Friction-Reducing Devices for Lateral Patient Transfers
A Biomechanical Evaluation

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Abstract
The purpose of this study was to evaluate the efficacy of friction-reducing devices used for lateral patient transfers. A mannequin used to represent a dependent patient was transferred laterally from bed to stretcher. One male investigator repeated this task using 11 comparable lateral transfer aids or techniques. Applied force was measured using a dynamometer; postural analysis was prepared from still photography. Mean applied force, spinal forces, and population strength capabilities were calculated. The most efficacious mechanism for lateral patient transfers had extendable pull straps, low-friction material, and optimally located handles. Findings of this study will aid occupational health and safety clinicians and hospital-based caregivers in the selection of appropriate technologies to be used during lateral patient transfers. These devices improve patient safety and reduce the risk of back injury to caregivers.

Nursing is ranked second only to industrial work for physical workload intensity and is a high-risk profession for back injury (Engels, Landeweerd, & Kant, 1994; Kjellberg, Johnsson, Proper, Olsson, & Hagberg, 2000; Skovron, Nordin, Sterling, & Mulvihill, 1987). Compared with the general working population, nurses have a considerably higher prevalence and incidence of back pain and back injuries (Hignett, 1996; Kjellberg et al., 2000; Smedley, Egger, Cooper, & Coggon, 1997). Pheasant and Stubbs (1992) reported that nurses have approximately 30% more days off due to back pain compared with only 8% in the general working population. Key risk factors for back pain include excessive physical workload, low job satisfaction, history of back injury, age, lack of sports activities, and night shift work (Elfering et al., 2002; Nordin & Frankel, 1980).

Yassi et al. (1995) found that lifting and transferring patients were the two most common mechanisms for back injury among nurses. Stubbs and Buckle (1984) found that 36% of all low back pain in nurses was associated with patient handling. This is in agreement with a study by Jensen (1990), who found that the prevalence rate of back injuries among nurses who frequently handled patients was 3.7 times that of those who infrequently handled patients. Due to the nature of their work, including repositioning, transferring, and bathing patients, nurses are required to twist and bend simultaneously at the lumbar region. Retsas and Pinikahana (2000) reported that during an 8-hour work period, nurses may lift a total of 1.8 tons. Patient transfers increase the spinal loading in nurses (Hignett, 1996; Marras, Davis, Kirking, &
The findings of this study will aid occupational health and safety clinicians and hospital-based caregivers in the identification and selection of appropriate technologies to be used during the lateral transfer of patients. These devices improve patient safety during such tasks, while affording less risk of back injury to caregivers.

Bertsche, 1999; Nelson et al., 2002; Smedley et al., 1997).

The aspects of patient handling that make it ergonomically hazardous include:

- Awkward posture during positioning or transferring patients.
- Patient weight.
- Dependency level of the patient.
- Physical and cognitive limitations of the patient.
- Space limitations in the room.
- Insufficient nurse-to-patient ratio.
- Inadequate equipment.

The horizontal distance between the nurse and the patient is called the lever arm. The shorter the lever arm, the lower the magnitude of the bending moment and thus the lower the load on the spine (Anderson, Örtengren, & Nachemson, 1976; Németh, 1984).

Zelenka, Floren, and Jordan (1996) evaluated the efficiency of two lateral transfer devices: a patient roller and a patient shifter. They compared each with a standard draw sheet. Patient weight, direction of transfer, and transfer device were investigated. Patient weight was found to be directly proportional to the force required to operate all three devices. Further, Zelenka, Floren, and Jordan discovered that the amount of initial force required was similar for push and pull transfers. They found that the patient roller was the most effective device for bed-to-stretcher transfers and that the firmness of the surfaces and the angle of pull were important factors in the reduction of frictional forces.

In a study of lateral transfers for a supine patient, Bohannon (1999) compared external pulling forces associated with such transfers when using a draw sheet, a patient shifter, an Easy Slide (ErgoSafe Products, LLC, St. Louis, MO), and no assistive device. The patient shifter is a 5-mm–thick plastic sliding board measuring 1,820 × 560 mm and the Easy Slide is a tubular fabric sleeve measuring 1,900 × 600 mm. Bohannon found that pulling forces were reduced the most by the Easy Slide. In another study, Grevelding and Bohannon (2001) evaluated and compared two devices requiring a pushing action to move a seated patient 20 cm laterally on an examination table. The Ross Easy Glide (Ross Medical Equipment, Sollentuna, Sweden) (sliding board), Ross Minimove (Ross Medical Equipment) (fabric tube), or both were used. The results indicated that combined use of the sliding board and the fabric tube required the lowest push forces.

The objective of the current study was to evaluate the biomechanical efficacy of 11 lateral transfer technologies or techniques. The goal was to improve the safety of occupational health and safety clinicians, hospital-based caregivers, and patients by making transfers less physically demanding, thereby contributing to a healthier workplace.

METHODS

An evaluation of 11 lateral transfer technologies or techniques was conducted in the Biomechanics Research Laboratory of the James A. Haley Veterans’ Hospital in Tampa, Florida. The products and their manufacturers, as well as brief descriptions of their operation in this study, are provided in the Sidebar on the next page.

One male investigator whose height, weight, and strength were representative of the 50th percentile U.S. adult male performed all lateral transfer tasks. A mannequin constructed by Medical Plastics Laboratory of Gatesville, Texas, was used to represent the patient. This mannequin was representative of the 10th percentile U.S. adult male in stature (1,670 mm) and the 87th percentile U.S. adult male in weight (88.5 kg). Key joints had realistic ranges of motion, and the mannequin was dressed in standard hospital pajamas. Overall, study conditions closely resembled a normal patient care environment.

A Chatillon dynamometer (model DMG 250; AMETEK TCI Division, Chatillon Force Measurement Systems, Largo, FL) was used to measure the force required to perform the lateral transfers. Prior to the study, calibration of the Chatillon dynamometer was verified by an independent laboratory. The investigator held the dynamometer, which
The 11 Lateral Transfer Technologies or Techniques Included in This Study

- AIRPAL (AIRPAL Patient Transfer Systems, Inc., Center Valley, PA)
- Flat Sheet Set (Phil-E-Slide Inc., Salem, NH)
- Disposable plastic bag (in-house technique)
- Draw sheet (in-house technique)
- RoMedic Easy Transfer System (Dynamic Health Care Solutions, Tottenham, Ontario, Canada)
- HoverMatt (HoverTech International, D. T. Davis Enterprises, Ltd., Bethlehem, PA)
- Lateral Transfer Aid (Phil-E-Slide Inc.)
- Maxi Slide (Arjo Inc., Roselle, IL)
- Maxi Trans (Arjo Inc.)
- Resident Transfer Assist (Hill-Rom, Batesville, IN)
- The Slipp (Inventive Products Inc., Springfield, IL)

The following are brief descriptions regarding the operation of each lateral transfer technology or technique in this study:

- The AIRPAL and HoverMatt are both air mattresses with approximately 4,000 tiny holes on their undersides. These technologies work by inflating the air mattress using a high-volume, low-pressure blower to lift the air mattress and patient off the bed. Two handles located at chest and waist levels allow caregivers to pull the mattress toward them, moving the patient to the desired location (Fig. 2).

- The Slipp consists of polyurethane bonded to nylon with silicone inside. It is placed under a draw sheet. The caregiver grasps the draw sheet and pulls, moving the patient laterally over the top of the friction-reducing device. The technique for the draw sheet is similar to that of The Slipp. Similarly, for the disposable plastic bag, a large plastic bag of heavy-duty material is placed beneath a draw sheet, thereby facilitating the lateral transfer.

- The Lateral Transfer Aid uses two sheets, a padded sheet and a slippery thin sheet. The latter is placed halfway under the padded sheet under the patient, whereas the padded sheet is positioned directly under the patient. Five plastic slats can be inserted into leaflets in the padded sheet to provide additional support and minimize the risk of the patient falling between the two surfaces during the transfer. The caregiver, standing one foot in front of the other, then pulls the strap, hand over hand, to move the patient. Two optional straps are available, one located at the shoulders and one between the hips and the knees. Thus, for heavier patients, two or more caregivers might share the load.

- The Flat Sheet Set operates with two sheets directly on top of each other with the slippery sides facing together. Caregivers pull the top sheet, sliding the patient over the bottom layer toward them. Two straps are used, one located at the shoulders and one between the hips and the knees (Fig. 3).

- The Resident Transfer Assist and the Maxi Slide work in the same manner as the Flat Sheet Set in that the transfer is performed with a pull force. However, there are no pull straps available for these products.

- In contrast, the RoMedic Easy Transfer System and the Maxi Trans consist of one tubular piece of material and operate by pushing, so the patient slides on the sheet over to the other surface.
was attached to a lightweight metal rod. Pull straps from the friction-reducing devices were perpendicularly attached to this rod, where force vectors similar to those of a typical transfer method were generated (Fig. 1). Typical transfer methods from the training manual of each product were followed.

The system described above was used to quantify the maximum externally applied force during transfer tasks. While one investigator performed the patient transfer, another investigator recorded the reading from the Chatillon dynamometer. The investigators calculated the mean across five measurements of maximum applied force required to perform the transfer task for each of the 11 devices, which were evaluated in random order.

The standard hospital equipment used in this study consisted of one hospital bed (Centra, Hill-Rom, Batesville, IN), which was 0.76 m (30 inches) high (adjustable), 2.06 m (81 inches) long, and 0.89 m (35 inches) wide, with a standard non-inflating mattress that was 150 mm (6 inches) thick and fitted with an under sheet and a top sheet. A stretcher trolley (Hausted 800 Series Unicare III, Baxter Healthcare Ltd./Unicare, Glasgow, Scotland), which was 0.71 m (28 inches) high, 2.01 m (79 inches) long, and 0.81 m (32 inches) wide, was used as the destination point of the transfer. The stretcher mattress was 90 mm (3.5 inches) thick. A Surgilift (Sunrise Medical, Carlsbad, CA) prone mechanical lifting device was used to lift and position the mannequin onto the various friction-reducing devices. All pieces of equipment were in working condition. The wheels on all equipment were locked to ensure safety during all transfers.

For a typical transfer, postural data were captured at the moment of load inception using still photography. Biomechanical force and postural data were then analyzed using the University of Michigan 3D Static Strength Prediction Program (University of Michigan, 1999). This analysis estimates spinal compression, anterior–posterior forces, and lateral shear forces as a function of externally applied force vectors, participant anthropometry, and posture. This software also calculates the percentage of the population with adequate strength in specific joints to execute the task. The three key joints analyzed included the elbow, shoulder, and torso.

RESULTS

The results of this study are based on precise biomechanical modeling of actual transfer tasks using the University of Michigan 3D Static Strength Prediction Program (1999). Consequently, they are descriptive and do not offer the opportunity for statistical analysis.

Spinal Forces (Fig. 4)

Compression of the spine at L5/S1 was greatest during use of the Maxi Trans (2,941 N) and least during use of the Flat Sheet Set (966 N). The Lateral Transfer Aid produced the greatest, although negligible (27 N), lateral shear force.

Anterior–posterior shear forces were greatest during use of the disposable plastic bag (797 N) and lowest during use of the Maxi Trans (27 N). A specific benefit of using a disposable plastic bag is that it remains stationary while the patient slides over it, thus eliminating the need to remove it after task completion.

Percentage of Population Capable of Task Execution (Fig. 5)

With the use of the University of Michigan 3D Static Strength Prediction Program (1999), the percentage of health care professionals who would have adequate strength in the elbow, shoulder, and torso joints to execute lateral transfer was calculated.

Approximately 90% of health care professionals were predicted to have sufficient torso strength to perform a lateral transfer using the traditional draw sheet.
technique or a disposable plastic bag. However, none of this population would have adequate shoulder or elbow strength to safely execute this task. More than 70% of health care professionals would have sufficient shoulder and elbow strength to sustain force demands of lateral transfer when using the AIRPAL, HoverMatt, The Slipp, Lateral Transfer Aid, Flat Sheet Set, Resident Transfer Assist, and Maxi Slide.

The pushing required by the RoMedic Easy Transfer System and the Maxi Trans proved biomechanically demanding. Only 15% and 10% of health care professionals, respectively, would have the shoulder strength required to successfully execute lateral transfer using these devices. However, approximately, 80% to 100% of this population would be able to sustain strength at the elbow and torso to perform lateral transfer using these technologies.

Applied Force (Fig. 6)

Applied force was calculated as the sum of forces (push or pull) acting on the left and right upper extremities during execution of the transfer task. The Maxi Slide required the least applied force (177 N). The AIRPAL and HoverMatt required an applied force of 191 N and 192 N, respectively. By comparison, the draw sheet method required an applied force of 646 N, which is significant because this is the technique health care professionals use most when transferring patients. Although the draw sheet and the disposable plastic bag may be less expensive than some other devices, the risk of injury from them is too high to recommend their continued use.

Best-in-Class Analysis

A best-in-class ranking system was derived to determine an overall rating for each of the 11 friction-reducing devices. This was achieved by calculating the mean from the ranks of spinal loading, strength capability across joints, and external applied force. This calculation assumes that those objective outcome measures were equally weighted, an assumption needed to reach a definitive decision regarding the best-in-class product. Based on this ranking system, the top 5 recommended friction-reducing devices, in descending order, were the Lateral Transfer Aid, Flat Sheet Set, Maxi Slide, HoverMatt, and AIRPAL. The two lowest ranked products were the draw sheet and the disposable plastic bag (Table).

**DISCUSSION**

In an attempt to minimize the physical workload demands imposed on health care professionals during the safe execution of lateral patient transfers, this study evaluated conventional and commercially available solutions from a biomechanical perspective. On the basis of the results, various recommendations can be made.

Although the spinal compressive forces cited in this study are below the action limit of 3,400 N at L5/S1 defined by the National Institute for Occupational Safety and Health (Waters, Putz-Anderson, Garg, & Fine, 1993), considerations of the National Institute for Occupational Safety and Health lifting equation are not directly applicable to patient-handling tasks, including lateral patient transfers, due to limitations of the equation (Waters, Putz-Anderson, & Garg, 1994). Specifically, the non-lifting elements of this task are greater than minimal and substantially contribute to the biomechanical and physiologic demands of the task. This study attempted to identify those task variations that present the least shear force on the spine while controlling compressive loads.

The traditional draw sheet method and use of a disposable plastic bag proved to be physically demand-
ing and are not recommended for the lateral transfer of patients. Although their spinal compressive forces were lower than those for the Maxi Trans and several of the other products, they had higher anterior–posterior shear forces acting on the lumbar spine, placed high physical demand on key joints, and had high applied forces.

On comparison of the performance of air-assisted devices with that of the traditional methods, some interesting findings were observed. Although AIRPAL and HoverMatt both had low mean forces (191 and 192 N, respectively), the spinal compression at L5/S1 was greater with the AIRPAL (2,283 N) than with a disposable plastic bag (1,838 N) or a draw sheet (1,562 N). Postural differences during the transfers explain this. Although compressive spinal forces were higher with the AIRPAL, anterior–posterior shear forces were higher with a disposable plastic bag. Although not the most efficacious, the air-assisted devices did offer other benefits, including superior support for patients with conditions such as decubitus ulcers (pressure sores) and patients recovering from surgery.

Extendable handles were beneficial in reducing flexion at the lumbar spine, thereby minimizing spinal load, which is calculated as the sum of compressive, anterior–posterior, and lateral forces acting on the spine. The benefit of extended pull straps was clearly illustrated in the spinal force results with the Maxi Trans versus the Flat Sheet Set (Fig. 4). Compression of the spine at L5/S1 was lower with the Flat Sheet Set due to the availability of pull straps, which substantially improved the investigator’s posture. Lateral shear force on the spine may be reduced by having health care professionals alter their stance during the transfer, as seen when the Flat Sheet Set was compared with the Lateral Transfer Aid (Fig. 4). The latter device had a greater lateral shear force (27 N) due to a single pull strap, which resulted in twisting of the torso. Conversely, the Flat Sheet Set had two straps, which minimized rotation of the torso.

CONCLUSION

The findings of this study can aid occupational health and safety clinicians and hospital-based caregivers in the identification and selection of appropriate devices to be used during the lateral transfer of patients. Such devices improve patient safety during transfer and decrease the risk of back injury for caregivers.

The biomechanical results of this study indicate that using a draw sheet or a disposable plastic bag poses a high risk for low back injuries to caregivers. Of the devices tested, the Lateral Transfer Aid was the best option, followed closely by the Flat Sheet Set.

Key factors that affect spinal loading include:
- Caregiver’s stance and posture.
- Friction-reducing properties of the device.
- Relative height of transfer surfaces.
- Extendable handles or pull straps, the number used, and their location.
- Angle of pull.
- Patient weight.

Extended handles or pull straps seem to be most significant because they reduce flexion of the spine. Although these devices are beneficial during the lateral transfer of patients, they are not without limitations. Due to projected higher spinal forces, mechanical, rather than manual, aids may be warranted in situations involving bariatric patients. Caregivers should maximize the benefits of these technologies while respecting the limitations of manual friction-reducing devices to ensure the safety of themselves and their patients. Further research should be conducted in long-term care and nursing home settings to evaluate practical implications and organizational issues such as cost–benefit ratios, time management, storage, infection control, ease of use, and acceptance by caregivers.

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REFERENCES


