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Ergonomic evaluation of hospital bed design features during patient handling tasks

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ABSTRACT

Patient handling tasks (e.g., transportation and repositioning) are important causes of musculoskeletal disorders among healthcare workers. The purpose of this study was to evaluate, during two patient handling tasks, the physical demands resulting from alternative hospital bed design features. Twenty-four novice participants were involved in two laboratory-based studies. The effects of a steering lock and adjustable push height were evaluated during a patient transportation task using perceptual responses and measures of performance and physical demands, and the effect of a bed contour feature was determined based on patient sliding distance during repeated bed raising/lowering. Use of the steering lock reduced the number of adjustments during bed maneuvering by 28% and decreased ratings of physical demands. Use of the adjustable push height reduced shoulder moments by 30%. With the contour feature, patient sliding distance was reduced by ~40% over 12 raise/lower cycles. These results suggest that the steering lock and adjustable push height features can reduce physical demands placed on healthcare workers during patient transportation tasks. Although patient sliding distance was reduced using the contour feature, assessing direct effects of this feature on physical demands (e.g., reduced need for workers to reposition patients) will require further investigation.

Relevance to industry: Hospital bed design features have the potential to reduce physical demands required of healthcare workers, yet there have been only limited empirical studies of these. Findings of the two current studies suggest that proactive ergonomic considerations in hospital bed design can reduce these physical demands.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) are prevalent among healthcare workers. Recent data indicate that nursing aides, orderlies, and attendants in the U.S. experienced injuries or illnesses requiring days away from work at a rate of 455/10,000 workers, approximately 4 times higher than the national average across all occupations, and resulting in a total of 50,620 days away from work (BLS, 2010). Among nurses and nursing aides, there is a particularly high prevalence of back pain and a high rate of workers' compensation claims for back injuries (Waters et al., 2006; Zhuang et al., 1999). Thus, there is a need to further identify and control exposures that ultimately lead to such outcomes.

Existing evidence suggests that several manual patient handling tasks (e.g., positioning patients on a bed, transferring patients between a bed and chair, repositioning patients in bed) lead to high physical demands (Petzall et al., 2001) and are strongly associated with the development of low back disorders and pain (ANA, 2009; Engkvist, 2008; Marras et al., 1999; Smedley et al., 1995; Yip, 2001). Training and/or assistive devices are common approaches used to control the risk of WMSDs associated with performing such tasks. Training on manual patient handling techniques can reduce low back loads during patient handling (Garg and Owen, 1994; Hodder et al., 2010; Winkelmolen et al., 1994); however, even with training it has been suggested that high physical demands remain (Marras et al., 1999). Assistive devices, such as lift and transfer aids, can decrease physical demands during patient handling, particularly in the low back (Keir and MacDonell, 2004; Marras et al., 1999; McGill and Kavcic, 2005; Zhuang et al., 1999). However, such devices alone may not reduce demands enough to ensure worker safety (Nelson and Baptiste, 2006; Waters et al., 2007). Furthermore, unavailability of these devices, lack of proper training in the use of mechanical aids, and nurses' perceptions of increased time and difficulty in using mechanical aids, have hindered the effectiveness of assistive devices in reducing physical demands (Nelson and Baptiste, 2006).

An increased emphasis has been placed on developing medical device designs that can accommodate the needs of both patients

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and healthcare workers (Martin et al., 2008). In the context of ergonomics, a few studies have indicated that design features of hospital beds can reduce physical demands during hospital bed use and related activities. For example, hospital bed heights and brake pedal location can influence spinal loads during patient handling and transportation (De Looze et al., 1994; Kim et al., 2008). Specifically, during in-bed patient transportation, perceived physical effort difficulty is substantially affected by wheel arrangements (Petzall and Petzall, 2003) and also by steering assistance features (i.e., a retractable 5th wheel and front caster locks) among mid-range medical/surgical beds (Kim et al., 2008). Front caster steering locks are designed to minimize sideways drifting while pushing hospital beds, which can otherwise require readjustments to be made to the direction of the bed. When sideways drifting occurs, often the bed needs to be stopped and adjusted to the desired direction, resulting in high push/pull forces and asymmetrical spinal loading. Furthermore, when beds are stopped from moving to be adjusted, the initial start-up forces may be twice as much as in the sustained phase (Ciriello et al., 2001). These remedial actions (i.e. adjustments) to improve bed maneuverability increase physical demands (specifically low back spinal loads). Thus, a steering lock can potentially reduce the demands placed on workers and increase the efficiency with which they can maneuver beds. Of note, prior studies on steering locks focused mainly on transportation beds and it is unknown whether comparable effects will be found for other bed types with different masses. For example, Petzall and Petzall (2003) employed transportation beds with mass ~94 kg, while Kim et al. (2008) evaluated beds up to 214 kg. Several studies have reported beneficial effects of handle heights on low back and shoulder loads during cart pushing and pulling (Hoozemans et al., 2004; Resnick and Chaffin, 1995). Specifically, it was found that pushing carts with handle heights of 1.09 m resulted in lower spinal compressive forces compared to handle heights of 0.66 m and 1.52 m (Lee et al., 1991). However, it remains to be determined if adjustable handle heights in hospital beds can reduce shoulder and spinal loads during patient transportation.

Though adopted and marketed by manufacturers, several other design features also remain to be formally evaluated in terms of physical demands. One such feature involves an adjustable contour, which enables patients or healthcare workers to easily configure the bed in different positions (e.g., sitting, knee-raising, etc). A contour feature can reduce patient sliding (toward the bed foot) while beds are raised/lowered during the course of day, and this in turn can minimize the need to reposition patients in bed. As repositioning patients is associated with high spinal compressive forces (Marras et al., 1999) and is considered to be a high-risk task for injuries (Badger, 1981), the use of a contour feature can potentially reduce the demands and risks placed on healthcare workers.

The aim of this study was to assess the effectiveness, from an ergonomics perspective, of a steering assistance feature (i.e., front caster lock), an adjustable push height feature, and a bed contour feature at reducing both directly measurable and perceived task-related physical demands. Fig. 1 illustrates the patient handling tasks, related risk factors, and study measures used to evaluate the hospital bed design features. Two commercially-available "Medical/Surgical" hospital beds, from different North American hospital bed manufacturers, were used without modification to quantify the effects of these design features. A combination of objective and subjective measures was employed to assess physical demands associated with the design features of interest. It was hypothesized: (1) the use of a steering lock will reduce the number of adjustments made by users in a patient transportation task and result in lower perceptions of physical demands, (2) an adjustable push height will result in lower shoulder and torso moments generated during initial bed movement, and (3) a contour feature will reduce patient sliding during repeated bed raising/lowering.

2. Methods

Two separate laboratory-based studies were conducted to assess the design features during patient handling tasks. The effectiveness of the steering lock and adjustable push height features were evaluated in the "patient transportation study", and the effect of a contour feature was assessed in the "bed contour study".

2.1. Participants

In the first study (patient transportation), twelve participants (7 male and 5 female) were recruited from the Virginia Tech student community, whose mean (SD) age, stature, and body mass were 24.4 (2.6) years, 1.69 (0.07) m, and 68.4 (14.9) kg, respectively. For the second study (bed contour), 12 participants (2 males and 10 females) were recruited, with respective mean (SD) age, stature, and body mass of 25.8 (3.1) years, 1.64 (0.068) m, and 65.4 (12.3) kg. All participants were novices in healthcare-related tasks, to minimize potential bias from prior experiences in performing related tasks. Participation was limited to individuals with no self-report injuries, illnesses, or musculoskeletal disorders within the past

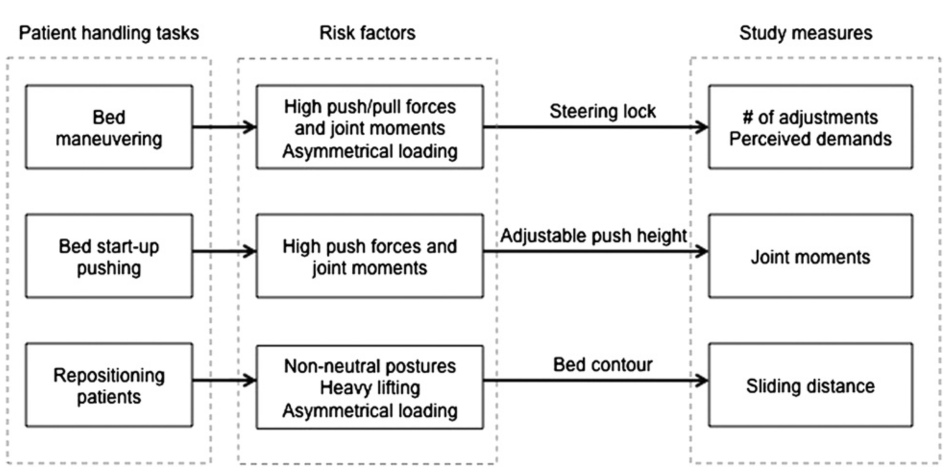

Fig. 1. Links between patient handling tasks and associated risk factors, and the effect of design features on study measures to address the risk factors.

year. Informed consent was obtained using procedures approved by the Institutional Review board of Virginia Tech.

2.2. Patient transportation study

2.2.1. Design

A three-factor repeated measures design was employed to assess the physical demands resulting from use of a steering lock feature during a simulated patient transportation task. The independent variables manipulated were bed type (Bed 1 vs. Bed 2), steering lock (Engaged vs. Disengaged), and patient mass (Light vs. Heavy). A second experimental design was employed to evaluate the effectiveness of the adjustable push height feature, in which participants performed an initial bed movement task in a single-factors repeated measures design. The independent variable manipulated was push height: Adjustable push height (using Bed 1) vs. Fixed push height (using Bed 2).

The length, width, and mass of the beds were 2.36 m, 1.08 m, and 244 kg for Bed 1 and 2.10 m, 1.02 m, and 224 kg for Bed 2. The headboard height for Bed 1 was self-adjusted by each participant prior to testing to their perceived most-comfortable push height; adjusted heights across participants were 0.94–1.10 m. No such adjustment was available for Bed 2; instead, the headboard and subsequent pushing height remained fixed at 1.10 m. The steering lock feature in each bed, a controllable function that locks the front casters, is designed to minimize sideways motion during bed maneuvering. This feature was either Engaged or Disengaged. To simulate patient transportation, loads were distributed evenly over the mattress of the hospital bed representing two "patient" mass conditions: 50 kg (Light) representing a 5th percentile female, and 121 kg (Heavy) representing a 95th percentile male (McDowell et al., 2005). The total bed-system weight in the Light condition for Bed 1 and Bed 2 was 294 kg and 274 kg, respectively, and 365 kg and 345 kg in the Heavy condition.

2.2.2. Procedures and dependent measures

To assess the effectiveness of the steering lock feature, participants were asked to push the bed down a straight hallway (17.5 m long × 2.5 m wide) at a comfortable pace, and were instructed to avoid hitting the walls. At the end of the hallway, the experimenter turned the bed around, and the participants pushed the bed back to the starting point. The exposure to bed conditions was counterbalanced across participants, and the steering lock and patient mass conditions were randomized within each bed condition. Each participant performed one trial per treatment condition with adequate rest in between, with a total of 96 trials (2 bed × 2 steering lock × 2 patient mass × 12 participants). During each trial, the number of adjustments made by the participant was recorded, and defined as the number of times participants had to stop the bed to prevent it from hitting the walls or let go of the handle bar to push or pull from the side of the bed. It was assumed that the number of adjustments was a reasonable proxy for physical demands and/or musculoskeletal stress. After each treatment condition, participants provided subjective ratings of overall difficulty (1 = easy to 5 = difficult), physical effort required to push and pull the bed (1 = low to 5 = high), and perceived confidence in maneuvering the bed (1 = low to 5 = high). Similar five-point Likert-type scales were used in a previous related study (Kim et al., 2008). Participants also estimated the number of healthcare workers (from 1 to 5) they felt would be required to maneuver the bed while avoiding high physical efforts. Each participant took approximately 1.5–2 h to complete this study.

To represent the biomechanical demands associated with each push height, participants performed an initial bed movement task in which they pushed an unloaded bed in both of the push height conditions (Adjustable vs. Fixed). For Bed 1, the push height was set to each participant's most-comfortable push height, as determined at the start of the study. The push height for Bed 2 was constant, at 1.10 m. A total of 24 trials were completed (2 push height × 12 participants), with participants performing each treatment condition once. Each participant completed the entire task within 30 min. Hand forces required to push the bed were measured using a pair of load cells (Interface SM500, AZ, USA) attached to the bed. Using each participant's stature, body mass, and push height, a representative posture and mean push force, net moments at the shoulder and the torso in each bed condition were estimated using The University of Michigan 3-D Static Strength Prediction Program™ (3DSSPP).

2.3. Bed contour study

2.3.1. Design

A three-factor repeated measures design was employed to assess physical demands associated with readjusting patient position with the use of a bed contour feature in a simulated hospital bed raising/lowering task using Bed 2. The independent variables manipulated were contour (feature On vs. Off), repetition (number of raise/lower cycles), and patient dependency (Adjustment vs. No Adjustment). A contour feature in a hospital bed allows for patients to be positioned in different positions, such as sitting and knee-

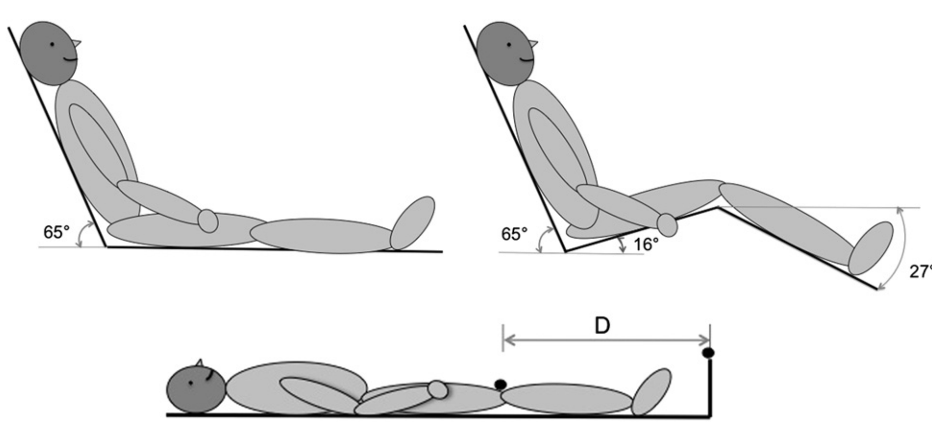

Fig. 2. Schematic representation of the upright (raised) bed and patient configuration without (top-left) and with (top-right) the contour feature activated. Horizontal distances (D) were measured as indicated in the bottom figure. Marks (shown as solid circles) were placed on the foot-end portion of the bed frame and at the center of each patella.

raising (Fig. 2). Repetition of bed raising/lowering represented beds being raised/lowered during the course of a day for patient-care activities, such as administering medication and serving food. Patient dependency can vary from “fully dependent” (i.e., patient can’t move at all) to “not dependent” (i.e., patient can move on their own). As such, to evaluate the effectiveness of the contour feature on patient sliding, patient dependency was included as a study variable, with participants (simulated patients) either allowed to adjust their position (simulating no dependency) or not adjust at all (simulating full dependency).

2.3.2. Procedures and dependent measures

At the beginning of each trial, participants acting as “simulated patients” were asked to place themselves comfortably in the fully raised bed. Following this, the bed was adjusted to the fully lowered position. Using a 3-D coordinate measurement system (Faro Technologies Inc., Lake Mary, FL, USA), horizontal distances (D) between a reference point on the foot-end portion of the bed frame and the participants’ knees (mean locations of marks in the center of each patella) were measured (Fig. 2(bottom)). Initial measurements (D_0) were determined based on the patients’ position after the first bed raising/lowering cycle. The bed was then raised and lowered 12 times, and sliding distances ($\Delta D = D_i - D_0$) were calculated after each cycle (positive values corresponding to sliding motion toward the foot of the bed). The effect of repetition on sliding distance was quantified at the 4th, 8th, and 12th cycles, representing hospital bed raising/lowering throughout a day. Based on the patient dependency levels, participants (simulated patients) were allowed/not allowed to adjust their body as needed in both the fully raised and fully lowered positions of each test repetition. A total of 48 trials were completed (2 contour × 2 patient dependency × 12 participants), each involving 12 raise/lower cycles, and with participants performing each treatment condition once. The total experimental time was approximately 2–3 h per participant. To maintain consistent friction between the participant and the bed, the bed was covered with a standard hospital mattress cover, and all participants were asked to wear a standard hospital gown.

2.4. Statistical analyses

2.4.1. Patient transportation study

Separate 2 (bed) × 2 (steering lock) × 2 (patient mass) repeated measures analyses of variance (ANOVAs) were performed on the number of adjustments and each of the subjective ratings in the patient transportation study, with questionnaire responses assumed to have interval scale properties. To determine the effect of the adjustable push height feature, single-factor (push height condition) repeated measures ANOVAs were performed on the net external moments at the shoulder and torso. *Bed Contour Study:* A multivariate analysis of variance (MANOVA) was used to assess the effects of repetition on sliding distance and any interactions with contour and patient dependency. Mauchly’s test indicated a violation of the sphericity assumption ($p < 0.05$); therefore the Huynh-Feldt (H-F) correction was used. An additional two-way repeated measures ANOVA was performed to identify any effects of contour and patient dependency on sliding distance at the last (12th) repetition.

For both studies, no other substantial violations of parametric assumptions were evident for any of the aforementioned tests, and all statistical analyses were conducted using JMP 7.0 (SAS Institute Inc., Cary, NC). Where relevant, post-hoc pairwise contrasts were used to explore interaction effects (with a Scheffé procedure). Statistical significance was determined when $p < 0.05$. All summary values are presented as means (SD).

3. Results

3.1. Patient transportation study

The main effect of bed was significant for number of adjustments ($F_{(1,77)} = 104.65$, $p < 0.0001$), perceived overall difficulty ($F_{(1,77)} = 71.84$, $p < 0.0001$), physical effort for pushing ($F_{(1,77)} = 42.67$, $p < 0.0001$) and pulling ($F_{(1,49)} = 11.53$, $p = 0.0014$), perceived confidence in maneuvering ($F_{(1,77)} = 84.64$, $p < 0.0001$), and the number of healthcare workers required ($F_{(1,76)} = 34.23$, $p < 0.0001$). In all cases results for Bed 2 were inferior, and the relative responses to the two beds were consistent across levels of mass and steering lock (i.e., no significant interactive effects). The “patient” mass had significant main effects only on perceived efforts for pushing ($F_{(1,77)} = 6.42$, $p = 0.0133$) and pulling ($F_{(1,47)} = 10.42$, $p = 0.0023$), with higher values obtained in the Heavy condition.

As a main effect, the influence of steering lock condition on the number of adjustments approached significance ($F_{(1,77)} = 3.51$, $p = 0.065$). More important, however, were a significant ($F_{(1,77)} = 19.95$, $p < 0.0001$) lock × mass interaction ($F_{(1,77)} = 19.95$, $p < 0.0001$) and a significant ($F_{(1,77)} = 15.13$, $p = 0.0002$) second-order interaction of bed × mass × lock ($F_{(1,77)} = 15.13$, $p = 0.0002$). Decomposing these interactions (Fig. 3(top)) indicated that engaging the lock decreased the number of adjustments made when using Bed 2 to move a heavy patient but slightly increased these for a light patient; there were no effects of the lock for Bed 1.

Perceived overall difficulty was significantly ($F_{(1,77)} = 9.31$, $p = 0.0031$) lower when the lock was Engaged (2.71 (1.41)) vs. Disengaged (3.32 (1.27)). An interactive effect with patient mass

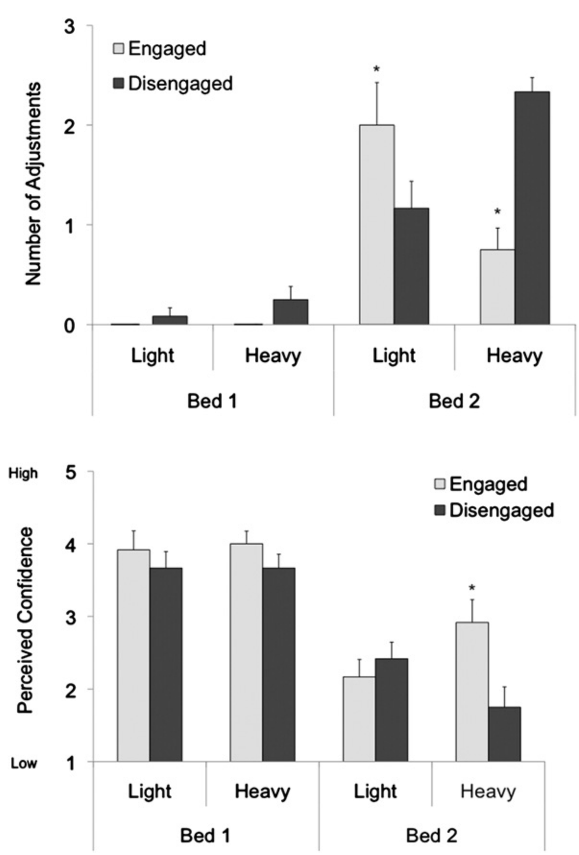

Fig. 3. The effects of bed, patient mass, and steering lock on number of adjustments (top) and perceived confidence (bottom) during the patient transportation task. Significant differences between steering lock conditions (engaged vs. disengaged) are indicated by the symbol *, and error bars indicate standard errors.

was also found ($F_{(1,77)} = 9.31$, $p = 0.0031$), in which the decrease in perceived overall difficulty caused by lock engagement was slightly larger for the Light patient condition (2.96 (1.57)) compared to the Heavy patient condition (2.46 (1.22)). Engaging the lock also significantly ($F_{(1,77)} = 6.42$, $p = 0.0133$) decreased perceived pushing efforts (Engaged = 2.85 (1.09), Disengaged = 3.25 (1.12)). While a similar main effect was not evident for pulling efforts, there was a significant lock × mass interaction ($F_{(1,47)} = 4.31$, $p = 0.0434$); specifically the effect of lock engagement was inconsistent when Light (Engaged = 3 (1.13), Disengaged = 2.73 (0.8)) or Heavy (Engaged = 3.2 (0.94), Disengaged = 3.71 (0.77)) patients were transported. While perceived confidence in maneuvering was significantly ($F_{(1,77)} = 5.29$, $p = 0.0242$) lower in the Engaged condition, there was also a significant ($F_{(1,77)} = 5.29$, $p = 0.0242$) interaction with mass and a significant ($F_{(1,77)} = 4.18$, $p = 0.0443$) three−way interaction of bed × mass × lock. Decomposing these revealed similar results as for the number of adjustments: (1) there was no effect of lock engagement when using Bed 1; (2) engaging the lock led to a small (and non-significant) decrease in perceived confidence when moving a light patient in Bed 2; and (3) engaging the lock led to a significant increase in confidence when moving a heavy patient in Bed 2 (Fig. 3(bottom)). Finally, though a small effect, participants indicated that significantly ($F_{(1,76)} = 4.01$, $p = 0.0487$) fewer healthcare workers would be needed when the lock was Engaged (1.62 (0.49)) vs. Disengaged (1.79 (0.62)).

Initial start-up forces required in the two push height conditions (Adjustable push height = 233 (51.8) N, Fixed push height = 231 (67.2) N) were nearly identical (within 1%) and not significantly different. However, net shoulder moments were significantly ($F_{(1,11)} = 107.13$, $p < 0.0001$) affected by the push height condition, being lower with an Adjustable push height (32.8 (9.2) Nm) than with a Fixed push height (45.8 (8.4) Nm). Net torso moments (Adjustable = 23.58 (15.67) Nm, Fixed = 21.08 (12.49) Nm), in contrast, did not differ significantly between the two push height conditions.

3.2. Bed contour study

MANOVA indicated a main effect of repetition on sliding distance ($F = 25.01$, $p < 0.0001$), with a progressive increase in sliding distance with additional repetitions. A significant repetition × contour interaction was found ($F = 2.99$, $p = 0.024$), with the Contour On condition resulting in smaller sliding distances with increasing repetitions (Fig. 4). The effect of increasing repetitions, however, was not influenced by patient dependency ($F = 0.3486$, $p = 0.83$). At the 12th repetition, sliding distance was significantly larger in the Contour Off condition ($F_{(1,33)} = 4.53$, $p = 0.041$), but was not affected by patient dependency ($F_{(1,33)} = 0.0018$, $p = 0.97$).

4. Discussion

The steering lock feature showed potential for reducing adjustments required and perceived physical demands by participants during hallway maneuvering. With the steering lock activated, the degrees of freedom of the bed movement were decreased such that “sideways drift” was controlled. This change in available motion was likely responsible for reducing the required number of adjustments to maintain the desired direction of motion and, in turn, reducing the required biomechanical demands on participants to maneuver the beds. The effect of steering lock on number of adjustments was largely dependent on the weight of the patient being pushed (Fig. 3(top)), given that the feature was only shown to be statistically significant during the heavy patient condition. Similarly, participants reported greater confidence and that maneuvering the bed was less difficult and required less effort with the steering lock on, but generally only in the heavy patient condition. These differences in the effectiveness may be due to the lower inertia involved, causing a greater likelihood of drift when pushing a light patient. Differences between beds were apparent even with the steering lock on, evidenced through both increased adjustments required as well as reports from participants. Though previous studies have reported that steering lock features can reduce perceived difficulties and efforts (Kim et al., 2008; Petzall and Petzall, 2003), the inconsistencies found between patient mass and bed conditions demonstrate the need to further assess the effectiveness of the steering lock with varying bed loads as well as on different types of hospital beds.

It should be noted that although the steering lock has the potential to reduce physical demands during bed maneuvering, pushing hospital beds might still pose high risk on healthcare workers. Pushing cart loads of 225 kg has been found to cause static L5/S1 compression forces that exceed the NIOSH Action Limit of 3400 N (Resnick and Chaffin, 1995). The beds used in the current study had masses of 224 and 244 kg; with the added mass of a patient, compressive forces are thus likely to be well in excess of the NIOSH limit. Furthermore, the inclusion of an adjustable push height feature reduced the external shoulder moments by almost 30% during initial bed pushing, though the feature had no effect on moments at the torso. It should be noted that these latter moments were calculated using a biomechanical model (3DSSPP) based on participants' anthropometric measures and observed hand forces, and thus are not direct measures of spinal loading.

Cumulative sliding distance increased with bed raising/lowering repetitions. Furthermore, the bed contour feature significantly reduced patient sliding over time (i.e., with increased bed raising/lowering cycles, see Fig. 4). Overall patient sliding distance from the first bed raising/lowering cycle to the last cycle ranged from 9.7 cm with the contour feature on to 25.7 cm with the contour feature off. It was observed that as the number of repetitions increased, patient sliding with the contour feature on seemed to reach a plateau with maximum displacement ranging from 10 to 14 cm. However, an increasing trend was observed with the contour feature off, where patient sliding distance ranged from 21 to 25 cm at the end of the 12th repetition (Fig. 4). Since the contour feature reduced patient sliding, it is likely that fewer adjustments would be required from healthcare workers to readjust patients in beds, which may translate to a reduction in the physical demands on workers. Common repositioning activities include grasping patients under arms,

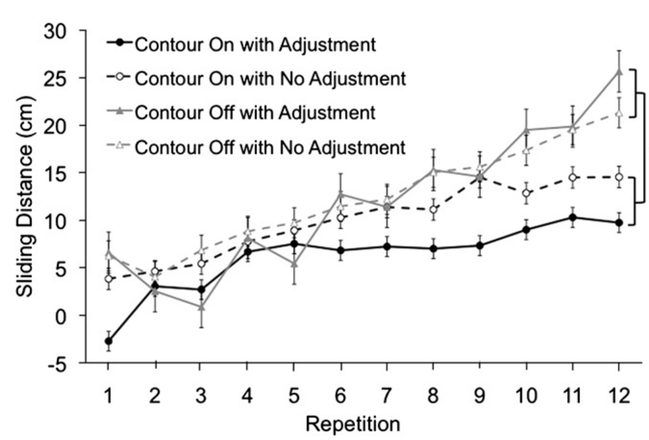

Fig. 4. Cumulative sliding distances at the bottom bed position during repeated bed raising/lowering cycles. Significant differences between contour conditions (feature On vs. Off) at the 12th repetition are indicated by the symbol *, and error bars indicate standard errors.

shoulder, or thighs to lift them in bed. The frequency with which these activities are performed due to repeated bed raising/lowering may thus be reduced with the use of the contour feature. Although the influence of the contour feature on reducing demands may be modest, it may be further reduced by using specific repositioning techniques (Marras et al., 1999) or by employing assistive equipment (Keir and MacDonell, 2004). Patient dependency did not affect patient sliding, which indicates that contour feature might effectively lower patient sliding irrespective of whether patients could or could not adjust their positions. However, the study employed participants acting as patients, who may not have accurately simulated complete dependency.

There are several limitations of this work that should be acknowledged. First, the main effect of bed type observed in the patient transportation study may have been influenced by the inherent differences between the two beds. Although measured differences between the two beds were not substantial (length, width, and mass) and the beds appeared to be in similar condition, there was no control of potential differences in wear and tear, efficiency of mechanical components, etc. Second, participants were novices, having no experience with maneuvering hospital beds. Although participants practiced maneuvering the beds prior to the study, performance and discomfort ratings during the trials may not be representative of experienced healthcare workers and the pattern of results may actually be conservative. Third, the studies were performed in a laboratory rather than an actual healthcare facility. The two simulated tasks, however, were considered a reasonable recreation of specific patient handling activities commonly performed by healthcare workers. Fourth, participants acted as “simulated” patients in the bed contour study, who may not have accurately simulated complete dependency. However, due to safety concerns and limited access, real patients were not recruited.

As healthcare workers are a particularly high-risk group for musculoskeletal injury, it is important to make efforts to reduce the physical demands associated with their daily tasks. Coupled with existing ergonomic interventions, such as training and assistive devices, hospital bed design features have the potential to lower physical demands during patient handling tasks. However, future research is warranted to provide alternative hospital bed features, in addition to steering locks, adjustable push heights, and bed contour features, that have a direct impact on reducing physical demands as well as accommodate variability associated with patient handling tasks. To evaluate the effectiveness of proactive hospital bed design features, further ergonomic assessments should be made in more realistic work environments and with actual healthcare workers and patients. Future research should also incorporate direct biomechanical evaluations of such hospital bed features when assessing physical demands placed on healthcare workers.

5. Conclusions

Hospital bed design features have the potential to alleviate physical demands placed on healthcare workers, yet there have been only limited empirical studies of these features. In the patient transportation study, the use of a steering lock reduced the number of adjustments and decreased perceived physical demands during bed maneuvering. Additionally, the adjustable push height reduced shoulder moments during an in-room bed start-up task. In the bed contour study, the contour feature reduced patient sliding distance with repeated bed raising/lowering, which can potentially reduce the demands placed on healthcare workers to reposition them. Results of the two studies suggest that proactive ergonomic considerations in hospital bed design can reduce physical demands placed on healthcare workers.

Acknowledgments

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