The case for powered bed transport

Matz, M., Morgan, J. (2018)

Introduction

Transporting patients in beds throughout hospitals is an ergonomically high risk patient handling task[1-8] and has been rated as one of the top patient handling tasks that result in complaints of musculoskeletal pain.[9] Performing such an activity can stress the musculoskeletal system and exceed the body's capabilities, frequently resulting in low back pain, spinal problems,[10] shoulder injuries [11, 12] and, in general, many of the patient handling injuries that are found in healthcare environments.[13] Ergonomic interventions are available to decrease the risk of injuries for this high risk task.

This White Paper discusses the physical impacts of transportation and resultant push/pull forces on caregivers along with suggestions for decreasing the amount of work required from users by utilizing new technology such as the IndiGo drive assist. Factors that impact push forces on caregivers are also discussed and transportation technologies are reviewed.

Ergonomics of patient transportation

Pushing and pulling excessive loads (patients) on a repeated basis, constitutes a high ergonomic risk, as does any task or motion that negatively impacts the musculoskeletal system due to excessive stress or force. The spine is subject to extensive mechanical stress from both compressive and shear forces[14] but it has a greater tolerance for compressive forces than shear. Shear force tolerance in spinal discs is nearly one-third less than compressive force tolerance. [15, 16] Examples of compressive forces on the spine are lifting heavy objects (people) and lifting lighter weight objects for long periods of time. Shear forces come from both lateral and anterior/posterior movements of the spine, and are an outcome from twisting, turning, bending, reaching, and awkward postures.

Awkward postures are due to various factors such as available space, equipment used, number of caregivers handling the patient, and caregiver anthropometry.[17] As can be surmised, very high shear forces are common during pushing/pulling activities.[18] These high shear forces create excessive loads on the spine and resultant injuries to the spine.

Reducing shear forces on the spine, i.e., ergonomic risks, while transporting patients is critical. The Liberty Mutual Manual Materials Handling Tables relayed that only 49% of women and 65% of men can be expected to initiate a push of a bed (weighing 800 pounds), with an average patient (weighing 200 pounds), with an average wheel diameter of six (6) inches, on a hard floor surface.[19] To reduce the excessive ergonomic effort and push forces when transporting patients, adaptations have been made to some beds adding power drive features and fifth wheels. Battery-powered bed pushing devices have also been designed to assist in bed transport.[20-22]

Factors impacting forces on caregivers during manual transportation tasks

Many factors impact ergonomic risk while caregivers are manually transporting beds without power assistance. When these factors are accounted for, as they are with the IndiGo, forces are greatly reduced and caregiver risk of injury diminishes. Increases in the shear forces to the spine are attributable to the following.

Lateral Transfers. The most effective injury risk control measure is elimination of a hazard.[23] Transportation of patients cannot be totally eliminated, but lateral transfers for transportation

purposes can. Use of power drive technology eliminates the need to laterally transfer a patient from/to bed and stretcher in order to transport them. If you can keep a patient in their bed to move them, then you have eliminated the need for a lateral transfer and the risk of injury associated with it.

Flooring. Rolling Resistance (or surface resistance) of flooring material is a critical factor related to push forces.[24] It is related to the difficulty in overcoming inertia when initially pushing or pulling a wheeled object.[25] The lower the resistance, the easier to move the object and the less work it takes.[26] There is growing concern about caregiver risk associated with the movement of patients on carpeted or padded tile surfaces, especially when performing turns.[27] Flooring with soft cushioning features has a higher rolling resistance, and is more difficult to push over than a flooring that is less resilient, such as tile. Other design features impact push forces and safety. Thresholds should be flush with the floor surface to facilitate safe movement of rolling equipment. Transitions between different adjacent floor surfaces should eliminate tripping, bumps, and strain on staff pushing or guiding equipment and should be noticeable. Slopes should be eliminated or minimized.[28]

Weight of Bed. The weight of the bed impacts push forces[29], as it is the load that must overcome inertia for movement to occur. When all else is equal, the heavier the load, the greater the push forces required to initiate the move and sustain it. Some beds, without a patient, weighs 800 pounds, and an occupied bed may weigh more than 1,000 pounds.[30]

Weight of Patient. The obesity rate among U.S. adults in 2015 climbed to a new high of 28.0%, up 2.5 percentage points since 2008.[31] Unfortunately, this trend continues and already high risk patient handling tasks are greatly increased in risk when moving heavier patients. The tasks associated with bariatric populations are more complex because of excess patient weight and weight distribution, decreased mobility, and the many co-morbid conditions found in bariatric patients.[32] In relation to patient transport, the heavier the load, the greater the push forces required to initiate the move and sustain it. Additionally, the weight distribution of a heavier patient may impact their placement and stability on a bed or other rolling device. Finally, with less mobility and functionality, and higher acuity levels, bariatric patients rely more on caregiver assistance, thus increase a caregiver's risk of injury.

Wheel/Caster design and condition. Wheel size, diameter, and condition will affect the ease of rolling a patient bed.[33, 34]

Space and Clearances. Inadequate space and clearances for performing patient handling activities such as pushing hospitals beds makes challenging tasks even more difficult and increases the risk of caregiver injury. Pushing beds is impacted by space allowances and clearances in hallways. For instance, if there is inadequate room to turn into a patient room, push forces are elevated. Doorway widths also impact the ease in which beds are moved in and out of an area. It is essential to have adequate room clearances for safely maneuvering beds and other rolling equipment. When a patient must be laterally transferred onto a stretcher to be transported to another area and there is insufficient space, room furniture must often be moved, putting caregivers at high risk.

Elevator Dimensions. Elevator dimensions may prevent the use of high-tech and bariatric beds.[35] Standard elevators may also not accommodate beds that are extended with power drive features.

Excessive Push Forces. Push forces are impacted by the above factors. When they become excessive and exceed the maximum allowable forces found in the AORN Guidance Statement (2007), the recommendations are to reduce the weight of the load and use two or more caregivers to push the piece of rolling equipment, or, utilize a powered transport device.[36] Though good advice, few are aware of these maximum allowable forces. An easier rule-of-thumb is that caregivers should avoid push/pull forces greater than 20% of their own weight.[37]

Bed Moving/Patient Transportation Technologies

Bed transfers between clinical units are on the increase according to researchers who aimed to quantify frequencies of transfers between and within wards. Within the hospital research site, they found that a patient was moved, on average, 2.4 times during their stay. Transfers between clinical units took an average of 42 minutes and within the unit, 11 minutes. Nurses at the site spent over 1700 hours each month on transporting patients and activities related to this task, resulting in less time to care for patients.[38] Bed transportation technologies, may help facilitate reduction in time spent transporting patients and, in doing so, improve staff efficiency by eliminating the need for lateral transfers onto stretchers for patient transport and requiring fewer staff to be involved in patient transportation.

To reduce the excessive ergonomic effort and risk of injury when transporting patients, adaptations have been made to standard beds adding power features and fifth wheels. Battery-powered bed pushing devices have also been designed to assist in bed transport.[39-44] Each has their benefits and challenges. Such technology, especially beds with power drive features, are available and frequently used with critical care and bariatric beds. However, few medical/surgical units, although they have frequent 'road trips', have beds with this power technology. Summaries of studies exhibiting the positive benefits of power technology are found below.

When a **powered hospital bed mover** was trialed against manual transport, and muscle activation was captured, nearly all muscles tested showed lower muscle activation levels with the bed mover. Additionally, users maintained a more upright posture. The authors surmised that lower levels of muscle activation may result in decreased incidence of lower back injury.[45] These bed movers facilitate pushing patients up an incline and reduce acceleration when going down. However, when a bed mover is attached to a patient bed, the bed cannot fit into most standard elevators. The device needs to be removed prior to inserting the bed into an elevator or one should be available near the elevator on each floor.[46] Storage of this device can be problematic.

Indigo Drive Assist Fitted to A Citadel Bed

A **robotic hospital bed mover** with omni-directional mobility demonstrated better performance than use of a manual transport stretcher. It was estimated that the robotic device halved the force required to push hospital beds, reducing physical demands, requiring less manpower, and reducing back muscle activities.[47]

Steering assistance features such as a 5th wheel design are perceived to improved caregiver productivity during patient transportation tasks within a patient room and when moving down a corridor.[48]

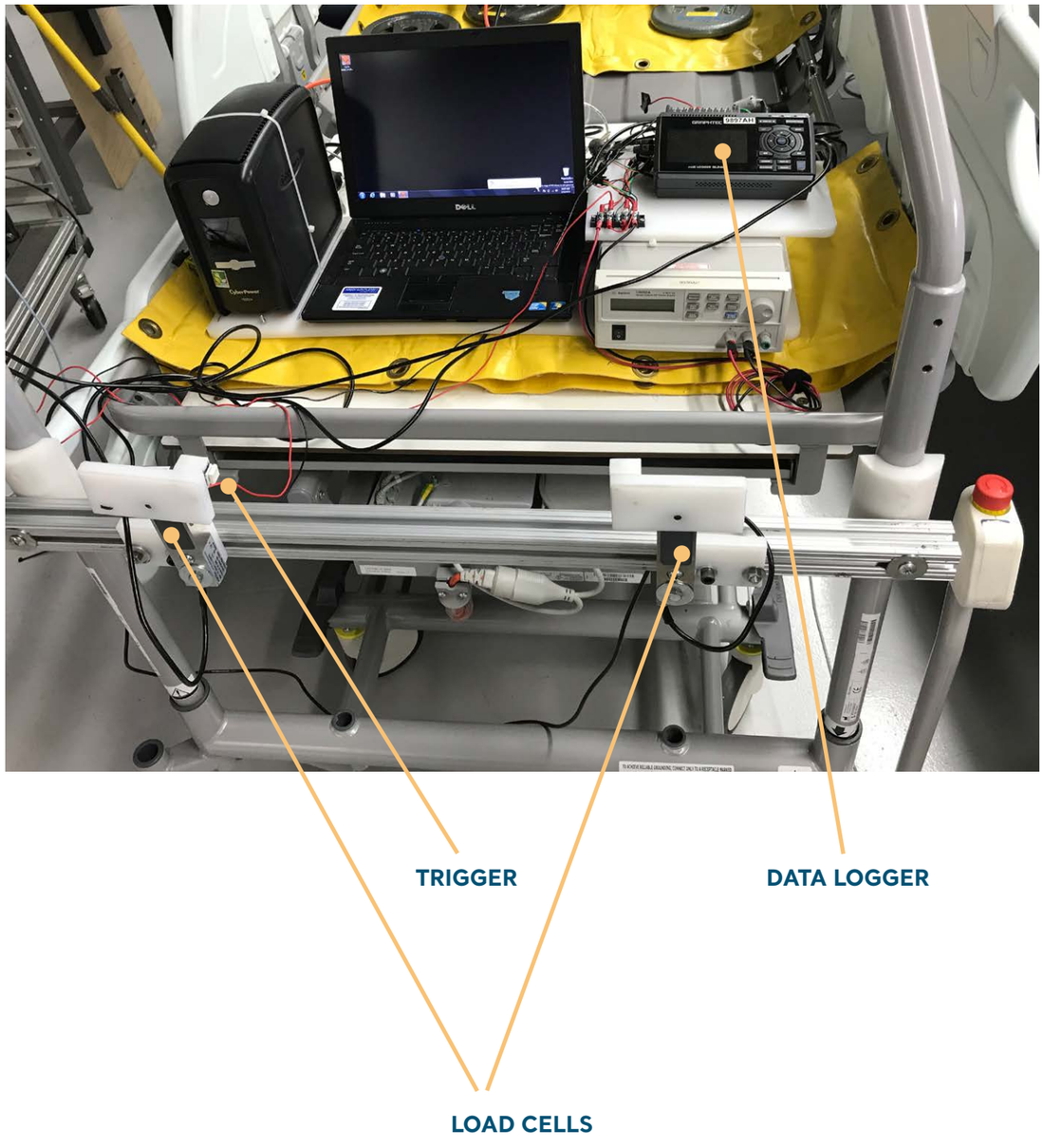
Power drives, are used to facilitate movement of hospital beds. Wiggermann (2017) conducted a study that measured hand forces on 10 caregivers while they moved a bariatric bed manually and while using a powered drive. The powered drive decreased peak forces between 38% (while maneuvering into an elevator) and 94% (while going down a ramp). The powered drive also reduced stopping distance by 55%. During straight-line pushing, average hand forces did not vary between bed designs but when maneuvering the bed, the force was reduced by 34% when using powered drive beds.[49]

Insufficient numbers of beds with motorization capabilities place staff who transport patients at a higher risk of injury than necessary. When staff are working injured, patient safety and quality of care are impacted. Introduction of these devices should be a priority for healthcare organizations.

A new power transport design, IndiGo drive assist from Arjo, reduces work required to transport patients on their bed to help reduce the risk of staff injury. Unlike power drive systems the innovative design does not change the user interface of the bed. Users push or pull the bed as usual from any touch point and IndiGo assists movement in the direction the user wants to move. It provides drive and braking assistance based on caregiver input as well as automatic slope detection. Blue lights project onto the floor when the device is activated, letting users know the power device is operational. Indigo is compatible with most Arjo patient bed frame systems and attaches underneath the bed so it does not impact any of the bed's existing functionality. It requires less work to move a bed with IndiGo installed and has the potential to improve the bed transport process and improve safety for those involved.

Testing of the IndiGo power drive system produced very positive results. The following describes the testing protocol and outcomes.

Figure 1: Test Setup



IndiGo Testing Protocol and Outcomes

Figure 2: Encoder System

Test Setup

Four different Arjo beds were used to evaluate the IndiGo drive assist. The beds used were Citadel™ Bed Frame System, Enterprise™ 5000X, Enterprise™ 8000X, and Enterprise™ 9000X. Each bed was configured with 150mm casters and had a simulated patient load of 112 kg with a mattress and an additional accessory load of 20kg.

The bed frame was configured with a set of calibrated load cells to record user input force into the system. A calibrated encoder system was used to measure the speed and distance traveled for each trial. An external trigger was fitted to the bed to assist with start and stop of data analysis. A calibrated data logger (GL240) was used as the interface. This test set up was first verified using internal Standard operating procedure, SOP requirements before being used to execute formal testing. The same test setup up was used on each bed for all tests.

Table 1: Test Requirements and Acceptance Criteria

1	The initial work to accelerate a bed with a Power Assist Module (PAM) installed to a speed above 0.8m/s ±0.15m/s within 2 ±0.2m with a load of 112 ±2kg patient weight and 20 ±2kg accessory on a hard and flat horizontal surface, shall be 15% less than a bed without PA module tested at the same parameters.
2	The work to decelerated a bed with a PAM installed from 1.2m/s ±0.15 to a stop within a 4.0 +0.4m distance with a load of 112 ±2kg patient weight and 20 ±2kg accessory on a hard and flat horizontal surface, shall be 15% less than a bed without a PA module tested at the same parameters.
3	The work to move a bed with a PAM installed with a load of 112 ±2kg patient weight and 20 ±2kg accessory a distance of 4.0 +0.4m up a 3.5° +0.5° slope at a speed of 0.8m/s ±0.15m/s on a hard floor shall be <40% of a bed without PA module installed.
4	The work to control the speed of a bed with a PAM installed at a speed <1.4m/s at a load of 112 ±2kg and 20 ±2kg down a 3.5° +0.5° slope a distance of 4.0m +0.4m on a hard floor shall be <40% of a bed without PA module installed.

Test Procedure:

Each bed was fitted with the test set up noted in Figures 1 and 2. The four requirements evaluated are listed in Table 1.
The same bed was used for both Power Assist Module (PAM) and bed without Power Assist (PA) module.
The PA module was simply deactivated to obtain “without PA module” configuration.

The figures below illustrate the procedure for each test scenario.

Figure 3: Test 1 Illustration

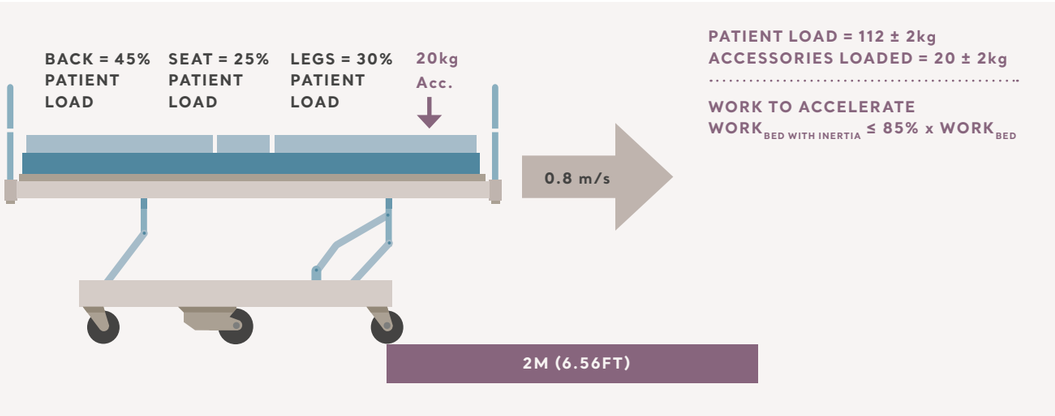


Figure 4: Test 2 Illustration

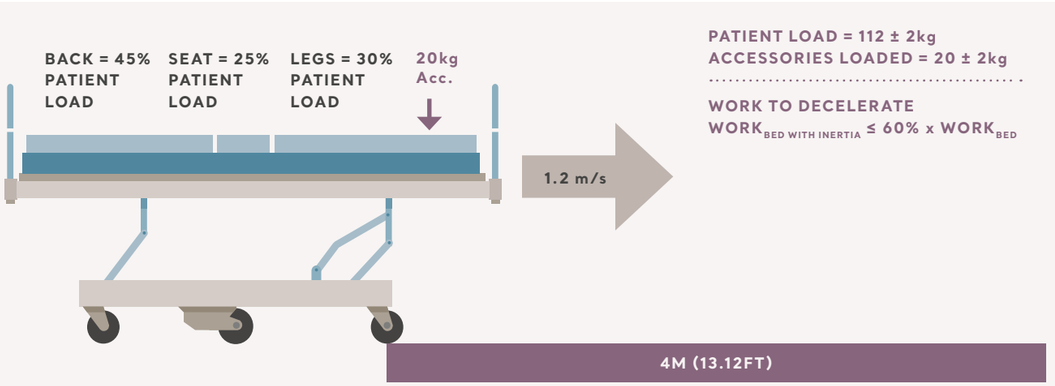


Figure 5: Test 3 Illustration

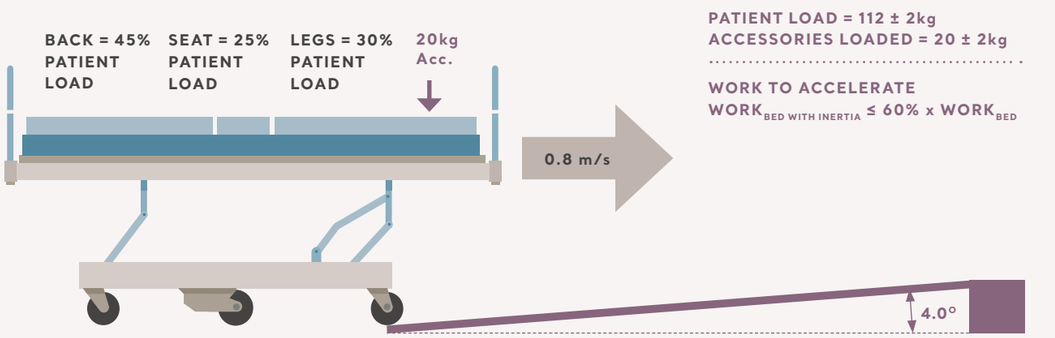


Figure 6 : Test 4 Illustration

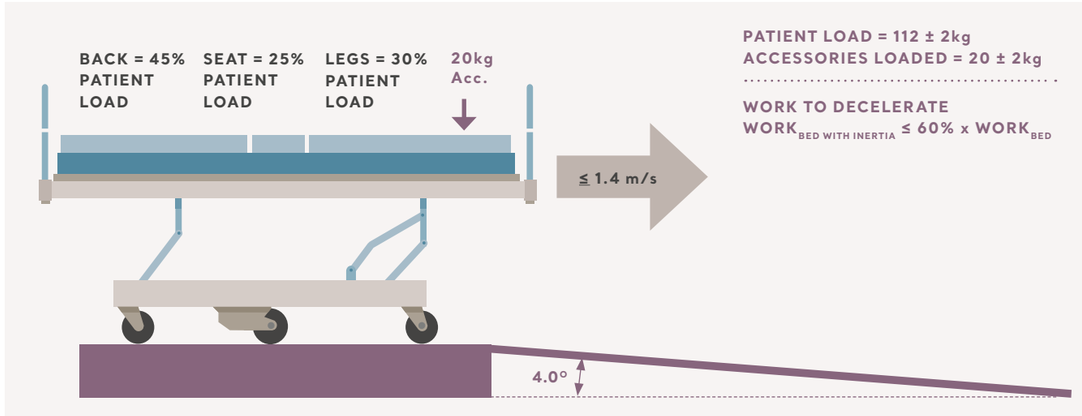
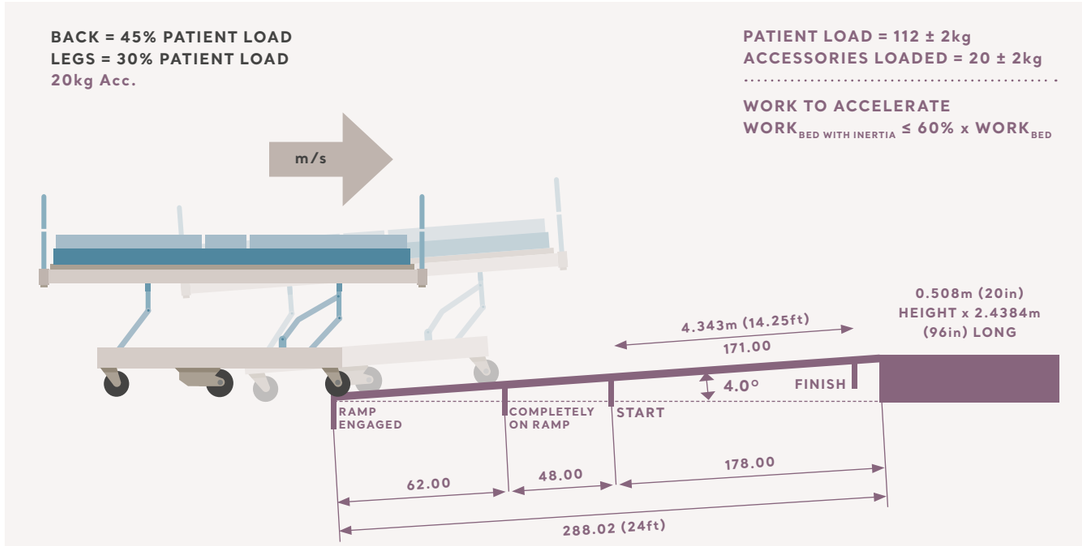


Figure 7: Additional details for Test 3



Data Analysis

The data collected was force to move the bed, speed, distance and time. This data was used to calculate Work (force x distance) and evaluated against other internal acceptance criteria. Work was chosen as the baseline factor to evaluate as it is the true measure of how much energy is transferred from one entity to another. Each bed ran through the testing procedure three times. Figures 8-11 below break the data down for each test description.

Figure 8: Test 1 Summary Results

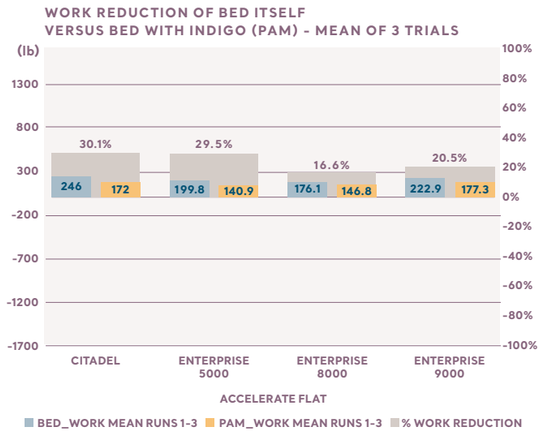


Figure 9: Test 3 Summary Results

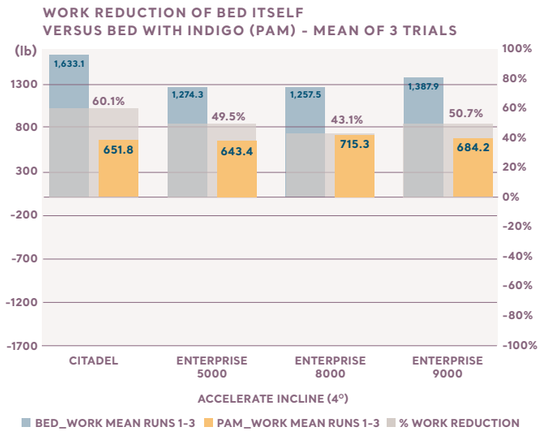


Figure 10: Test 2 Summary Results

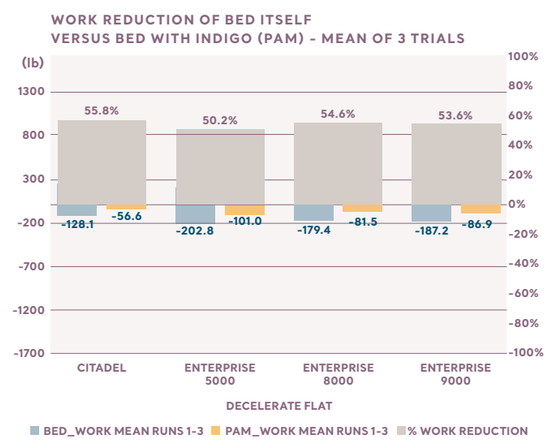
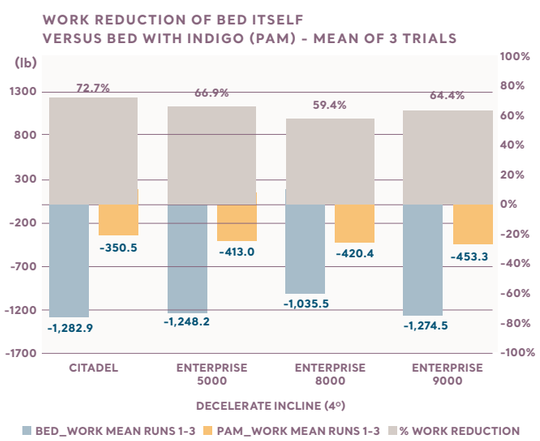


Figure 11: Test 4 Summary Results



The final percent Work reduction calculation is the mean percent Work reduction of 3 trials.

Table 2: Work Reduction Summary

Test	Test Description	Target	% Work Reduction			
			Citadel	Enterprise 9000X	Enterprise 8000X	Enterprise 5000X
1	Accelerate the bed on flat surface	>15%	30.1%	20.5%	16.6%	29.5%
2	Decelerate the bed on flat surface		55.8%	53.6%	54.6%	50.2%
3	Accelerate the bed up slope	>40%	60.1%	50.7%	43.1%	49.5%
4	Decelerate the bed down slope		72.7%	64.4%	59.4%	66.9%

Test Summary

When evaluating the Work reduction data of the IndiGo drive assist on the heaviest bed frame, Citadel, it shows that it can provide up to:

- 72% work reduction when decelerating down 4 degree slopes
- Up to 60% work reduction when accelerating up 4 degree slopes
- Up to 55% work reduction when decelerating on a flat surface
- Up to 30% work reduction when accelerating on a flat surface

Conclusion

Use of power transport devices has a tremendous impact on the safety and efficiency of hospital work environments. Ergonomic risk and caregiver potential for injuries are directly affected by the decrease in push forces and the elimination of high risk lateral transfer tasks associated with patient transport. When transporting patients on their beds, work reduction is evidenced by fewer staff that may be required to transport patients as well as the elimination of transport lateral transfer tasks.

The introduction of IndiGo drive assist adds to existing technology - a 'grab anywhere' interface that allows caregivers to move the bed and push in any direction, delivering significant work/force reduction when accelerating,decelerating and moving up and down slopes. Work reduction helps improve safety for caregivers during high risk bed transport and provides the possibility of reducing the number of staff required to complete this task. Unlike bed power drive systems used in specialist critical care and bariatric beds the introduction of new technologies such as Indigo drive assist brings work reduction benefits to many other departments in the hospital that account for the majority of a hospital's bed transport activities.

References

[1] Guo, Z., Yee, R.B., Mun, K.R. & Yu, H. Experimental evaluation of a novel robotic hospital bed mover with omni-directional mobility. Appl Ergon. 2017 Nov;65:389-397.

[2] Paul, G. & Quintero-Duran, M. Ergonomic assessment of hospital bed moving using DHM Siemens JACK. Proceedings 19th Triennial Congress of the IEA, Melbourne 9-14 August 2015. Retrieved February 11, 2018 from https://eprints.qut.edu.au/86239/3/86239.pdf.

[3] Waters T., Lloyd, J.D., Hernandez, E. & Nelson, A. AORN Ergonomic Tool 7: Pushing, Pulling, and Moving Equipment on Wheels. AORN J. 2011 Sept;94(3):254-260.

[4] Matz, M. (2010). Rationale for Including the PHAMA in the 2010 Guidelines for Design and Construction of Health Care Facilities. In Borden, C.(Ed), Patient Handling and Movement Assessments: A White Paper. Dallas:The Facilities Guidelines Institute.

[5] Kim, S., Barker, L.M., Jia, B., Agnew, M.J., Nussbaum, M.A. Effects of two hospital bed design features on physical demands and usability during brake engagement and patient transportation: a repeated measures experimental study. Int J Nurs Stud. 2009 Mar;46(3):317-25.

[6] AORN Workplace Safety Taskforce, Safe Patient Handling and Movement in the Perioperative Setting. Denver, CO: Association of periOperative Registered Nurses [AORN], 2007.

[7] Nelson, A. L. (2006). Variations in high-rick patient handling tasks by practice setting. In A.Nelson (Ed.), Safe Patient Handling and Movement: A Practical Guide for Health Care Professionals (pp. 47-56). New York: Springer.

[8] Department of Veterans Affairs (VA), VISN 8 Patient Safety Center of Inquiry. (2006). Tampa, FL. No longer available. Patient Care Ergonomics Resource Guide: Safe Patient Handling and Movement.

[9] Paul, G. & Quintero-Duran, M. Ergonomic assessment of hospital bed moving using DHM Siemens JACK. Proceedings 19th Triennial Congress of the IEA, Melbourne 9-14 August 2015. Retrieved February 11, 2018 from https://eprints.qut.edu.au/86239/3/86239.pdf.

[10] International Organization for Standardization (ISO). Ergonomics — Manual handling of people in the healthcare sector. Reference number ISO/TR 12296:2012(E). 2012.

[11] J+J Flooring Group. Flooring Selection for Acute Care Facilities: Safety Implications. ND. https://www.jjflooringgroup.com/wp-content/uploads/Safety_Technical_White_Paper_FINAL.pdf.

[12] Waters T., Lloyd, J.D., Hernandez, E. & Nelson, A. AORN Ergonomic Tool 7: Pushing, Pulling, and Moving Equipment on Wheels. AORN J. 2011 Sept;94(3):254-260.

[13] OSHA (2003). Ergonomic Guidelines for Nursing Homes Washington, DC: US Department of Labor.

[14] International Organization for Standardization (ISO). Ergonomics — Manual handling of people in the healthcare sector. Reference number ISO/TR 12296:2012(E). 2012.

[15] Waters T., Lloyd, J.D., Hernandez, E. & Nelson, A. AORN Ergonomic Tool 7: Pushing, Pulling, and Moving Equipment on Wheels. AORN J. 2011 Sept;94(3):254-260.

[16] Paul, G. & Quintero-Duran, M. Ergonomic assessment of hospital bed moving using DHM Siemens JACK. Proceedings 19th Triennial Congress of the IEA, Melbourne 9-14 August 2015. Retrieved February 11, 2018 from https://eprints.qut.edu.au/86239/3/86239.pdf.

[17] International Organization for Standardization (ISO). Ergonomics — Manual handling of people in the healthcare sector. Reference number ISO/TR 12296:2012(E). 2012.

[18] Waters T., Lloyd, J.D., Hernandez, E. & Nelson, A. AORN Ergonomic Tool 7: Pushing, Pulling, and Moving Equipment on Wheels. AORN J. 2011 Sept;94(3):254-260.

[19] Marras, W.S., Knapik, G.G., and Ferguson, S. Lumbar spine forces during manoeuvring of ceiling-based and floor-based patient transfer devices. Ergonomics. Vol. 52, No. 3, March 2009, 384–397.

[20] Department of Veterans Affairs (VA), Center for Engineering and Occupational Safety and Health (CEOSH). Safe Patient Handling and Mobility Guidebook. (2016). St. Louis, MO.

[21] International Organization for Standardization (ISO). rgonomics — Manual handling of people in the healthcare sector. Reference number ISO/TR 12296:2012(E). 2012.

[22] Matz, M. (2010). Rationale for Including the PHAMA in the 2010 Guidelines for Design and Construction of Health Care Facilities. In Borden, C.(Ed), Patient Handling and Movement Assessments: A White Paper. Dallas:The Facilities Guidelines Institute.

[23] Wikipedia. Hierarchy of hazard control Hierarchy of hazard control. Retrieved 2/10/2018 from https://en.wikipedia.org/wiki/Hierarchy_of_hazard_controls.

[24] Rice, MS. Woolley SM, Waters TR. Comparison of required operating forces between floor-based and overhead-mounted patient lifting devices. Ergonomics. 2009 Jan;52(1):112-20.

[25] AORN Workplace Safety Taskforce, Safe Patient Handling and Movement in the Perioperative Setting. Denver, CO: Association of periOperative Registered Nurses [AORN], 2007.

[26] J+J Flooring Group. Flooring Selection for Acute Care Facilities: Safety Implications. ND. https://www.jjflooringgroup.com/wp-content/uploads/Safety_Technical_White_Paper_FINAL.pdf.

[27] Marras, W.S., Knapik, G.G., and Ferguson, S. Lumbar spine forces during manoeuvring of ceiling-based and floor-based patient transfer devices. Ergonomics. Vol. 52, No. 3, March 2009, 384–397.

[28] Matz, M. (2010). Rationale for Including the PHAMA in the 2010 Guidelines for Design and Construction of Health Care Facilities. In Borden, C.(Ed), Patient Handling and Movement Assessments: A White Paper. Dallas:The Facilities Guidelines Institute.

[29] Rice, MS. Woolley SM, Waters TR. Comparison of required operating forces between floor-based and overhead-mounted patient lifting devices. Ergonomics. 2009 Jan;52(1):112-20.

[30] J+J Flooring Group. Flooring Selection for Acute Care Facilities: Safety Implications. ND. https://www.jjflooringgroup.com/wp-content/uploads/Safety_Technical_White_Paper_FINAL.pdf.

[31] Witters, Dan. "U.S. Obesity Rate Climbs to Record High in 2015." Gallup.com. N.p., 12 Feb. 2016. Web. 6 Mar. 2016.

[32] Department of Veterans Affairs (VA), Center for Engineering and Occupational Safety and Health (CEOSH). Bariatric Safe Patient Handling and Mobility Guidebook: A Resource Guide for Care of Persons of Size. (2015). St. Louis, MO.

[33] Rice, MS. Woolley SM, Waters TR. Comparison of required operating forces between floor-based and overhead-mounted patient lifting devices. Ergonomics. 2009 Jan;52(1):112-20.

[34] Marras, W.S., Knapik, G.G., and Ferguson, S. Lumbar spine forces during manoeuvring of ceiling-based and floor-based patient transfer devices. Ergonomics. Vol. 52, No. 3, March 2009, 384–397.

[35] Matz, M. (2010). Rationale for Including the PHAMA in the 2010 Guidelines for Design and Construction of Health Care Facilities. In Borden, C.(Ed), Patient Handling and Movement Assessments: A White Paper. Dallas:The Facilities Guidelines Institute.

[36] AORN Workplace Safety Taskforce, Safe Patient Handling and Movement in the Perioperative Setting. Denver, CO: Association of periOperative Registered Nurses [AORN], 2007.

[37] Knapik GG, Marras WS. Spine loading at different lumbar levels during pushing and pulling. Ergonomics. 2009;52(1):60-70.

[38] Blay N, Roche MA, Duffield C, Gallagher R. Intrahospital transfers and the impact on nursing workload. J Clin Nurs. 2017;26:4822–4829. Retrieved February 11, 2018 from https://doi.org/10.1111/jocn.13838.

[39] Department of Veterans Affairs (VA), Center for Engineering and Occupational Safety and Health (CEOSH). Safe Patient Handling and Mobility Guidebook. (2016). St. Louis, MO.

[40] J+J Flooring Group. Flooring Selection for Acute Care Facilities: Safety Implications. ND. https://www.jjflooringgroup.com/wp-content/uploads/Safety_Technical_White_Paper_FINAL.pdf.

[41] International Organization for Standardization (ISO). Ergonomics — Manual handling of people in the healthcare sector. Reference number ISO/TR 12296:2012(E). 2012.

[42] Matz, M. (2010). Rationale for Including the PHAMA in the 2010 Guidelines for Design and Construction of Health Care Facilities. In Borden, C.(Ed), Patient Handling and Movement Assessments: A White Paper. Dallas:The Facilities Guidelines Institute.

[43] Menzel, N.N. Strengthening your evidence base: Focus on safe patient. American Nurse Today, 5(7):38-40. (2010) Retrieved February 11, 2018 from https://www.americannursetoday.com/strengthening-your-evidence-base-focus-on-safe-patient-handling/.

[44] Kim, S., Barker, L.M., Jia, B., Agnew, M.J., Nussbaum, M.A. Effects of two hospital bed design features on physical demands and usability during brake engagement and patient transportation: a repeated measures experimental study. Int J Nurs Stud. 2009 Mar;46(3):317-25.

[45] Daniell, N., Merrett, S., & Paul, G. Effectiveness of powered hospital bed movers for reducing physiological strain and back muscle activation. App Ergon. 2014 Jul;45(4):849-56.

[46] Matz, M. (2010). Rationale for Including the PHAMA in the 2010 Guidelines for Design and Construction of Health Care Facilities. In Borden, C.(Ed), Patient Handling and Movement Assessments: A White Paper. Dallas:The Facilities Guidelines Institute.

[47] Guo, Z., Yee, R.B., Mun, K.R. & Yu, H. Experimental evaluation of a novel robotic hospital bed mover with omni-directional mobility. Appl Ergon. 2017 Nov;65:389-397.

[48] Kim, S., Barker, L.M., Jia, B., Agnew, M.J., Nussbaum, M.A. Effects of two hospital bed design features on physical demands and usability during brake engagement and patient transportation: a repeated measures experimental study. Int J Nurs Stud. 2009 Mar;46(3):317-25.

[49] Wiggermann, N. Effect of a powered drive on pushing and pulling forces when transporting bariatric hospital beds. Appl Ergon. 2017Jan;58:59-65.

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