



Patient handling through moving of the beds and stretchers

Susan E. Kotowski^{a,*}, Kermit G. Davis^b, William S. Marras^c

^a Department of Rehabilitation, Exercise and Nutrition Sciences, College of Allied Health Sciences, University of Cincinnati, USA

^b Department of Environmental and Public Health Science, College of Medicine, University of Cincinnati, USA

^c The Spine Institute, Department of Integrated Systems Engineering, The Ohio State University, USA

ARTICLE INFO

Keywords:

Hospitals
Transport
Ergonomics
Power-drive
Musculoskeletal disorders

ABSTRACT

Transporting patients in beds and stretchers throughout hospitals is a significant manual handling concern for transport teams, nurses, and nursing aides. The objective of this study was to evaluate a power-drive intervention when pushing beds and stretchers with different weight patients. Twelve participants were part of a laboratory simulation where beds and stretchers were pushed down a straight away, around a corner, down a ramp, and up a ramp with and without utilization of the power-drive feature. Peak three-dimensional spine loads were estimated during the trials. In all, power-drive reduced the three-dimensional spine loads by 8%–21% as compared to the manual pushing of the beds and stretchers. Larger reductions were found for the tasks performed with the bed as opposed to the stretcher. The inexperience of the participants may have reduced the benefit of the power-drive as they appeared to not use it to the full extent. To minimize the loads being placed on healthcare providers' spines and reduce the potential for injury hospitals should implement power-drive technologies on beds and stretchers.

1. Introduction

Nurses and nursing aides continue to be one of the top professions that suffer from musculoskeletal disorders (MSDs), specifically low back and shoulder injuries, with costs estimates being in the multi-billions of dollars each year (Waehrer et al., 2005; Davis and Kotowski, 2015). There are several handling tasks which nurses and nursing aides routinely complete in hospitals that have been identified as risky for MSDs such as repositioning patients in bed, lateral transfers between beds/stretchers, transfers to and from the toilet, and assisting patients out of bed (Alexopoulos et al., 2005; Cameron et al., 2008; Pompeii et al., 2008, 2009; Waehrer et al., 2005; Yip, 2004). Repositioning of patients in bed is the most routine direct patient handling activity, occurring about 35 times per 12-h shift (Callison and Nussbaum, 2012; Waehrer et al., 2005).

While handling the patient is a significant part of manual handling in the hospital (Wilson et al., 2015), transfer teams, nurses, and nursing aides will transfer patients by moving the bed between rooms when procedures and tests are required. There are two typical methods of transfer: by hospital bed (e.g. keeping patient in one bed so no lateral transfer required) and by stretcher (e.g. more mobile but requires lateral transfer from bed). When moving the beds or stretchers through the

hospitals, beds tend to be moved long distances which requires movers to use high pushing and pulling forces. Peak hand forces during the initial pushing phase have been found to be extremely high (222 N–450 N) when no power-drive was used (Leban et al., 2019, 2021; Metha et al., 2011; Wiggermann, 2017). When the bed is moving, the hand forces were lower when moving bed straight, around the corner or maneuvering the bed into place (around 110–150 N after initial force) (Leban et al., 2019, 2021).

One way to potentially reduce the physical demands on the nurses and other individuals who transport patients may be through the use of power-drive assist device technology. The power-drive is controlled through strain gauges in the two handles, which the healthcare provider pushes or pulls with minimal force to engage a motorized fifth wheel under the bed (Wiggermann, 2017). Power-drive has been found to be an effective way to reduce the pushing and pulling forces while moving beds with patients with a 97% reduction descending down a ramp and 38% maneuvering into an elevator (Wiggermann, 2017). No difference was found between no power-drive and power-drive when pushing the bed down a straightaway (Wiggermann, 2017). Daniell and associates (2014) provided further evidence that the use of a power assist device reduced the muscle activation in the low back, arms, shoulders, and upper back (by 10–20%). Similar reductions in muscle activity were

* Corresponding author.

E-mail address: Susan.kotowski@uc.edu (S.E. Kotowski).

found with other power-drive designs (Guo et al., 2017).

To date, the biomechanical analysis of the impact of power-drive during the transporting of beds or stretchers has been limited to hand forces and muscle activation patterns. To truly understand the impact, spine loading estimates must be employed to get to the actual loading on the body. The study objective was to estimate the three-dimensional spine loads during the maneuvering of beds and stretchers in a simulated hospital setting.

2. Methods

2.1. Overall study design

The study design was a repeated measures laboratory simulation of bed and stretcher transports with different “sized” patients. The transporting tasks attempted to replicate the movement of beds/stretchers in a hospital under varying conditions: down a hallway, around a corner in the hall, and up and down a ramp. Walls were built out of cardboard

boxes stacked on each other where they could be positioned around the room at a similar distance as measured by the widths of the local university hospital. During the simulated tasks, the activity of the trunk muscles and instantaneous trunk postures were recorded and then enter into a spinal load model.

2.2. Participants

There were 12 participants (6 males and 6 females) in the study. All participants read and signed a consent form that was approved by the University of Cincinnati’s Institutional Review Board (IRB). The subjects were recruited into the study based on 6 weight-height classifications: 1) tall-average weight, 2) tall-overweight, 3) average height-average weight, 4) average height-overweight, 5) short-average weight, and 6) short-overweight. The height categories were defined as being below the 25th percentile, 26th to 75th percentile, and above 76th percentile for males and females while overweight was based on the body mass index of normal weight having BMI below 25 kg/cm² and overweight having



Fig. 1. Participant pushing bed and stretcher under the four transport tasks a) straight, b) around the corner, c) down the ramp, and d) up the ramp.

BMI between 25 kg/cm² and 30 kg/cm². The average age of the males and females were 25.8 years and 28.5 years, respectively. The average weight and standing height for males and females were 70.2 kg and 65.2 kg and 179.6 cm and 146.0 cm, respectively. All participants were inexperienced with using the power-drive and manual transporting of the beds and stretchers. There were no specific instructions provided to engage the power drive or maneuver the beds and stretchers other than what the specific tasks was and not to allow the bed or stretcher to hit the walls. If they hit the wall, the trial was repeated.

2.3. Independent variables

The independent variables consisted of the following: 1) type of bed, 2) patient size, 3) transport task, and 4) power drive type. **Two bed types** were evaluated including 1) *standard med-surg bed* (Advanta bed with a weight capacity of 227.3 kg) and 2) *stretcher* (transport stretcher bed with a weight capacity of 317.5 kg). There were **three patient weights** tested: empty stretcher (or no patient), 90.9 kg, and 227.3 kg. The weight consisted of bags of sand that were stacked at approximately the position of a patient in bed/stretcher, thus simulating a natural weight distribution on the stretcher. The positioning of the bags was consistent across all bed conditions.

Each of the bed/stretchers was transported by the caregiver under the following four transport tasks: 1) pushing a straight distance and stopping at specific point, 2) pushing around corner and then stopping at specific point, 3) pushing down a ramp of 4.8° and stopping at the bottom at specific point, and 4) pushing up a ramp of 4.8° and stopping at the top at specific point (Fig. 1). The **straight** transport tasks consisted of pushing the bed/stretcher for 6.1 m, and stopping prior to a simulated wall (e.g. stacked boxes). Each subject was instructed to push the bed/stretcher as fast as possible but so that he/she remained under-control so that the “walls” were not hit. The **corner** transport tasks consisted of pushing the bed/stretchers 3.05 m, then maneuvering it around a simulated corner wall, and then continuing to push it for another 3.05 m where it was stopped just before a simulated wall. The **down-ramp** transport tasks had the subject push and control the stretcher a short distance on a flat surface (1.8 m), then down a ramp of 3.05 m (with slope of 4.8°), and then out a door where they stopped short of a wall (3.05 m away from ramp). The **up-ramp** transport tasks had the subject push the bed/stretcher a short distance on flat surface (3.05 m from ramp) through a door way, then up a ramp of 3.05 m (with slope of 4.8°), and then a short distance (1.8 m) where they stopped short of a wall. For both the ramp conditions, the stretcher had to be maneuvered between a wall and the side of the ramp as well as around the handle of the door and hand rail along the ramp. Anytime that the bed/stretcher came into contact with the rail, door, or side of ramp, the trial was re-done.

The final independent variable is power drive which had two levels: 1) no power-drive and 2) power-drive. Under the no power drive, the participant utilized the standard handles to push the bed/stretcher manually. For the power drive conditions, the motorized power system (IntelliDrive® Powered Transport Systems) engaged as the handles were pushed/pulled, and would move the bed.

2.4. Dependent variables

The dependent variables fall into two main groups: 1) spine loading and 2) perceived exertion (RPE). The three-dimensional spine loading (lateral shear, anterior-posterior shear and compression) were predicted for each of the trials by the EMG-assisted model Davis et al. (1998); Fathallah et al. (1998); Granata and Marras (1995); Marras and Sommerich (1991). The prediction utilized an open loop model where an estimated muscle gain (based on closed-loop conditions) was applied to the muscle activity and trunk kinematics. The loads are predicted at L5/S1. The rating of perceived exertion (RPE) was based on the Borg scale (Borg, 1982) which has been widely used and validated (Pfeiffer et al., 2002). The scale ranges from 6 (minimal effort) to 20 (maximal

effort).

2.5. Procedures

When the subjects arrived at the laboratory, the research team explained the study and completed the consent process. The subject was then instrumented with the electrodes followed by taking maximum exertions to normalize the electromyographic signals. The lumbar motion monitor (LMM) was placed appropriately on the subjects. A set of calibration lifts under “closed loop” conditions were completed to calculate the gain for the model. A short practice session was conducted to ensure the subjects were able to use the power-drive adequately. When the subject was acclimated to the power-drive, the individual combinations of transport tasks, patient weight, and power-drive conditions were completed in random order. Immediately following the completion of each task, the subject rated the perceived exertion level by providing the research team a number from 6 to 20, which was recorded in an Excel database. Each condition was completed twice.

2.6. Data and statistical analyses

Descriptive statistics including means and standard deviations were computed for all of the outcome variables. A repeated analyses of variance (ANOVA) was completed on each dependent variable to identify whether there were differences between beds, and interactions with other factors such as power-drive, transporting task, and patient weight. Post hoc analyses in the form of Tukey standardized Honest difference were conducted where significant effects were identified to determine the source of the differences between conditions. All significance was determined at $p = 0.05$.

3. Results

The use of a power drive to move beds and stretchers significantly reduced the three-dimensional loads (Fig. 2). Overall, the power drive significantly reduced lateral shear and A-P shear (125 N) while compression had a significant interaction effect with power drive and bed type (see Fig. 2). There was a decrease when comparing power drive and no power drive in lateral shear for the bed of about 200 N (21%) and for stretcher of about 45 N (6%). Similar decreases were seen for A-P shear and compression with a drop of 120 N (8%) and 125 N (7%) for bed and stretcher, and about 700 N (17%) and 270 N (7%) for bed and stretcher, respectively. The patient weight had no direct impact on the spine loads.

There was also a significant interaction for power drive and transport task for lateral shear and compression (Fig. 3). Shear forces were greatest for the no power drive during the corner and compression for more complex transport tasks (corner, up ramp, and down ramp). Fig. 3

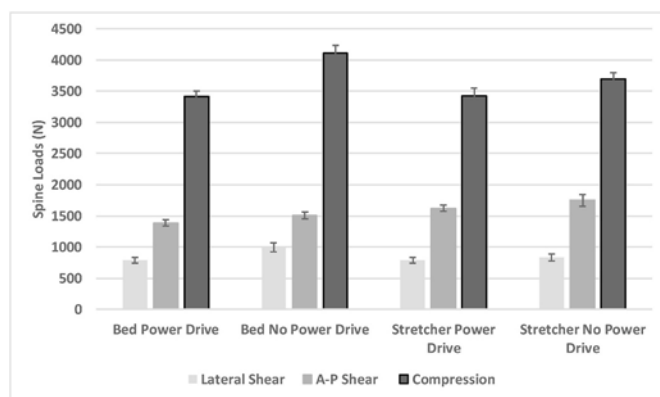


Fig. 2. Three-dimensional spine loads as a function of power drive (with and without) and bed type (Med-Surg Bed and stretcher).

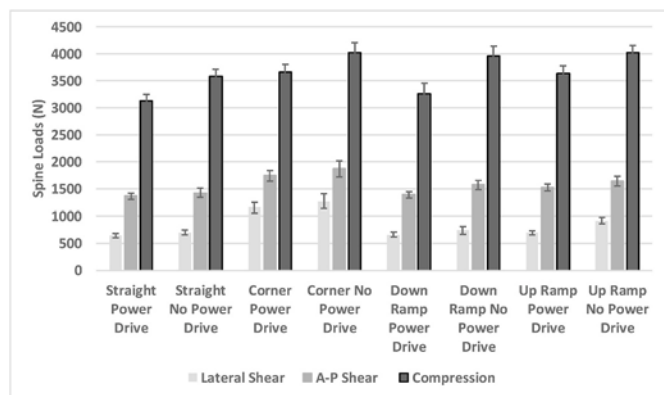


Fig. 3. Three-dimensional spine loads as a function of power drive (with and without) and transport task (straight down hall, around a corner, down ramp, and up ramp).

also shows that generally the three-dimensional loads are lowest for the straight conditions and highest for the corner transport tasks. The lateral shear, A-P shear, and compression were 545 N (81%), 410 N (30%), and 500 N (15%) greater for corner than straighter transport tasks, respectively. The up-ramp task was found to have similar differences as compared to the straight transport tasks. The worst condition was the no power drive with the corner task followed by no power drive up the ramp (about 1200 N lateral shear, 1870 N A-P shear, and 4100 N compression for Corner and about 920 N lateral shear, 1650 N A-P shear, and 4000 N compression for up the ramp).

Perceived exertion levels had a similar trend as the spine loads where the highest RPE was for no power-drive for the bed (RPE = 11) and the stretcher (RPE = 10), about 1–1.5 points higher than power-drive (see Fig. 4). The transport tasks with the largest RPE were up the ramp (RPE = 11.7), corner (RPE = 10.6), and down ramp (RPE = 10.6) without power-drive (see Fig. 5). The straight (RPE = 9.2) and down the ramp (RPE = 9.3) with power drive conditions had the lowest perceived effort.

4. Discussion

Power-drive was found to significantly reduce the three-dimension loads as compared to manual pushing of the beds and stretchers (8–21% for bed and 6%–7% for stretcher). Although not a part of this paper, a perplexing, but interesting, result was the lack of difference in hand forces between the power-drive and manual transporting of the bed and stretcher (peak forces were less than 40 N (8%) lower). This would indicate that the hand forces to start the bed/stretcher and maintain movement was not impacted as much as expected by the

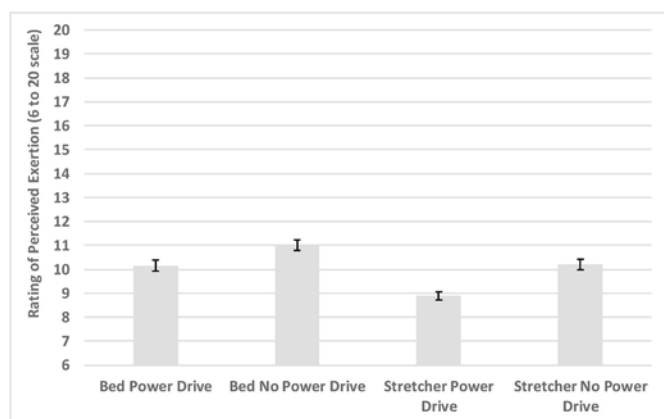


Fig. 4. Rating of perceived exertion as a function of power drive (with and without) and bed type (Med-Surg Bed and stretcher).

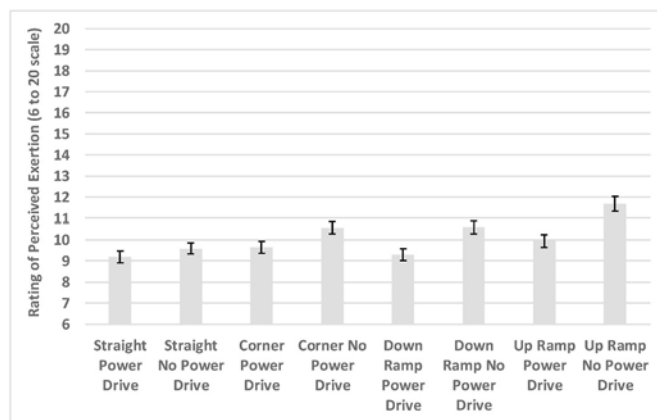


Fig. 5. Rating of perceived exertion as a function of power drive (with and without) and transport task (straight down hall, around a corner, down ramp, and up ramp).

power-drive, likely a result of not responding to the feedback from the handles that result in continued excessive hand forces (e.g. they over push the handles). The participants were inexperienced in the use of power-drive to maneuver the beds/stretchers, likely resulting in over-pushing of the power-drive handles. Other researchers found significantly lower hand forces when moving beds with automated power movers as compared to manual (about 2-fold) (Wiggermann, 2017). The large differences found by Wiggermann (2017) may have resulted from having participants who normally moved beds in hospitals (had 1 year of experience transporting beds). The methods to measure hand forces were quite different in the current study than previous studies (e.g. finger and hand forces sensors vs. force transducer at the handles), which make any direct comparisons between studies difficult. This difference in methodology was the reason for the focus on hand forces between power drive and none within the study. There are other potential reasons for the limited difference between the power-drive conditions. The instructions to move the bed/stretchers as fast as they can without hitting any walls may have influenced the pushing/pulling forces on the handles. Also, all the tasks had relatively short pushing durations which may have influenced the peak forces to move the beds/stretchers. Finally, the peak values of forces and loads were investigated in the current study, which may not be a complete representation of difference between power-drive and none for the duration of the tasks. The small differences in hand forces from the current study appeared to translate in less difference in spinal loads between manual and power-drive conditions.

The trunk movement during these bed and stretcher maneuvers were slightly faster for power-drive and participant postures were slightly more upright and neutral (1° in more upright posture and 2°/s for velocity in all planes of motion). Additionally, trunk muscle activations were reduced by 3%–15% when using the power-drive as compared to manually maneuvering of the beds and stretchers. These difference between posture and muscle activation patterns were shown across all conditions for power-drive and none. These reductions in actual muscle coactivation were at the same level of found by others (Daniell et al., 2014; Guo et al., 2017). Thus, there may be a complex relationship between hand forces exerted and the translation to the three-dimensional spine loads, minimizing the benefit of the power-drive observed in this study. More extensive training in the use of the power-drive, focusing on exerting minimal hand forces when engaging the power-drive mechanism, may provide more significant benefit.

The three-dimensional spine loads were not impacted by patient size, at least statistically. The weight of the bed with no patient was significant (approximately 227 kg), requiring large forces to start moving and continue to maneuver it and the addition of a patient only had marginal

impact on the forces required to move the beds/stretchers. There was a difference between the spine loads when moving beds as compared to stretchers (about 70 N in lateral shear and 300 N in compression across all conditions). The transport task had a major impact on the spine loads with the shear forces being greatest during the corner task and compression being largest for more complex transport tasks (corner, up ramp, and down ramp). Maneuvering the bed/stretcher straight was found to biomechanically be the easiest in the current study. Wiggermann (2017) found hand forces to be lowest for straight maneuvering (but no difference between power-drive and no power-drive). Overall, the biomechanical loads were greatest for the more complex maneuvering of the beds and stretcher.

The perceptions of the physical exertion also indicated that power-drive reduced the efforts significantly. As with the biomechanical loads, the perceived exertions were highest for the up-ramp, corner, and down-ramp without power-drive. Straight with power-drive was a full point lower than all other transport tasks with no power-drive.

There are several limitations to consider when interpreting the results. First, there was a small number of participants with very limited experience with moving hospital beds and stretchers. Actual nurses who are familiar with using power-drive or have had extensive training in its use, may have resulted in larger benefits of the power-drive. A more robust subject population may also solidify the differences between power-drive and manual maneuvering of beds/stretchers. Second, the evaluation was conducted through a laboratory simulation. The patient was bags of sand set-up to simulate the patient's body by positioning them in an expected pattern on the bed. Walls were simulated by stacks of cardboard boxes. In all, the simulation represented typical transports conducted in hospitals with expected loads of different sized patients. Third, the biomechanical model estimated the loads on the spine. During maneuvering of the beds/stretchers, loads under other structure within the body (e.g. shoulders) would also be loaded significantly. Pushing and pulling is very different from lifting and is just starting to be understood with respect to the potential injury mechanisms for the low back and shoulders. Future research needs to investigate the impact of pushing and pulling on the whole body. Fourth, the simulation did not include other interactions with other equipment, people, or environments when investigating the power drive intervention. Finally, only one style of power-drive was evaluated in the current assessment. Other power-drive designs may provide better feedback that may further decrease the loads on the back.

5. Conclusion

Power-drive was found to be beneficial in reducing the three-dimensional spine loads (8–21% for bed and 6%–7% for stretcher) with the more complex maneuvering tasks such as cornering, up-ramp, and down-ramp, having greater reductions (9–20%) as compared to manual maneuvering. However, these benefits may be larger if individuals are more experienced or better trained as it appeared that participants who were inexperienced over pushed on the handles when using power-drive. Participants perceived the exertion levels to be lower for the power-drive as compared to the manual maneuvering, likely meaning nurses and nursing aides would buy into using them when transporting beds and stretchers.

Author statement

We have attempted to address all comments from the reviewers and look forward to the manuscript to be published in the Special issue on Patient handling.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Kermit Davis and Susan Kotowski received financial support to conduct the study by HillRom Inc.

Acknowledgements

We would like to thank Hill-Rom, Inc. for partially funding this study.

References

- Alexopoulos, E.C., Burdorf, A., Kalokerinou, A., 2006. A comparative analysis on musculoskeletal disorders between Greek and Dutch nursing personnel. *Int. Arch. Occup. Environ. Health* 79 (1), 82–88. <https://doi.org/10.1007/s00420-005-0033-z>.
- Borg, G.A., 1982. Psychophysical bases of perceived exertion. *Med. Sci. Sports Exerc.* 14, 377–381. <https://doi.org/10.1249/00005768-198205000-00012>.
- Callison, M.C., Nussbaum, M.A., 2012. Identification of physically demanding patient-handling tasks in an acute care hospital. *Int. J. Ind. Ergon.* 42 (3), 261–267. <https://doi.org/10.1016/j.ergon.2012.02.001>.
- Cameron, S.J., Armstrong-Stassen, M., Kane, D., Moro, F.B., 2008. Musculoskeletal problems experienced by older nurses in hospital settings. *Nurs. Forum* 43 (2), 103–114. <https://doi.org/10.1111/j.1744-6198.2008.00101.x>.
- Daniell, N., Merrett, S., Paul, G., 2014. Effectiveness of powered hospital bed movers for reducing physiological strain and back muscle activation. *Appl. Ergon.* 45 (4), 849–856. <https://doi.org/10.1016/j.apergo.2013.11.001>.
- Davis, K.G., Kotowski, S.E., 2015. Prevalence of musculoskeletal disorders for nurses in hospitals, long-term care facilities, and home health care: a comprehensive review. *Hum. Factors* 57 (5), 754–792. <https://doi.org/10.1177/0018720815581933>.
- Davis, K.G., Marras, W.S., Waters, T.R., 1998. Evaluation of the spine loading during lowering and lifting. *Clin. Biomech.* 13 (3), 141–152. [https://doi.org/10.1016/S0268-0033\(97\)00037-5](https://doi.org/10.1016/S0268-0033(97)00037-5).
- Fathallah, F.A., Marras, W.S., Parnianpour, M., 1998. An assessment of complex spine loads during dynamic lifting tasks. *Spine* 23 (6), 706–716.
- Granata, K.P., Marras, W.S., 1995. An EMG-assisted model of trunk loading during free-dynamic lifting. *J. Biomech.* 28 (11), 1309–1317. [https://doi.org/10.1016/0021-9290\(95\)00003-Z](https://doi.org/10.1016/0021-9290(95)00003-Z).
- Guo, Z., Yee, R.B., Mun, K.R., Yu, H., 2017. Experimental evaluation of a novel robotic hospital bed mover with omni-directional mobility. *Appl. Ergon.* 65, 389–397. <https://doi.org/10.1016/j.apergo.2017.04.010>.
- Leban, B., Fabbri, D., Lecca, L.I., Uras, M., Monticone, M., Porta, M., Pau, M., Campagna, M., 2021. Characterization of hand forces exerted during non-powered hospital bed pushing and pulling tasks. *Int. J. Occup. Saf. Ergon.* 1–9 <https://doi.org/10.1080/10803548.2020.1857081>.
- Leban, B., Lecca, L.I., Fabbri, D., Campagna, M., Pau, M., 2019. Influence of trajectory and gender on pushing-pulling forces when maneuvering beds in actual hospital paths. *Mater. Today: Proceedings* 7, 435–442. <https://doi.org/10.1016/j.matpr.2018.11.106>.
- Marras, W.S., Sommerich, C.M., 1991. A three dimensional motion model of loads on the lumbar spine: II. Model validation. *Hum. Factors* 33 (2), 139–149. <https://doi.org/10.1177/001872089103300202>.
- Pfeiffer, K.A., Pivarnik, J.M., Womack, C.J., Reeves, M.J., Malina, R.M., 2002. Reliability and validity of the Borg and OMNI rating of perceived exertion scales in adolescent girls. *Med. Sci. Sports Exerc.* 34 (12), 2057–2061. <https://doi.org/10.1249/01.MSS.0000039302.54267.BF>.
- Pompeii, L.A., Lipscomb, H.J., Schoenfish, A.L., Dement, J.M., 2009. Musculoskeletal injuries resulting from patient handling tasks among hospital workers. *Am. J. Ind. Med.* 52 (7), 571–578. <https://doi.org/10.1002/ajim.20704>.
- Pompeii, L.A., Lipscomb, H.J., Dement, J.M., 2008. Surveillance of musculoskeletal injuries and disorders in a diverse cohort of workers at a tertiary care medical center. *Am. J. Ind. Med.* 51 (5), 344–356. <https://doi.org/10.1002/ajim.20572>.
- Waehrer, G., Leigh, J.P., Miller, T.R., 2005. Costs of occupational injury and illness within the health services sector. *Int. J. Health Serv.* 35 (2), 343–359. <https://doi.org/10.2190/RN93-0C13-U09M-TENP>.
- Wiggermann, N., 2017. Effect of a powered drive on pushing and pulling forces when transporting bariatric hospital beds. *Appl. Ergon.* 58, 59–65. <https://doi.org/10.1016/j.apergo.2016.05.015>.
- Wilson, T.P., Davis, K.G., Kotowski, S.E., Daraiseh, N., 2015. Quantification of patient and equipment handling for nurses through direct observation and subjective perceptions. *Adv. Nurs.* <https://doi.org/10.1155/2015/928538>.
- Yip, V.Y.B., 2004. New low back pain in nurses: work activities, work stress and sedentary lifestyle. *J. Adv. Nurs.* 46 (4), 430–440. <https://doi.org/10.1111/j.1365-2648.2004.03009.x>.