research partner, Robert Larson, for all of your efforts to help this project to go as smoothly as possible. Thank you for the extra time you put into the data analyzation process, as I certainly could not have completed it without your help. A special thanks to Elizabeth Stringer, Ellen Del Valle, and Rachel Griffin, for offering of your time to help me try to better understand the Cortex software. Thank you finally to all of the participants from the OTD class of 2014, 2015, and 2016 who gave of your time to make this study successful.

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Table 1

Summary of Mean and Standard Deviation for Peak Sum of Hand Force

Height	Mean (lbs.)	Std. Deviation	*n*
Low	61.05	11.42	38
Middle	66.44	11.23	38
High	62.12	9.70	38

Table 2

Analysis of Variance for Required Hand Force at Low, Middle, and High Bed Heights

Source	Height	Type III Sum of Squares	*df*	Mean Squares	F	*p*
	Low vs. High	43.46	1	43.46	1.25	.270
	Low vs. Middle	1105.73	1	1105.73	21.59	.000
	Middle vs. High	710.76	1	710.76	31.37	.000
Error	Low vs. High	1282.35	37	34.66		
	Low vs. Middle	1894.77	37	51.21		
	Middle vs. High	838.32	37	22.66		

Note. Alpha was set at 0.0167.

Table 3

Summary of Mean and Standard Deviation for Peak Sum of Compression, Forward Sheer, and Sagittal Sheer Forces at L4-L5 and L5-S1.

Force and Location	Height	Mean (Newtons)	Std. Deviation
	Low	1790.50	791.45
L4-L5 Compression	Middle	1475.65	641.80
	High	1349.65	591.07
	Low	680.89	358.07
L5-S1 Compression	Middle	657.50	303.83
	High	601.33	362.57
	Low	326.32	85.23
L4-L5 Forward Sheer	Middle	323.04	88.18
	High	311.21	75.59
	Low	153.05	47.54
L5-S1 Forward Sheer	Middle	150.42	58.17
	High	144.26	46.16
	Low	130.36	105.61
L4-L5 Sagittal Sheer	Middle	146.46	115.71
	High	155.00	92.21
	Low	378.68	83.39
L5-S1 Sagittal Sheer	Middle	401.27	81.94
	High	376.49	79.73

Note. Effect sizes were only calculated for the statistically significant variables.

Table 4

Analysis of Variance for Peak Sum of Compression, Forward Sheer, and Sagittal Sheer Forces at L4-L5 and L5-S1 at Low, Middle, and High Bed Heights

Source	Height	Type III Sum of Squares	*df*	Mean Squares	F	*p*	Effect Size
L4-L5 Compression	Low vs. High	363422.16	1	363422.16	29.04	.000	0.44
	Low vs. Middle	185367.85	1	185367.85	11.72	.002	0.63
	Middle vs. High	29687.77	1	29687.77	3.06	.089	0.20
Error	Low vs. High	450573.54	36	12515.93			
	Low vs. Middle	569182.64	36	15810.63			
	Middle vs. High	349094.11	36	9697.06			
L5-S1 Compression	Low vs. High	11836.21	1	11836.21	2.00	.166	
	Middle vs. High	5899.90	1	5899.90	2.46	.125	
Error	Low vs. High	213255.84	36	5923.77			
	Middle vs. High	86263.95	36	2396.22			
L4-L5Forward Sheer	Low vs. High	426.89	1	426.89	2.60	.116	
	Middle vs. High	261.37	1	261.37	2.82	.102	
Error	Low vs. High	5909.22	36	164.15			
	Middle vs. High	3341.42	36	92.82			
L5-S1Forward Sheer	Low vs. High	144.46	1	144.46	2.56	.119	
	Middle vs. High	70.89	1	70.89	1.33	.257	
Error	Low vs. High	2034.66	36	56.52			
	Middle vs. High	1925.24	36	53.48			
L4-L5Sagittal Sheer	Low vs. High	1135.41	1	1135.41	7.44	.010	-0.15
	Low vs. Middle	484.44	1	484.44	3.19	.083	-0.25
	Middle vs. High	136.56	1	136.56	1.07	.308	-0.08
Error	Low vs. High	5495.84	36	152.66			
	Low vs. Middle	5467.59	36	151.88			
	Middle vs. High	4602.69	36	127.85			
L5-S1Sagittal Sheer	Low vs. High	8.98	1	8.98	.10	.758	-0.27

	Low vs. Middle	954.48	1	954.58	7.19	.011	0.03
	Middle vs. High	1148.74	1	1148.74	17.79	.000	0.31
Error	Low vs. High	3366.35	36	93.51			
	Low vs. Middle	4778.46	36	132.74			
	Middle vs. High	2324.19	36	64.56			

Note. Effect sizes were only calculated for the statistically significant overall ANOVAs.