Forces involved when sliding a patient up in bed

Robert E. Larson

Forces Involved when Sliding a Patient Up in Bed

Robert E. Larson

Research Advisor: Martin S. Rice, PhD, OTR/L, FAOTA

Occupational Therapy Doctorate Program

Department of Rehabilitation Sciences

The University of Toledo

May, 2015

This scholarly project reflects individualized, original research conducted in partial fulfillment of the requirements for the Occupational Therapy Doctoral Program, The University of Toledo.

Abstract

OBJECTIVE: This study investigated the effects of 3 different types of slide sheets upon hand forces while sliding a patient up in. The sheets used were the Arjo Maxislide, the McAuley disposable sheet, and standard cotton sheet. METHOD: There were 37 participants in the course of this study, aged 20-57, both male and female. Hand forces were taken from the subjects for data analysis as they participated in the task of sliding a patient up in bed. RESULTS: A repeated measures analysis of variance (ANOVA) with 5 levels to the repeated factor (number of sheets and sheet type) was used, along with post-hoc repeated measures contrasts to compare differences between each condition. The results showed a significant reduction in required force when using the friction reducing sheets as compared to the cotton sheets when used according to manufacturer recommendations, as well as a reduction in one of the single friction reducing sheet categories compared to the cotton. However, even with the reduction in force when using friction reducing sheets, it is important to note that all forces were above the 35 pound recommended lifting limit. CONCLUSION: This study shows the importance of using friction reducing slide sheets while engaging in manual patient handling. The reductions of the forces exerted on the body are important in keeping healthcare workers safe. Other research that should be completed includes looking at the forces involved with other friction reducing materials and methods as well as the possibility of combining said materials and methods.

Keywords: Bedding and Linens, Cotton, Friction, Nursing Staff, Hospital, Moving and Lifting Patients, Aged, Posture, Body Mechanics, Sheets

Forces Involved when Sliding a Patient Up in Bed

Introduction

Healthcare is an important field as many people experience illness and injury every day and must be treated by appropriate professionals. While treating those injured and ill, these healthcare professionals put themselves in potentially hazardous situations on a daily basis. There are many situations in which there is potential for harm to the worker, and one of the foremost of those is when they manually handle patients (OSHA, 2011). This danger affects mainly nurses, as they are the ones most involved with patient repositioning, but it also affects occupational and physical therapists as they are involved in many similar and related healthcare tasks and thus are at risk for contracting comparable work related musculoskeletal disorders.

Occupational and physical therapists do receive training in their education and on the job regarding how to ergonomically transfer and handle patients during therapeutic interactions (Darragh, Campo, & Olson, 2009). In addition, there are also specific safe patient handling techniques and knowledge of materials bestowed upon students in this field, but there is variation on what and how it is taught (Slusser, Rice, & Miller, 2012). Notwithstanding, these professionals are still at risk for having a musculoskeletal disorder at some point in their careers (Bork et al., 1996). As such, there is a focus on how to reduce the number of injuries that healthcare workers incur (Li, Wolf, & Evanoff, 2004; Owen, Keene, & Olson, 2002; Waters, Collins, Galinsky, & Caruso 2006). This is particularly important as the demographics of the nation are changing to include older and larger individuals, which can pose an even more substantial risk to healthcare workers (CDC, 2013).

Although the overall numbers of work related injuries of employees in all fields of employment in the United States for 2011 were reduced from the previous year, musculoskeletal injuries between the two years remained statistically unchanged. Among those who incurred such injuries, nursing assistants and registered nurses continue to account for two of the top five careers which had musculoskeletal disorder claims in 2012 (BLS, 2013). Some of the other at risk professions include construction workers, landscapers, and janitors. In these lines of work there is a very strong physical component that must be done in the line of duty. Nursing also includes a physical component. It has also been reported that on an 8-hour shift a member of the nursing staff typically lifts up to 1.8 tons cumulatively during patient handling responsibilities, which plays into their having among the highest rates of musculoskeletal injury (Tuohy-Main, 1997).

The median recovery time for registered nurses was 8 days and for nursing aids was 6 days. There were 11,610 registered nurses and 23,390 nursing assistants who experienced a work related musculoskeletal disorder in 2012. The math on these numbers comes to a total of 233,220 days of missed work (BLS, 2013). Interestingly, that is just under 639 years of work for one person if they work every day of the week for as long as it would take to make up the deficit. This loss obviously costs our nation a significant amount of money both because of work that is lost as well as the cost for recovery of the individual. It is enlightening to look more in depth at injuries experienced by occupational therapists who often do the same or parallel tasks in similar workplace settings as the nursing staff throughout the course of their careers.

Within the field of occupational therapy, a study by Rice, Dusseau, and Miller (2011) found that of respondents, 5% of occupational therapists and occupational therapy assistants in Ohio experienced a musculoskeletal injury secondary to patient handling activities within the past year. When the study focused in on those therapists and assistants who were required to handle patients on a regular basis the injury rate jumped to 8.3%. Overall, 21% of respondents had experienced regular pain within the last 5 years due to patient handling. There were also a substantial amount of occupational therapists and occupational therapy assistants, specifically 11%, who had missed work due to a patient handling related musculoskeletal injury, and 12% of respondents had considered leaving the profession due to concerns about work related musculoskeletal disorders. Of the 1,113 emails that were sent out across the state, 285 of them were completed coming to a total response rate of 25.6%.

Another study, done by Darragh, Huddleston, and King (2009), reduced the propensity of therapists to underreport their injuries by having the therapists that were surveyed mark their pain level on a visual analog scale and then describe the frequency of the pain. If the response was greater than a four out of ten on the 0-10 point visual analog scale for either more than a week or at least once a month for current practitioners, then it was counted as a work related musculoskeletal injury. With this methodology the authors found that in Wisconsin 21.8% of occupational therapists experienced injuries. That is over one fifth of the therapist population. If all of them experienced a musculoskeletal disorder at the same time then the healthcare system of Wisconsin would be severely taxed and therapy departments would suffer across the state. Of the 3,297 physical and occupational therapists in Wisconsin who were mailed a survey, 1,158 were included in the final data analysis for a 35.1% return rate. Of those returned, 477 were from occupational therapists and 681 were from physical therapists.

Some facilities are attempting to address the issue of the high number of musculoskeletal disorders in healthcare professionals in a responsible and efficient manner. For instance, a unique patient handling program was implemented and tracked in skilled nursing facilities between the years 1995 and 2000. There were six different skilled nursing facilities that ranged from 60 to 120 beds for a total of 552 beds. This program implemented mechanical lifts, repositioning aids, a zero lift policy, and employee training for all of the equipment and policy implementation that was necessary for this to be successful. The initial cost to the facilities totaled $158,556. However, with the benefits that these facilities saw they were able to recover the cost within three years and proceeded to save the facilities $55,000 in worker's compensation costs annually (Collins, Wolf, Bell, & Evanoff, 2004). This shows the importance of reducing the risk of musculoskeletal disorders in order to prevent their occurrence, as well as showing how much money can be saved by using various safe patient handling methods and supplies.

A study by Yassi et al. (2001) outlines a randomized controlled trial in which facilities were assigned to one of three possibilities: a "no-strenuous lift" program, a "safe lifting" program, or "usual practice." The "no-strenuous lift" program involved the use of mechanical devices to do the majority of the actual lifting in place of the staff, thus reducing the workload required of the healthcare workers. The "safe lifting" program involved use of assistive devices such as transfer belts and slide devices whose purpose was to decrease biomechanical loading. "Usual practice" was, of course, leaving the facility to do what they typically do without the aid of any sort of devices. Three service areas were included in each condition: the medical, surgical, and rehabilitation wards. Thus there were 9 wards total involved in the study. All of the wards were similar in patient type, patient population, staffing, and number of caregiver injuries in the preceding 3 years.

Over the course of a year, 346 nurses and unit assistants were interviewed 3 times, once at baseline, once at 6 months, and once at the year mark (Yassi et al., 2001). The interviews were used in order to gain information on how many patient lifts and transfers the nurses and unit assistants perform during a typical shift, what sort of work fatigue and discomfort they were experiencing, and their current state of general health, safety, pain, and disability.

Interestingly, the total number of injuries was not statistically reduced overall for any of the arms of the study, but the type and location of the injuries changed (Yassi et al., 2001). It is important to note that this study only had a 40-60% power to detect changes in injury rates, which could be why there was no significant reduction in injuries found, as well as a small sample size and number of variables. Those who used more mechanical means of moving patients were found to have reduced numbers of back and trunk injuries. There was a very specific decline in injuries found in the medical ward of the no-strenuous lift program, but since it was only one part of one arm of the experiment it was not conclusively significant. However, it was the only detectable decline in injury rate and the authors feel that this shows that mechanical lifting devices are important in certain settings but not as much in others. Aside from injury data, the authors found that there was a significant decrease in levels of fatigue in both of the intervention arms compared with the usual care arm, which could indicate a better working environment and could influence job satisfaction. There was also an increase in comfort in patient handling tasks as well as an increase in the perception of safety among the intervention groups, which could also influence the aforementioned areas of workplace wellness.

There have been lifting limits derived from extensive research and sound equations for the lifting weight, lower back compressive force, anterior shear force, and lateral or sagittal shear force.

In 1993, Waters, Putz-Anderson, Garg, and Fine submitted that a healthcare provider should not lift more than 35 pounds during the manual handling of patients, which recommendation was reiterated later by Waters (2007). This guideline is known colloquially as the NIOSH equation and is based upon three criteria: biomechanical, physiological, and psychophysical aspects. The biomechanical area was defined by disc compression force and concentrates on the lumbosacral stresses placed on the body. The physiological area was defined by energy expenditure and outlines metabolic stress. The psychophysical area was defined by acceptable weight, which is the workers' perceived lifting capacity. These categories were chosen by a panel of experts in each of these areas. All of these areas were analyzed separately in order to discover the limits of each, and then they were united and combined with injury data to create a more conservative recommendation for maximum lifting tasks. The equation requires three categories, standard lifting location, the load constant, and the three factors mentioned above. The conclusion reached was that 35 pounds should not be exceeded in any sort of lifting task relating to the manual handling of patients. This guideline, if adhered to as Waters et al. suggest, has the potential to reduce work related musculoskeletal disorders.

McGill (2007) states that lower back compression limits come from NIOSH and was established in 1981, and reiterated by Marras in 1999. These limits were stated to be 6300 Newtons for the maximum compression limit, and 3400 Newtons for the lower action limit for repetitive motions. This conclusion was drawn based off of cadaver studies in conjunction with a review of factory work injury rates combined with the forces that were exerted by workers.

McGill, Norman, Yingling, Wells, and Neumann (1998) suggest a maximum shear limit, for anterior and posterior shear forces at the lumbar spine, of 1000 Newtons. They also recommend a lower action limit of 500 Newtons for tasks such as boosting a patient up in bed. This recommendation was formulated similarly to the compression recommendation by reviewing the cadaver studies combined with a studying factory work injury rates coupled with the forces that were being exerted by the workers.

Marras, Davis, Kirking, and Bertsche (1999) discuss the spinal forces involved in various transfer tasks. Certain transfer tasks were deemed “high risk.” These were where the participant was required to employ maximal sagittal flexion, a high lift rate, maximum external momentum, maximum lateral velocity, and high twisting velocity. During the high risk transfer tasks, it was found that there was a 10% increase in risk for lower back disorder and the forces involved were 300 to 400 N greater for lateral shear force and 1300 to 1700 N greater for compression forces than lower risk transfer techniques. The anterior-posterior shear force was relatively similar in most of the trials, whether high risk or not.

Even with two caregivers involved in the transfer task, 10-15% of the tasks surpassed the 6400 N top limit for force at the lumbosacral joint, which is well above the 3400 N limit prescribed as safe (Marras et al., 1999). The shear forces involved also approached or exceeded the prescribed limits, thus showing that all of the transfer tasks involved in this study can be considered unsafe. Also interesting is that the results showed the caregivers experiencing more shear force during the lowering phase which may indicate an increased risk of lower back disorder while lowering the patient. One of the tasks in this study was a repositioning task which included four different techniques: a manual one person hook, manual two person hook, manual two person using a draw sheet, and manual two person lifting under the thigh and shoulders. Of these, it was shown that the least amount of force was generated using the draw sheets, which shows that the draw sheet method is potentially the method with the least amount of risk involved for the caregivers. The authors also found that the single person hook method generated the highest amount of force for a repositioning task with a probability of high risk of lower back disorder above 90%. The draw sheet method had a risk of being considered high risk for lower back disorder at 70%, which is substantially lower than the hook method, but is still considered high risk.

It was further described by Skotte and Fallentin (2008) that in repositioning tasks with patients who have some type of plegia there is a higher risk of musculoskeletal disorder. This is due to an increased amount of force being put on the healthcare worker's body. Skotte and Fallentin had 9 healthcare workers perform 6 different repositioning tasks with the patient in bed, and of 418 trials used in the data analysis, 25% exceeded the compression force recommendation of 3400 N in the lower back. Further, the same tasks exceeded a recommended upper limit of 3300 N proposed by McGill and Kavcic (2005) for female caregivers. Skotte and Fallentin also observed the effect of different patient weights on the forces caregivers exerted and showed that heavier patients pose a greater risk than lighter patients.

The commonly accepted method of repositioning a patient in bed begins with two healthcare workers, one on each side of the patient. One of the workers counts to three and then they both lift the sheet upon which the patient is resting and slide the patient into the desired position. The recommended bed height is 46% of the shorter healthcare worker's height (Lindbeck & Engkvist, 1993).

With the 35 pound guideline in mind, there are many different methods that work at reducing the amount of force that a healthcare provider applies in a transfer task. Some of these include mechanical lifting equipment which includes sit-to-stand devices and floor lifts (Nelson, 2005). There is other equipment as well which is designed to ease the burden of the therapist including hover mats, repositioning sheets, gait belts, sliding transfer boards, and pivot discs (Nelson, 2005). One technique studied by Fragala (2011) may help to keep healthcare workers within the advised limit of force expenditure. He noted that it is possible to allow gravity to help with repositioning patients in bed fairly simply by inclining the bed so that the patient's head is lower than his or her feet, then sliding the patients up in bed, and then readjusting the bed back to normal. He found that this technique offers up to a 67% decrease in work with a 12 degree incline resulting in 58.59 pounds of force being exerted by the worker. This shows that even though it is closer to being within the recommended lift limit of 35 pounds, that the limit is still being exceeded. Another important indication for patient handling purposes is that there should always be more than one healthcare provider involved in the repositioning task in order to further protect healthcare workers (Nelson, 2005).

Researchers have also shown that low friction bed sheets effectively reduce the time that healthcare practitioner's muscles are contracting as well as reducing the percentage of muscle involved in the transfer task. These sheets also have been shown to reduce the amount of friction by 65% when a slide sheet was used in conjunction with another slide sheet underneath (Theou et al., 2011). McGill and Kavcic (2005) found that when using three different friction reducing devices at different times, they were able to reduce the amount of friction by about 50% when compared to a standard cotton sheet. They looked at a rollboard, bubbleboard, and a slider all versus a standard cotton sheet as a control. The 3 participants all moved a 72.7 kg manikin in three different trials with the various devices, a push transfer, a pull transfer, and a twist transfer. While it was shown that the friction was reduced significantly, there were tremendous variations on the spinal loads recorded.

In another study that also investigated friction reducing devices for positioning patients, Bartnik and Rice (2013), using uniaxial handheld force gauges, investigated the forces acting on the hands and lower back during the repositioning task of pulling a patient up in bed. They found that although effective at reducing friction and the time it takes to reposition a patient, friction reducing sheets, specifically the McAuley disposable sheet and the Arjo Maxislide, still required more force than the 35 pound lifting limit in order to complete the task. In fact, the sum of the peak forces at the hand in this study came out to be 45.86 pounds for the Arjo Maxislide, 44.43

pounds for the McAuley disposable, and 49.81 pounds for the standard cotton sheet. This shows that there is a decrease in required force when using a friction reducing device, but the levels are still too high for healthcare workers to be exerting and be considered safe.

Further analyzing the gathered data and using the University of Michigan's 3D Static Strength Prediction Program which relies on joint position data and force data in order to calculate spinal forces, Bartnik and Rice (2013) also investigated compression and shear forces in the lumbar region. They found that the compressive forces at the spinal levels of L5-S1 and L4-L5 varied depending on which type of sheet was used. The McAuley disposable sheet resulted in the least amount of compressive force at both joints, whereas the Arjo Maxislide resulted in less compressive force than traditional cotton sheets at the L4-L5 joint, but not at the L5-S1 joint. As far as shear forces are concerned, there was a significant difference between the various sheets. Specifically, the McAuley disposable sheet elicited the least amount of L4-L5 sagittal shear force followed by the Arjo Maxislide and finally the traditional cotton sheet. With this in mind, it is important to note that the shear forces did not approach the recommended action limit and only the traditional sheet barely surpassed the recommendation for compressive action limit force.

According to these results the impact of lifting and repositioning tasks on the muscles of the lower back is of chief concern, while the shear and compressive forces acting on the spine should not be ignored as they still may have a cumulative effect over time. There was the concern that since the Bartnick and Rice (2013) force gauges were uni-dimensional there may have been a significant amount of data lost during collection as they only collected force in the z plane and force was elicited in the x, y, and z planes. Another important note is that the University of Michigan's 3D Static Strength Prediction Program is, as its title states, static, whereas the task at hand is dynamic.

The purpose of the current study was to investigate the forces acting on the hand and lower back while sliding a "patient" up in bed. There was a variety of slide sheets used, both standard cotton sheets as well as two types of friction reducing sheets, the Arjo Maxislide ™ and the McAuley disposable slide sheets. The researchers hypothesized that there would be significantly less force required when sliding a "patient" up in bed when using the friction reducing slide sheets compared to traditional cotton sheets, as well as having further reduced required forces when using a double friction reducing slide sheet approach than a single sheet approach.

Methods

Participants

The participants of this study included 38 healthy adults, both male and female, between 20 and 57 years of age. Based on data from Bartnik and Rice (2013), it was estimated that the L4-L5 lateral shear forces generated from two different friction reducing slide sheets with this sample size was expected to generate enough statistical power to yield significant results. These results were estimated to include a mean difference of approximately 29 N, a standard deviation of 53.6 N, an $\alpha = .05$, and a $\beta = .8$. Participant recruitment was completed using university email, posting informational flyers in various areas around a public university, and through “word of mouth.” The “patient” throughout the entire data collection process was a 27-year-old male, weighing approximately 150 lbs.

Apparatus

A Motion Analysis system, using Cortex (version 3.1.0.1288) data acquisition software, coupled with eight Owl motion capture cameras provided 3D motion capture throughout this study. This system was used in conjunction with two force plates (Amti Model# OR6-5-1, 176 Waltham Street, Watertown, MA 02472 and Bertec Model# 2060A, 6171 Huntley Road, Suite J, Columbus, OH 43229) and the Futek MTA 400 tri-axial load cells, modified with handles and a coupler (Tri Axial Load Cell Model, 10 Thomas, Irvine CA 92618). 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. Data were collected at 120 Hz. The hospital bed 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 Maxislide ™ sheet, produced in Roselle, IL.

Dependent Variables

This study analyzed the forces at the hands and the lower back. The data from the Futek load cell force gauges was used and analyzed to determine the hand forces involved in sliding a patient up in bed generated using the three different types of slide sheets. Cortex was used to collect motion data, C-motion was used to determine body angles at the peak force moment during the transfers, and the University of Michigan’s 3DSSPP static strength prediction program was used to identify the lower back forces based on the joint angles. Results were then given for lower back compression, anterior shear, and lateral or sagittal shear.

Procedure

Approval from the Biomedical IRB from The University of Toledo occurred before study implementation. 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.” Upon recruitment, each participant read and signed the consent form, then the participant’s height and weight was recorded, 37 reflective markers were placed on the individual's body for motion detection by the Owl cameras, and a series of 33 patient transfers (3 for each of the 11 conditions) were performed. The "patient" participant also signed the informed consent, was weighed, and given instructions to lay supine in the hospital bed. The order of the presentation of the bed heights and sheet types were randomized into one of 11 possible combinations (41% of height with Sheet 1, 41% of height with Sheet 2, 41% of height with Sheet 3, 46% of height with Sheet 1, 46% of height with Sheet 2, 46% of height with Sheet 3, 46% of height with double sheet 2, 46% of height with double sheet 3, 51% of height with Sheet 1, 51% of height with Sheet 2, or 51% of height with Sheet 3). This particular transfer technique has been termed "pulling patient up in bed" (Fragala 2011). Please note that the height factor was explored in a different study, this current study addressed only the type of sheet.

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 participant "caregiver" (Bartnik & Rice, 2013; Lindbeck & Engkvist, 1993). The "patient" began in a position with his arms across his chest and his legs straight. Two marks 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 stood on the Bertec force plate and were instructed to grasp the handles in a forearm supinated position and to prepare to slide the "patient" up in the bed. The "caregiver" then moved to the force plates and communicated to the co-investigator by to counting up to three, at which point the "caregiver" and co-investigator slid the "patient" 12 inches up toward the head of the bed.

Statistical Analysis

This study used a repeated measures design with a focus on sheet type, as well as number of sheets (e.g., Arjo-Single, Arjo-Double, MaCauley-Single, MaCauley-Double, and Cotton-Single). A repeated measures analysis of variance (ANOVA) with 5 levels to the repeated factor (number of sheets and sheet type) was used, along with a post-hoc repeated measures contrasts analysis for the data at the hands. Similar statistics were used for the lower back data with 3 levels to the repeated factor. A paired *t*-test was also done to view the single sheet versus the double sheet hand force categories.

Results

Data were collected and analyzed from 5 males and 32 females and were recorded in analog units by the Cortex computer program from August 2013 through February 2014. The data were then converted into volts in order to further convert them into pounds of force in accordance with the baseline pound per volt level as reported by the Futek company calibration sheet. The lower back data was further converted into Newtons, as the respective force limits are given in Newtons. The data were then smoothed using a dual pass Butterworth low pass filter using a 10Hz cutoff frequency.

There was no order effect during the research process as reported by a test of between-subjects effects returning a *p*-value of greater than 0.05. Overall, there was a significant difference among the 5 repeated hand force conditions. $F(4,144)=66.83$, $p<.001$. The repeated measures contrasts analysis revealed no significant difference between the forces generated with the Single Arjo Maxislide and the standard Cotton Sheet. There were, however, significant differences between the Double Arjo condition and the Cotton Sheet condition as well as the Single and Double McAuley conditions and the Cotton Sheet condition in that the Double Arjo, Single McAuley, and Double McAuley all elicited less force from the participants than the

Cotton Sheet. See Tables 1 and 2. The average peak force utilized when transferring the patient up in bed with the Single Arjo was 66.78 pounds, the single McAuley was 54.76 pounds, the Cotton Sheet was 66.44 pounds, the Double Arjo was 57.03 pounds, and the Double McAuley was 52.72 pounds, see Figures 1 and 2. The forces at the lower back can be found in table 7. The important items of note in this table are that there was no statistically significant difference between the compression in any of the conditions either for the L4-L5 or L5-S1 joints. As far as the shear forces are concerned, the McAuley elicited less shear force than the cotton sheets in every category and elicits less L4-L5 forward shear and less L5-S1 sagittal shear than the Arjo. The Arjo elicits less force than the cotton in the L4-L5 forward shear category only.

Insert Tables 1 and 2 and Figures 1, 2, and 3 about here

Discussion

With so many healthcare workers putting themselves at risk on a daily basis, it is vital that the most effective methods of patient handling be used as a matter of best practice, while the least effective methods need to be abandoned. This study was an attempt to determine the efficacy of certain patient handling methods over others. The specific purpose of this study was to investigate the forces acting on the hand and lower back while sliding a "patient" up in bed using a variety of slide sheets. The researchers hypothesized that there would be significantly less force required when sliding a "patient" up in bed when using the single friction reducing slide sheets compared to traditional cotton sheets, as well as having a further reduction in required forces when using a doubled up friction reducing slide sheet approach than a single sheet approach per manufacturer’s recommendations with both Arjo Maxislide and McAuley disposable slide sheets.

There was not a significant difference between using a standard cotton sheet versus the single Arjo Maxislide friction reducing sheet, which is curious as the Arjo Maxislide is designed and marketed as a friction reducing slide sheet, and it was expected that even a single Arjo Maxislide sheet would outperform the cotton sheet, but that was not the case. It is also interesting in light of the study by Bartnik and Rice (2013) where the results of the same two sheets did result in a reduction of required force. One reason this could be is that the data in the Bartnik and Rice study were collected by uni-dimensional hand gauges and some force could have been lost in the process as the uni-dimensional hand gauges only recorded data in the z-axis, which is parallel to the line of pull. The tri-axial hand gauges used in the current study included orthogonal forces in the x-, y-, and z-axes. Either way, the manufacturer's recommended method of using the slide sheets is to have one on top and one on bottom, or if that is not possible, then fold one in half in order to still have a double layer of the friction reducing material (Arjo Huntleigh, 2010) . Even in light of the double sheet recommendation, there was a significant difference between the standard cotton sheet and the single McAuley friction reducing sheet, which was expected and was evident in the Bartnik and Rice article. Therefore, the single Arjo Maxislide not resulting in a reduction of required force and the single McAuley disposable sheet resulting in a reduction of required force partially supports the current study's first hypothesis.

More importantly, there was a significant difference between the standard cotton sheet and both of the double sheet conditions. This is important because this is the use for which these sheets are marketed, and it shows that if used as advised, these sheets have the potential to reduce strain on the human body. This is also enlightening as cotton sheets are typically used in healthcare facilities for patient repositioning tasks, and this shows that using the cotton sheets is not the most effective way to avoid contracting an injury throughout the process of handling and repositioning patients. That being said, the double friction reducing sheet condition only reduced the overall hand force required by the caregivers by 15% for the double Arjo Maxislide sheet and 22% for the double McAuley sheet, thus still requiring a minimum average of 52.7 pounds of force per transfer. This is a higher resulting force than the friction reducing slide sheet conditions in the Bartnik and Rice article, which reported 44-46 pounds of force being generated at the hands. This highlights the probability that some forces were lost to the uni-dimensional hand gauges that were used in that study, but more alarmingly, it shows that even with the “best” methods that we investigated resulted in the forces being far above the limits recommended by Waters et al. (1993). So even if healthcare workers are following the “safe” methodologies outlined in this article, there is still a risk that they will contract a musculoskeletal disorder due to patient handling.

It was seen that with the friction reducing slide sheets, the lowest mean amount of force exhibited was 52.7 pounds. It is important to note, that this was with participants that were cooperative and presumably understood all of the instructions given. It was also with a constant “patient” who was relatively light compared to many people who are receiving healthcare services, and who was very cooperative. All factors considered, this was an ideal and atypical situation. Even in this carefully controlled situation, the force being elicited was significantly greater than the 35 pound recommended lift limit (Waters et al., 1993).

The reduction in required force at the hands is important, but the force is still greater than recommended. This illustrates the importance of using mechanical lifts whenever possible. It would be wise of more facilities to adopt the zero lift policies described by Collins et al. (2004) until more effective and efficient devices can be contrived for the manual positioning and repositioning of patients. It is possible that any new materials that are fabricated could still not be as effective as mechanical lifts, and in this case it would be wise not to revert to manual patient handling unless absolutely required by a special situation or circumstance. Otherwise, even with innovations in materials and methods for transferring patients, there will continue to be injuries among healthcare workers, as so far there does not seem to be a way around stressing the body over the recommended limits besides possibly eliminating manual lifting altogether by the use of mechanical devices.

When considering the lower back forces, it can be seen that all of the forces elicited by the McAuley disposable slide sheet ended up being significantly lower than those elicited from the cotton sheet. The McAuley sheets also elicited less force than the Arjo at the L4-L5 joint in the forward shear direction and at the L5-S1 sagittal shear direction. The Arjo, however, only elicited less force than the cotton at the L4-L5 joint in the forward shear direction. This shows a benefit to healthcare workers should they choose to use the friction reducing slide sheets. These results are similar to what Bartnik and Rice (2012) found for the lower back forces in their study. The lower back forces only exceeded the action limit under one condition in that study, but in the current study none were ever surpassed. However, even with these benefits, it is important to note that none of the forces measured here exceeded the recommended action limits posed by McGill (2007) of 3400 Newtons for compressive force and that proposed by McGill et al. (1998) of 500 Newtons of shear force at the lower back. Even though the forces elicited in this study were all below the recommended action limits, it is important to note that this study was completed under ideal circumstances with a willing participant, and that forces elicited in an acute care setting are likely to be greater than those found in this study. It is also important to note that even with lower forces, repetitive strain injuries are possible.

As Marras et al. (1999) demonstrated, using a draw sheet is among the methods that elicit lower required forces while repositioning patients, and thus reduces risk of musculoskeletal disorder over other manual methods. In that study, a standard cotton sheet was used and was the most successful method of positioning a patient while reducing the risk of injuring the healthcare worker. In light of this information, the importance of using friction reducing draw sheets can be seen versus the other methods of moving people by lifting them by the arms, or even using a cotton draw sheet. It is a simple and relatively quick way in which one of the greatest risks posed to healthcare workers can be reduced significantly, which can potentially save the industry a lot of money over time.

Although the friction reducing slide sheets do indeed reduce friction when used in accordance with the manufacturer's guidelines, there is still a significant amount of force being placed on the bodies of caregivers and healthcare workers (Arjo Huntleigh, 2010). The reduced rate of required force outlined above was 22%. A 22% reduction in required force could be beneficial to the longevity of the healthcare worker’s career. For example, since according to Tuohy-Main the average member of nursing staff lifts 1.8 tons in an 8 hour shift, then a 22% decrease from 1.8 tons is a reduction of 792 pounds (1997). This illustrates the point that if the slide sheets were used as intended, healthcare workers might only be lifting 1.4 tons per shift rather than 1.8 tons, thereby saving wear and tear on the body. This reduction of nearly 800 pounds would reduce the risk exposure for developing a work related musculoskeletal injury.

Using these friction reducing sheets and other available materials for safe patient handling can help to reduce the number of days workers are out of the workforce. With regard to the previous numbers reported by Tuohy-Main (1997), a 22% reduction in the required force is a very real difference in the amount of stress being placed on a healthcare worker’s body, and thus nurses and nursing aides will have to be out of work secondary to work related musculoskeletal injury less often than they are currently. The costs associated with work related musculoskeletal injuries should also be considered. In the study by Collins et al. (2004), their facilities were able to reduce the amount of workers compensation that they were required to pay out due to work related musculoskeletal injuries by $55,000 every single year. If every facility in the United States adopted similar policies that were used in the facilities related to the study and were able to see comparable success, there would be millions if not billions of dollars saved in this country every year that could be put to better use elsewhere.

Along with reducing the amount of weight being moved per shift, in accordance with Yassi et al. (2001) it can be seen that the fatigue levels of healthcare workers will be reduced. This can positively impact the morale of the workers in the various types of healthcare facilities. If the workers are less fatigued when they go home at night, they will be motivated to provide better care throughout the day when they are at work.

One aspect that needs to be readdressed at this point is that of education. As mentioned previously, there seem to be different methods of general patient handling that are taught in different schools, and even different methods of safe patient handling (Darragh et al., 2009; Slusser et al., 2012). If the instruction was more standardized across the board, some methods could be combined in order to increase the effectiveness of each individual technique. The report from Fragala leads one to the thought that rationally follows this line of research (2011). If the method of tilting the bed was combined with the various friction reducing devices for repositioning a patient in bed, then the forces required in that repositioning task may be reduced even more than each individual process. This could further protect healthcare workers in their jobs and help them to stay in their chosen career paths longer. This is in keeping with the need to discover the most effective forms of patient handling, and once these more effective methods are found, they need to be taught to current and future practitioners rather than the less effective and more dangerous methods that are currently and have previously been used in the healthcare facilities.

If not significantly reduced so that they meet the recommended limits for patient handling, the stresses put on the healthcare worker's body from manually handling patients has a high risk of leading to injury. This is especially true with the changing demographics of United States citizens. These citizens are becoming larger and older and will thus cause even greater amounts of force to be placed on healthcare worker’s bodies as the patients increase in mass and decline in physical and cognitive ability (CDC, 2013). There are available strategies that guard against the high rates of injury among healthcare workers such as using friction reducing devices, using mechanical lifts, using gravity to assist in whatever task is at hand, and having more than one healthcare worker involved in the task, but these methods need to be more widely taught, utilized, and researched. The "patient" in this study was a 150 pound male who was very cooperative. Many patients are going to weigh more than 150 pounds, and some may not be particularly cooperative, which factors both lead to greater exertion by the healthcare worker and an increase in the risk of injury. By using the current most effective devices and methods of patient handling, these risks can likely be reduced.

Implications for Practice

It is vitally important to convey all of the aforementioned information to future and current practitioners. As Darragh et al. (2009) described, different information, methods, and techniques for patient handling are being taught across the board. This needs to change, and the most effective way to change starts with changing the current curriculum among future healthcare workers. It needs to include information about all of the available devices, as well as effective and ineffective techniques for using said devices during the education process for occupational therapists, occupational therapy assistants, physical therapists, physical therapy assistants, nurses, and nursing aides. In this way, those workers will be able to know and understand the current best practice guidelines and be able to effectively utilize those guidelines in their various clinical settings. This includes using friction reducing slide sheets during patient handling tasks in the clinic.

As shown in this study, it is imperative for healthcare workers to do as much as they can to protect themselves. One way in which they can protect themselves in a relatively easy manner is by incorporating the use of assistive transfer devices. One type of these devices is friction reducing slide sheets. Doing this in the manner that the various manufacturers recommend can reduce the amount of force applied to the bodies of healthcare workers. This can result in reduced strain placed on the healthcare worker. This will potentially reduce the amount of wear and tear on those workers, which will potentially reduce the amount of work related musculoskeletal disorders acquired by healthcare workers through the manually handling of patients. Healthcare workers will then be able to remain as healthy as possible. It can be seen from the results of this study that using doubled up friction reducing slide sheets is ideal in a manual patient handling task. If that is not possible, then there needs to be at least one McAuley disposable sheet, as it was effective at reducing the required force alone during a patient handling task. Lastly, only when absolutely necessary, and never before, should cotton sheets be used for the handling of patients.

Resources also need to be available and utilized at healthcare facilities across the country. There is very little good done by having the resources available and not utilized. Current practitioners need to make it a priority to use the tools available to them to help reduce the strain on their bodies so that they can have positive and productive careers and keep themselves out of those healthcare facilities themselves.

Limitations

This study was performed in a laboratory setting, so the results are not necessarily indicative of what would be found in the clinic. It was also completed by a population that was largely students and thus are not healthcare professionals at this point, so the results are not necessarily indicative of what healthcare workers would elicit in a similar situation.

The "patient" was standardized and was approximately 150 pounds throughout the course of the study. The population of the United States of America is currently on the rise, and in addition to the extra weight they come with many obesity related diseases and conditions. With this in mind, it is likely that many of the patients with whom healthcare workers will be dealing will weigh more than 150 pounds (CDC, 2013). This will lead to added stress on the bodies of healthcare workers and will lead to increases in the numbers of work-related musculoskeletal injuries.

Future research should include different friction reducing devices, healthcare professionals performing the transfers, patients of different weights, real patients, and hospital settings. Another aspect that would be intriguing would be convening research related to discovering the forces involved for caregivers when using mechanical lifts and further research related to the impact of zero lift policies in various settings. It would also be illuminating to investigate one method of patient handling combined with another such as with the case of tilting the head of the bed down while using a friction reducing device.

Conclusions

The Arjo Maxislide and McAuley friction reducing slide sheets, when doubled, were effective at reducing the hand force required to boost a patient up in bed when compared to using a cotton sheet. While this reduction was statistically significant, the elicited hand forces were greater than the recommended limit of 35 pounds established by Waters et al. (1993). Healthcare workers need to be aware of the impact that the handling of patients has on their bodies. In light of these risks, they need to take precautions against injury. Currently, the most effective and efficient way to do this is to utilize the various equipment that is available. Manual lifts should be used, and when those are not available, it is important to incorporate the use of friction reducing devices.

Acknowledgements

A special thank you to Dr. Martin Rice for his guidance, support, and tireless answering of relentless questions throughout the research process. Also, a thank you to the University of Toledo for providing the setting for the research. Thanks to Elise Murtagh for assisting with IRB and data collection. And finally, thanks to my wonderful family, starting with my sweet wife, Debi Larson, for her complete support and encouragement, and to my two boys, Hyrum and William Larson, for their energy and amazing personalities.

References

Arjo Huntleigh Getinge Group, (2010). *Maxi slide: Versatile repositioning sheets*. Sweden: Arjo International, AB. Retrieved from http://www.rochestermexico.com/PDF/20100723162630.pdf

Bartnik, L. M., & Rice, M. S. (2013). Comparison of caregiver forces required for sliding a patient up in bed using an array of slide sheets. *Workplace Health & Safety*, *61*(9), 393-400. doi:10.3928/21650799-20130816-52

Bork, B., Cook, T., Rosecrance, J., Engelhardt, K., Thomason, M., Wauford, I., & Worley, R. (1996). Work-related musculoskeletal disorders among physical therapists. *Physical Therapy*, *76*(8), 827-835.

Bureau of Labor Statistics [BLS]. (2013). *Nonfatal injuries and illnesses requiring days away from work, 2012*. Retrieved from http://www.bls.gov/news.release/archives/osh2_11262013.pdf

Centers for Disease Control and Prevention [CDC]. (2013). *Adult obesity facts*. Retrieved from http://www.cdc.gov/obesity/data/adult.html

Collins, J., Wolf, L., Bell, J., & Evanoff, B. (2004). An evaluation of a "best practices" musculoskeletal injury prevention program in nursing homes. *Injury Prevention*, *10*(4), 206-211.

Darragh, A., Campo, M., & Olson, D. (2009). Therapy practice within a minimal lift environment: perceptions of therapy staff. *Work*, *33*(3), 241-253. doi:10.3233/WOR-2009-0872

Darragh, A. R., Huddleston, W., & King, P. (2009). Work-related musculoskeletal injuries and disorders among occupational and physical therapists. *American Journal Of Occupational*

Therapy, *63*(3), 351-362. doi:10.5014/ajot.63.3.351

Fragala, G. (2011). Facilitating repositioning in bed. *AAOHN Journal*, *59*(2), 63-68. doi:10.3928/08910162-20110117-01

Li, J., Wolf, L., & Evanoff, B. (2004). Use of mechanical patient lifts decreased musculoskeletal symptoms and injuries among health care workers. *Injury Prevention*, *10*(4), 212-216.

Lindbeck, L., & Engkvist, I. L. (1993). Biomechanical analysis of two patient handling tasks. *International Journal of Industrial Ergonomics*, *12*(1), 117-125.

Marras, W., Davis, K., Kirking, B., & Bertsche, P. (1999). A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques. *Ergonomics*, *42*(7), 904-926.

McGill, S. (2007). *Low back disorders: evidence-based prevention and rehabilitation*. Human Kinetics.

McGill, S. M., & Kavcic, N. S. (2005). Transfer of the horizontal patient: The effect of a friction reducing assistive device on low back mechanics. *Ergonomics*, *48*(8), 915-929.

McGill, S. M., Norman, R. W., Yingling, V. R., Wells, R. P., & Neumann, P. (1998). Shear happens! Suggested guidelines for ergonomists to reduce the risk of low back injury from shear loading. In *Proceedings of the 30th annual conference of the human factors association of Canada* (pp. 157-161).

Nelson, A. L. (2005). *Safe patient handling and movement: A practical guide for health care professionals*. Springer Publishing Company.

Occupational Safety and Health Administration [OSHA]. (2011). *Safe patient handling*. Retrieved from http://www.osha.gov/SLTC/healthcarefacilities/safepatienthandling.html

Owen, B., Keene, K., & Olson, S. (2002). An ergonomic approach to reducing back/shoulder stress in hospital nursing personnel: a five year follow up. *International Journal Of Nursing Studies*, *39*(3), 295-302.

Rice, M. S., Dusseau, J. M., & Miller, B. K. (2011). A Questionnaire of Musculoskeletal Injuries Associated With Manual Patient Lifting in Occupational Therapy Practitioners in the State of Ohio. *Occupational Therapy In Health Care*, *25*(2/3), 95-107. doi:10.3109/07380577.2011.566308

Skotte, J., & Fallentin, N. (2008). Low back injury risk during repositioning of patients in bed: The influence of handling technique, patient weight and disability. *Ergonomics*, *51*(7), 1042-1052. doi:10.1080/00140130801915253

Slusser, L. R., Rice, M. S., & Miller, B. K. (2012). Safe patient handling curriculum in occupational therapy and occupational therapy assistant programs: A descriptive study of school curriculum within the United States of America. *Work (Reading, Mass.)*, *42*(3), 385-392.

Theou, O., Soon, Z., Filek, S., Brims, M., Leach-MacLeod, K., Binsted, G., & Jakobi, J. (2011). Changing the Sheets: A New System to Reduce Strain During Patient Repositioning. *Nursing Research*, *60*(5), 302-308. doi:10.1097/NNR.0b013e318225b8aa

Tuohy-Main, K. (1997). Why manual handling should be eliminated for resident and career safety. *Geriaction*, *15*(1), 10-14.

Waters, T., Collins, J., Galinsky, T., & Caruso, C. (2006). NIOSH research efforts to prevent musculoskeletal disorders in the healthcare industry. *Orthopaedic Nursing*, *25*(6), 380-389.

Waters, T., Putz-Anderson, V., Garg, A., & Fine, L. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*, *36*(7), 749-776.

Waters, T. (2007). When is it safe to manually lift a patient?. *American Journal Of Nursing*, *107*(8), 53-59. doi:10.1097/01.NAJ.0000282296.18688.b1

Yassi, A., Cooper, J., Tate, R., Gerlach, S., Muir, M., Trottier, J., & Massey, K. (2001). A randomized controlled trial to prevent patient lift and transfer injuries of health care workers. *Spine*, *26*(16), 1739-1746.

Table 1.

Total force in pounds at hands while boosting a patient in bed using three different sheet types in the double sheet condition.

Sheet Type	Mean	Standard Deviation
Arjo	57.03	9.24
Cotton	66.44	11.31
McAuley	52.72	9.18

Table 2.

Total force in pounds at hands while boosting a patient in bed using three different sheet types in the single sheet condition.

Sheet Type	Mean	Standard Deviation
Arjo	66.78	11.66
Cotton	66.44	11.31
McAuley	54.76	11.33

Table 3.

Pairwise comparisons of the double sheet conditions against each other.

Sheet Type 1	Sheet Type 2	Type III Sum of Squares	df	Mean Square	F	p-value	Effect Size
Arjo	Cotton	3369.41	1	3369.41	51.93	<.000	0.89
	McAuley	704.85	1	704.85	18.43	<.000	0.47
Error	Cotton	2400.71	37	64.88			
	McAuley	1415.10	37	38.25			
Cotton	Arjo	3369.41	1	3369.41	51.93	<.000	0.89
	McAuley	7156.42	1	7156.42	139.29	<.000	1.31
Error	Arjo	2400.71	37	64.88			
	McAuley	1900.92	37	51.38			
McAuley	Arjo	704.85	1	704.85	18.43	<.000	0.47
	Cotton	7156.42	1	7156.42	139.29	<.000	1.31
Error	Arjo	1415.10	37	38.25			
	Cotton	1900.92	37	51.38			

Table 4.

Pairwise comparisons of the single sheet conditions against each other.

Sheet Type 1	Sheet Type 2	Type III Sum of Squares	df	Mean Square	F	p-value	Effect Size
Arjo	Cotton	11.04	1	11.04	0.18	.680	0.05
	McAuley	5346.20	1	5346.20	85.76	<.000	1.05
Error	Cotton	2233.80	36	62.05			
	McAuley	2244.34	36	62.34			
Cotton	Arjo	11.04	1	11.04	0.18	.680	0.05
	McAuley	4871.41	1	4871.41	106.69	<.000	1.01
Error	Arjo	2233.80	36	62.05			
	McAuley	1643.72	36	45.66			
McAuley	Arjo	5346.20	1	5346.20	85.76	<.000	1.05
	Cotton	4871.41	1	4871.41	106.69	<.000	1.01
Error	Arjo	2244.34	36	62.34			
	Cotton	1643.72	36	45.66			

Table 5.

Mean force at the hands in the single and double sheet conditions compared.

Sheet	Number	Mean	Standard Deviation
Arjo	Single	66.78	11.66
	Double	57.03	9.24
McAuley	Single	54.93	11.22
	Double	52.72	9.06

Table 6.

Paired t-test of single versus double sheet conditions by sheet type.

Sheet Number and Type 1	Sheet Number and Type 2	df	F	p-value	Effect Size
Single Arjo	Double Arjo	36	175.88	<.000	0.93
Single McAuley	Double McAuley	37	8.89	.005	0.22

Table 7.

Mean compression, forward sheer, and sagittal sheer forces at L4-L5 and L5-S1 in the double sheet condition.

Force and Location	Sheet	Mean (Newtons)	Standard Deviation
L4-L5 Compression	Arjo	1456.51	765.61
	Cotton	1420.09	652.72
	McAuley	1367.32	582.39
L4-L5 Sagittal (A-P) Shear	Arjo	328.77	73.91
	Cotton	332.08	87.66
	McAuley	301.67	65.66
L4-L5 Frontal (Lateral) Shear	Arjo	122.44	77.14
	Cotton	145.14	122.85
	McAuley	113.70	92.87
L5-S1 Compression	Arjo	756.60	427.28
	Cotton	686.51	291.67
	McAuley	741.85	455.08
L5-S1 Sagittal (A-P) Shear	Arjo	392.54	67.07
	Cotton	406.45	75.05
	McAuley	370.91	66.84
L5-S1 Frontal (Lateral) Shear	Arjo	119.53	38.24
	Cotton	150.57	58.81
	McAuley	115.99	47.25

Table 8.

Pairwise comparisons of low back forces against sheet type in the double sheet condition.

Force and Location	Type III Sum of Squares	df	Mean Squares	F	p-value
L4-L5 Compression	7519.12	2.00	3759.91	0.33	.721
Error	824944.50	72.00	11457.56		
L4-L5 Sagittal (A-P) Shear	1041.30	1.43	727.56	5.42	.014
Error	6921.20	72.00	96.13		
L4-L5 Frontal (Lateral) Shear	984.92	1.53	644.73	4.78	.019
Error	7413.87	72.00	102.97		
L5-S1 Compression	5105.63	2.00	2552.82	1.19	.310
Error	154398.02	72.00	2144.42		
L5-S1 Sagittal (A-P) Shear	1198.88	1.55	775.71	11.66	<.000
Error	3702.66	55.64	66.55		
L5-S1 Frontal (Lateral) Shear	1353.96	1.71	794.23	20.67	<.000
Error	2357.65	61.37	38.42		

Table 9.

Post hoc analysis of significant low back force differences.

Force and Location	Sheet Type	Type III Sum of Squares	df	Mean Squares	F	p-value	Effect Size
L4-L5 Sagittal	Cotton vs Arjo	20.44	1	20.44	0.07	.796	0.04
(A-P) Shear	Arjo vs McAuley	1373.93	1	1373.93	14.62	.001	0.39
	Cotton vs McAuley	1729.54	1	1729.54	9.61	.004	0.39
Error	Cotton vs Arjo	10901.36	36	302.82			
	Arjo vs McAuley	3383.06	36	93.97			
	Cotton vs McAuley	6479.16	36	179.98			
L4-L5 Frontal	Cotton vs Arjo	963.36	1	963.36	3.00	.091	0.22
(Lateral) Shear	Arjo vs McAuley	142.94	1	142.94	0.94	.339	0.10
	Cotton vs McAuley	1848.45	1	1848.45	12.72	.001	0.29
Error	Cotton vs Arjo	11533.97	36	320.39			
	Arjo vs McAuley	5477.56	36	152.15			
	Cotton vs McAuley	5230.08	36	145.28			
L5-S1 Sagittal	Cotton vs Arjo	361.82	1	361.82	2.39	.131	0.195
(A-P) Shear	Arjo vs McAuley	874.12	1	874.12	16.04	<.000	0.32
	Cotton vs McAuley	2360.70	1	2360.70	22.94	<.000	0.50
Error	Cotton vs Arjo	5440.24	36	151.12			
	Arjo vs McAuley	1962.51	36	54.51			
	Cotton vs McAuley	3705.24	36	102.92			
L5-S1 Frontal	Cotton vs Arjo	1802.14	1	1802.14	20.75	<.000	0.63
(Lateral) Shear	Arjo vs McAuley	23.41	1	23.41	0.58	.450	0.08
	Cotton vs McAuley	2236.34	1	2236.34	32.19	<.000	0.65
Error	Cotton vs Arjo	3126.55	36	86.85			
	Arjo vs McAuley	1445.35	36	40.15			
	Cotton vs McAuley	2501.06	36	69.47			

Figure 1.

Mean and standard deviation of total force at the hands while boosting a patient up in bed using three different sheet types.

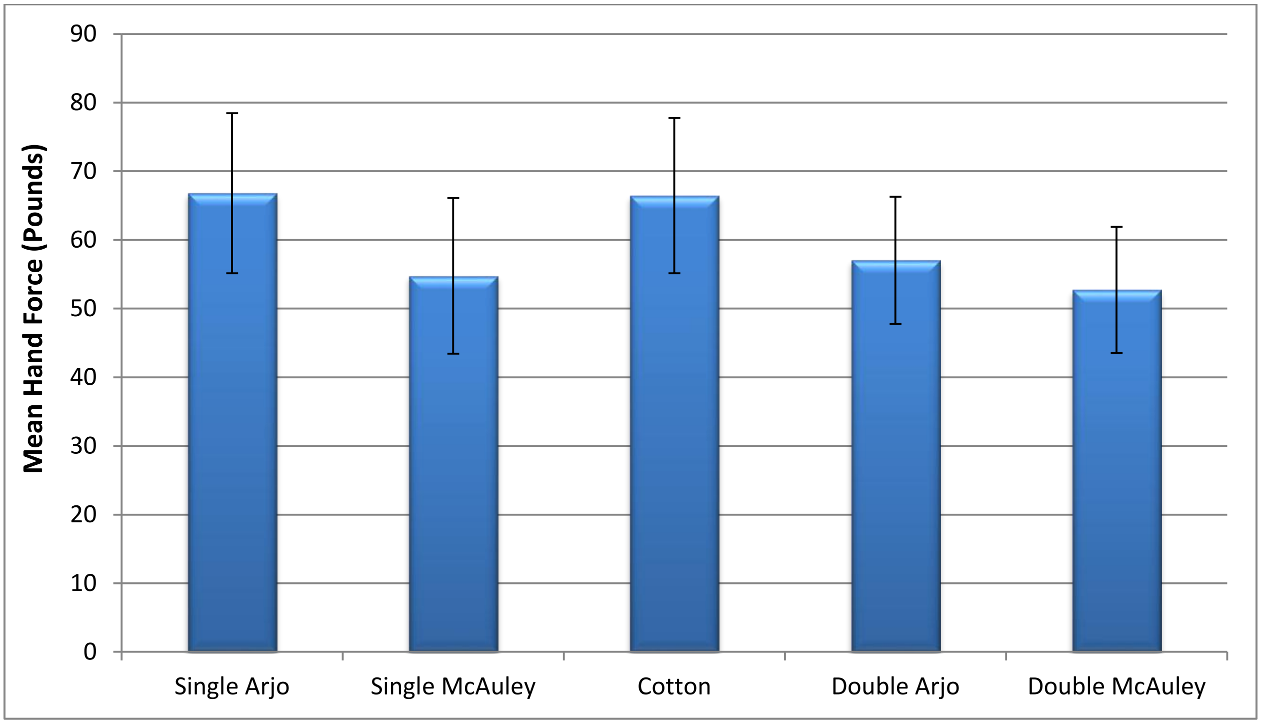

Figure 2.

Mean and standard deviation of hand force comparing single and double sheet categories.

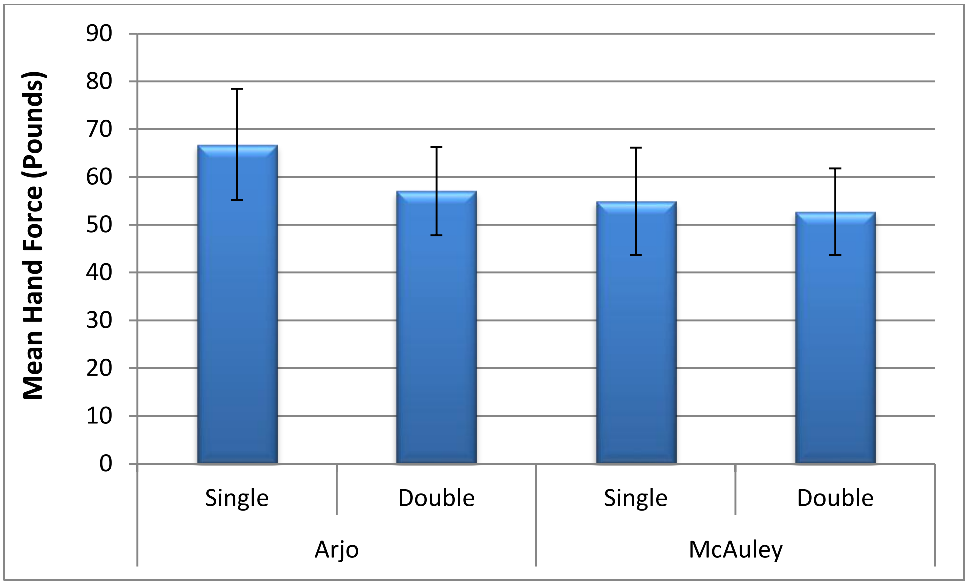

Figure 3.

Mean and standard deviation of total force at various back locations and directions while boosting a patient up in bed using three different sheet types.

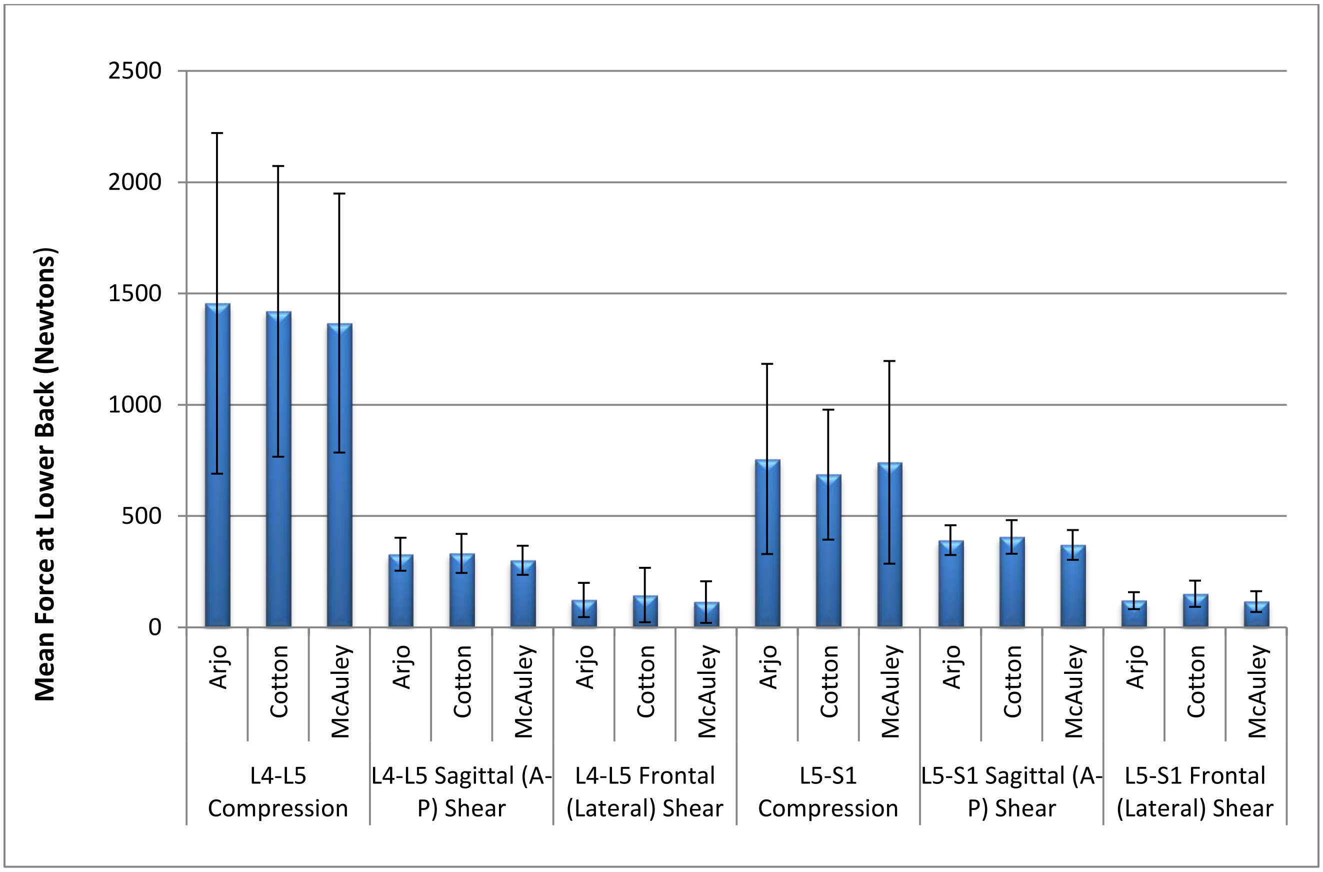

Figure 4.

Research setup. Note that the transfer also included a second caregiver standing opposite of the pictured caregiver to help pull the slide sheet.

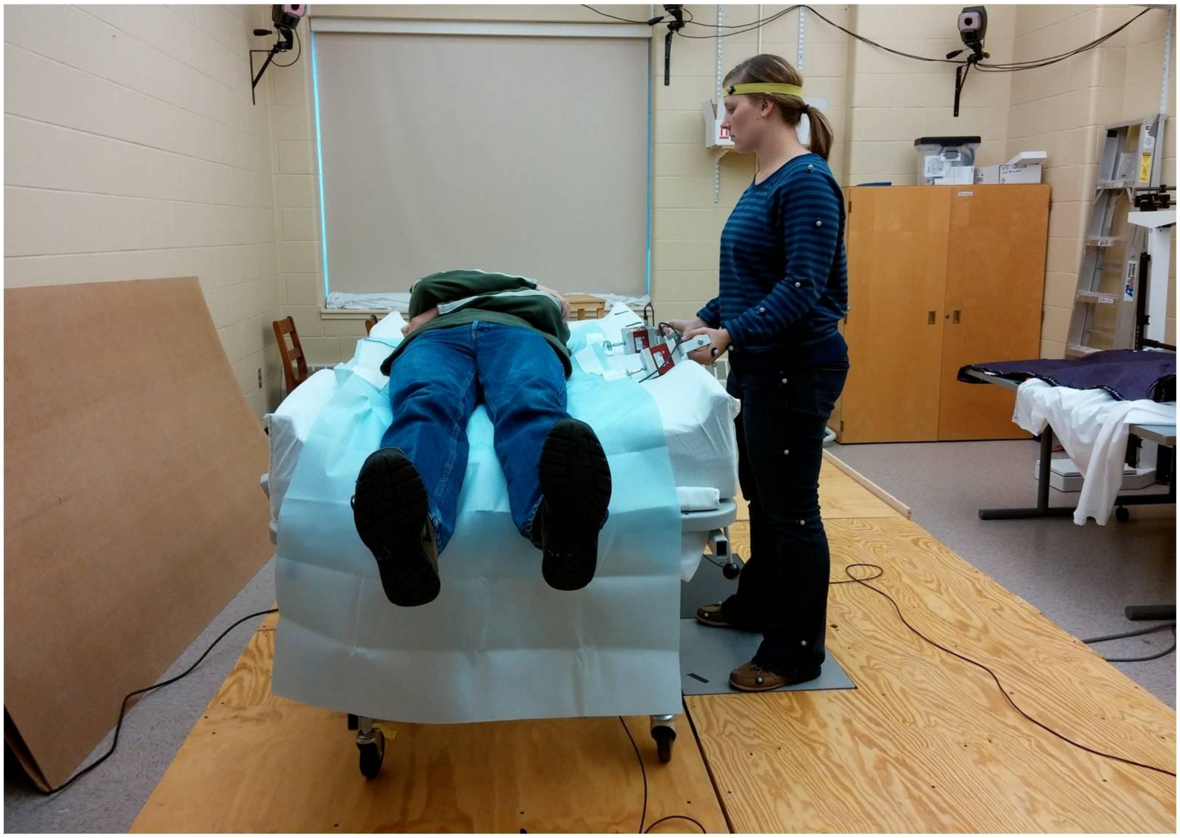

Figure 4.

Tri-dimensional hand gauges