Safety Research

The Effects of Restricting Space

A study involving a patient-handling task

By Grady T. Holman, Troy Blackburn and S. Maghsoodloo

FOR MORE THAN 5 YEARS, nurses and healthcare workers have had the second highest injury and severity rates among listed professions in the U.S. (BLS, 2005). Consequently, many nurses may consider alternate careers, decreasing the average career life span of practicing nurses during this period.

One reason for the short career span of nurses may be the high incidence of severe injuries, especially to the lower back. The latest BLS (2005) data note that in 2003 42% of all nursing injuries were back related. Some experts estimate that most of the injuries were attributed to patient transfer tasks (Evanoff, Wolfe, Aton, et al., 2003; Nelson, Matz, Chen, et al., 2006).

For the past 20 years, much of the back-injury-related research has focused on techniques and methods to reduce lower back injury. In the past 10 years, devices have been developed for patient handling, a primary contributor to lower back injury (Marras, 2005; Nelson, et al., 2006).

A review of literature found notable studies in modeling nurses' perceptions of on-the-job influences (Hignett & Richardson, 1995); analysis of mechanical devices such as slings (Elford, Straker & Strauss, 2000); long-term ergonomic program evaluation (Owen, Keene & Olson, 2002); and biomechanical analysis of manual handling techniques (Schibye, Hansen, Hye-Knudsen, et al., 2003).

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The strength of these studies is that they approach the low back issue from different perspectives. The weakness is that none consider the task environment and/or physical restrictions (i.e., space) orconditions affecting the patient transfer task.

The research presented here is the third part of a three-part, 3-year study investigating the physical restrictions and conditions affecting patient handling. Part one was a descriptive study using literature and focus group information to define and map the interaction of known factors affecting patient handling (Holman, 2006). Part two used a survey to examine the personal health of nurses and determined what environmental factors have the most influence on a patient transfer based on the opinions of working nurses.

Part three was a biomechanical study based on findings from parts one and two, which dictated that the worst location to perform a transfer was in the bathroom (Nelson, 2005) while transferring a patient from the floor to toilet given that a fall had occurred in the main bathroom or shower. The rationale for this finding was that space was restricted and/or congested, thus not allowing for team lifts or use of patient-handling equipment (a common problem).

Related specific physical and/or psychological stressors identified by nurses were: 1) lowering or lifting heavy loads; 2) pushing or pulling heavy loads; 3) twisting of the back; 4) bending forward/toward work (stooped posture); 5) carrying heavy loads; 6) highly repetitive motion; and 7) pace or duration. The goal of this study was to quantify the effects of space restriction on a patient transfer.

Study Methodology

The research team recognized that for this study to succeed the setting had to replicate a "true to life" hospital bathroom environment. To accomplish this, the team constructed a mock-up bathroom in a biomechanics laboratory. Attention to detail was high to ensure the fidelity of the recreated environment. Only participant safety was considered more important during the execution of the study.

Biomechanics Laboratory

The biomechanics laboratory is equipped with a five-camera PEAK motion capture system (Motus 8.5), an AMTI OR6-7 1000 forceplate, four lumbar motion monitors and a pressure pad system. General lab specifications include variable level remote lighting, synchronized time encoding, anti-glare flooring, blackout curtains and 80 sq ft of capture area. For this study, only the five-camera motion capture system with integrated forceplate sampling at 60 Hz would be utilized.

Equipment

To expedite the motion capture process and to standardize clothing and footwear between subjects, participants wore full-body motion capture suits with a black hairnet and black latex gloves. Footwear included form-fitting black diving boots with polymer treaded soles to ensure firm, stable footing (i.e., no slipping). For tracking, a series of 30 markers were placed on the subjects using anthropometric landmarks as guides, thus allowing for a full body spatial model representation (Daynard, Yassi, Cooper, et al., 2001). Figure 1 presents a general diagram of marker placements and the subsequent spatial model rendered.

Testing Apparatus

The testing apparatus was constructed from dimensions provided by a collaborating Missouri hospital. The objective was to emulate a private room bath fitted with standard hardware, including a toilet measuring 16 in. in height, and three handrails, one for each wall. The unique feature of this bathroom was that it was made of Plexiglas to allow for motion capture through the walls. The walls were made of ⅜-in. Plexiglas with clarity of 0.92 with clear Lexan angle strips to reinforce the corners. Both upper and lower track supports were used to ensure structural stability, and no door was used as though a pocket door was installed.

The design was modular, allowing for the bathroom to be assembled or disassembled in 25 minutes. This allowed for testing of restricted versus unrestricted space for the same subject. Photos 1 and 2 show the bathroom apparatus in the biomechanical laboratory.

Other apparatus employed included a dummy to simulate a human. The decision to use a transfer dummy instead of a live person was based on several criteria. First, the introduction of uncontrollable variables associated with a person, such as level of patient assistance, was seen as unnecessary since the team was evaluating the effect of restricted space not patient cooperation (which can affect a transfer either positively or negatively). Second, participant availability could have become problematic and an uncontrollable factor in test scheduling. Third, the conditions for which each trial was performed must be repeatable. Finally, based on the activity, safety issues for the person being transferred were viewed as unacceptable.

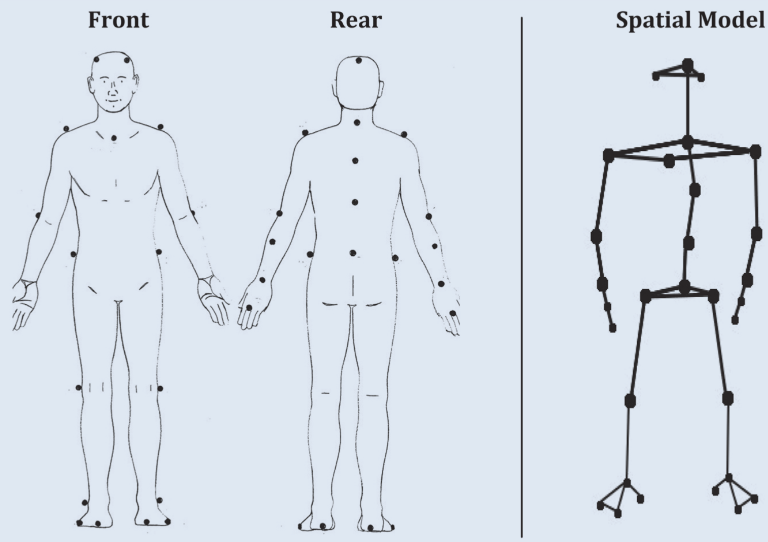
The grappling dummy used was designed to be durable with a metal rod and cable reinforced frame. It was first constructed using a human mold, then sculpted to give representative range of motion in the joints. In addition, its outer shell is a lifelike polymer skin that gives it a "natural" feel.

Initial weight was 60 lb, but the dummy's design allows for it to be load-weighted by body segment to a desired weight based on cadaver studies (Kroemer, Kroemer & Kroemer-Elbert, 1997). The dummy was weighted to a target weight of 110 lb with the final weight being 113.7 lb. The target weight was considered to be representative of a fifth percentile female based on a combination of multiple anthropometric tables examining body weight by nationality (Kroemer, et al., 1997; Roebuck, 1995) and military tables (Gordon, Churchill, Clauser, et al., 1989). The use of this weight was viewed by the committee as both a safety precaution and testing under best-case scenario. Figure 2 illustrates the dummy's weight distribution by body segment.

A limitation with the dummy was that it was 71

Figure 1

Tracking Marker Transitioning From Subject to Spatial Model



Photos 1 and 2: The biomechanics laboratory and the mock-up bathroom apparatus.

Abstract: *Nurses constitute the largest proportion of the healthcare industry's workforce. Understanding job factors that impact their health and subsequent working life is essential. In general industry, work is often performed where space is restricted. Understanding how this factor changes the demand on a worker is key to maintaining both a safe work environment and an efficient workplace. This study evaluated the influence of space restriction on patient transfer.*

The grappling dummy used was designed to be durable. It was first constructed using a human mold, then sculpted to give representative range of motion in the joints. In addition, its outer shell is a lifelike polymer skin that gives it a "natural" feel.

in. tall, roughly 5 in. taller than preferred, and with the stature of a medium-build male, rather than a small female. However, these characteristics were standardized across subjects and conditions, thus the influence on the results was negligible compared to using a live subject, whose ranges of height, weight and anthropometric dimensions would add considerably more variation to the study.

Subjects

The university's Institutional Review Board for Human Subjects in Research approved the study prior to subject recruitment. Based on the statistical model, *a priori* power analysis showed 10 licensed nurses were needed for this study to obtain a power of at least 0.80. All participants were compensated. Potential subjects had to clear both a telephone prescreen and physical activity questionnaire before participating.

The screening criteria were as follows:

•Participants must have been licensed for at least 1 year with the Alabama Board of Nursing as a licensed practical nurse, which was set as the minimum degree for participation.

•Participants must have been currently employed for a period of greater than 3 months as a nurse with patient handling duties composing at least 15% of their daily regimen.

•Participants must have been between ages 20 and 50 with a body mass index of less than 30.0.

•Participants must have been in good health with no current injuries or illnesses.

•Participants must have use of and full range of motion in joints and extremities.

•Participants could not have been on medications that could affect mood, thought process, postural stability, physical strength or impair judgment.

•Participants must verbally indicate, then demonstrate that they can successfully transfer the dummy.

Statistical Model

The statistical model for this portion of the study was a randomized complete block with a replicate. The independent measure was restricted versus unrestricted space and the mechanism for testing was determined to be the floor-to-toilet transfer, which the surveyed nurses identified as the worst transfer to perform. Simple definitions of space restriction are:

•Unrestricted space. Only the toilet and the dummy are present in an open floor space allowing for maximum access to the dummy for transfer. The dummy position/posture is standardized between all transfers, both restricted and unrestricted.

•Restricted space. The space is representative of real life, with walls, handrails, doorway access and a toilet. The dummy is laying/placed in a standardized position.

Dependent measures were determined based on four categories:

1) **Time.** Time to complete a task is an accurate indicator of the effect sustained by a person's body relative to conditions. Time is also a strong indicator of task efficiency and/or performance. Time intervals were measured via frame rate or time encoding.

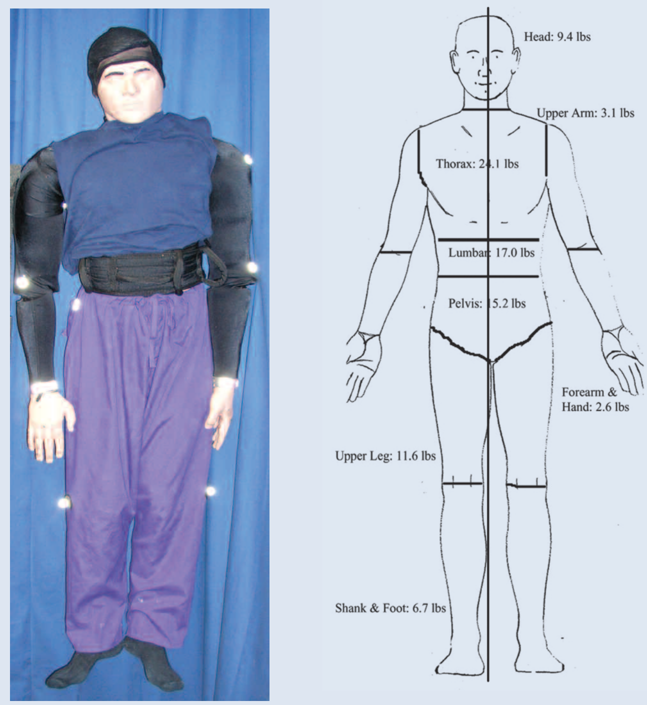
2) **Posture.** The posture that a person's body assumes while completing a given task is normally directly correlated to the requirements of the task and the immediate surroundings (Chung, Lee & Kee, 2003). Therefore, two methods of postural evaluation were needed to accurately depict the effects of restricting space:

•Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000). This tool was selected due to its ability to account for most joint angles and body positions required when transferring a patient (Chung, et al., 2003). Its ability to provide a single composite score for each individual video frame captured made it ideal for use in a biomechanical laboratory setting. Additionally, this application eliminates the two most common causes of error previously experienced when performing evaluations in workplace settings: lack of a sufficient number of samples to gain validity and single per-

Figure 2

Weight Distribution by Body Segment

Patient transfer dummy with distribution of load-weight by body segment.



spective user error in which joint angles are inaccurately determined.

•Ovako Working Analysis System (OWAS) (Karhu, Kansi & Kuorinka, 1977). This well-known classification tool has been used extensively for evaluation of nurses' working postures (Engels, Landeweerd & Kant, 1994; Lee & Chiou, 1995). Its limitation is that its sensitivity only allows for bulk classification of samples taken from a single event. However, this should be adequate when coupled with the REBA analysis.

3) **Joint moment.** In light of abundant literature relating to the prevalence of back injuries in nursing (Hignett, Fray, Rossi, et al., 2007; Nelson, et al., 2006; Waters, Collins, Galinsky, et al., 2006), it is reasonable to include an estimated measure of moment about the L5 vertebra in this study. For this purpose, the revised Utah Back Compressive Force Equation was used.

•Utah Back Compressive Force Equation (Loertscher, Merryweather & Bloswick, 2006). This gender-specific equation predicts the peak moment about the L5 given specific body angles and the weight of the load being transferred. Body angles used in the equation are specific and were measured based on anatomical landmarks, coordinate axis or reference planes. Initial testing of the equation showed an $r^2 = 0.96$ and $r^2 = 0.95$, for males and females, repetitively (Loertscher, et al.).

For the current study, the Utah equation was utilized both statically and dynamically. The static equation had a constant load, which was introduced into the system as a constant. The constant load was determined using a push/pull dynamometer prior to laboratory testing. The dynamic equation received the calculated hand moment directly from the forceplate, which allowed for direct sampling and a second load estimate for analysis. The hand moment was calculated using upward inverse dynamics from the resulting forceplate moment less the mass of the subject, yielding a resulting moment related to only the dummy's mass.

4) **User perception.** User perception and perceived ratings were important parts of this research. The objectives were to understand what the subjects were feeling (e.g., stress/fatigue/difficulty) (Chung, et al., 2003), and whether they felt the testing scenario corresponded to real-world environments and situations (Hignett, et al., 2007).

An underlying premise of this study was that working nurses were involved in each aspect of the study design based on information provided in earlier studies. Therefore, surveying user perception was a critical step in the overall evaluation of the study. Not doing so would leave out an important step in the validation of this research. Thus, surveys were given for each individual trial after completion, then for the study after all trials were complete. Each survey consisted of seven questions using a six-point Borg scale with verbal anchors. Information collected related to transfer planning, execution, difficulty, equipment and resemblance to real life.

Procedures

Testing procedures were defined in detail through pilot studies prior to testing. They were designed with three objectives in mind: participant safety, study repeatability and standardization of data collection through use of protocol. Therefore, the following activities were undertaken in either the introduction or testing phases of this study:

Familiarization. After prescreening was completed and the IRB consent signed, participants were asked to watch a 10-minute video summarizing the research to date and finishing with the purpose of the laboratory study in which they were to participate. Following the video, each participant was required to examine the bathroom's handrails, toilet position and sturdiness. They were then asked to perform a trial transfer to gain perspective of the dummy's weight and motion when being moved. Finally, they were instructed on what to do in the event of interruption, marker loss or if something "just did not feel right."

The goal of these procedures was to ensure that all participants received the same instructions and to reduce the learning curve relative to transferring a dummy instead of a human. However, nurses were not instructed how to perform the transfer, as this is a function of the individual's training and experience and, therefore, procedurally, a best-case scenario for the nurse.

Recovery time. It was noted during prior pilot testing that while a patient transfer is a relatively brief task, consisting of only seconds, a patient transfer requires a high percentage of the maximum voluntary contraction (MVC) capability of most of the active muscles used due to the weight being transferred. Therefore, it was determined a minimum recovery period of 5 minutes would be required between transfers to minimize fatigue (Hebestreit, Mimura & Bar-or, 1993; Holbein & Chaffin, 1997; Burnley, Doust & Jones, 2006).

Patient transfer belt. A common patient-handling device recommended by most hospital programs and nursing professionals is a patient transfer belt, sometimes called a gait belt (Menzel, Brooks, Bernard, et al., 2004; Nelson, et al., 2006). For most circumstances where normal lift/transfer equipment cannot be used, these belts are recommended. They are described as easy to use, allowing the user handles to better maintain grip and leverage during the transfer process. Thus, the research team decided in the interest of participant safety to use a patient transfer belt during the laboratory trials. In addition, the belts provided a standardized handhold that proved to be beneficial in testing.

Best-case scenario. An item not controlled in the study was the participants' approach and/or method to the transfer. Since no standardized transfer procedure is consistently taught to all nurses in every nursing school, the research team decided, in light of the subject pool being experienced nurses, to allow participants to accomplish the transfer by the method they knew best. This reasoning was sup-

User perceptions and perceived ratings were important to understand what the subjects were feeling and whether they felt the testing scenario corresponded to the real world.

Table 1

OWAS Distribution by Back Position

OWAS distribution by back position with percentage of time posture was loaded per category for the transfer event.

Measure	Category: 1000 "back straight"		Category: 2000 "back bent"		Category: 3000 "back twisted"		Category: 4000 "back twisted and bent"	
	Event (%)	Loaded (%)	Event (%)	Loaded (%)	Event (%)	Loaded (%)	Event (%)	Loaded (%)
Unrestricted	25.10%	22.06%	51.31%	50.59%	8.30%	9.84%	15.30%	48.26%
Restricted	25.40%	33.20%	56.53%	45.70%	5.88%	12.64%	12.19%	32.68%
Difference	0.30%	11.14%	5.22%	4.89%	2.41%	2.80%	3.11%	15.58%

Table 2

Utah Back Compressive Force Equation's Average Peak Estimation

Utah Back Compressive Force Equation's average peak estimation of the L5 moment for the restricted and unrestricted patient transfers using both static and dynamic loading.

Measure	Utah back compressive force estimation		
	Static load (N)	Dynamic load (N)	Average estimation (N)
Unrestricted Transfer	3094	2661	2878
Restricted Transfer	3100	2662	2881

OWAS is a well-known classification tool that has been used extensively for evaluation of nurses' working postures. The Utah equation is a gender-specific tool that predicts the peak moment about the L5 given specific body angles and the weight of the load being transferred.

ported by the logic that the study was assessing the effects of restricting space on the task based on the person, not the procedure.

Consequently, the goal was to permit each participant to use the method most beneficial to them, while still accomplishing the task (i.e., the best-case scenario for the nurse). Additionally, from a statistical standpoint, allowing subjects to use their preferred lifting technique will improve within-subject reliability. As the design of the study with respect to space restriction is completely within-subjects, this will improve the internal and external validity.

User Perception

Evaluation of testing status, procedures and environment were conducted throughout to monitor/gauge the study's validity and participant's safety. As noted, participants completed a questionnaire after each transfer performed, then again after all transfers were complete.

Study Results

Testing was performed from March 2007 to June 2007. During that time, more than 100 potential subjects were contacted and 14 were invited to the laboratory. Of the 14, 10 cleared all screening protocols and were allowed to participate. The other four potential participants did not clear the screening process for various reasons, including 1) current position does not involve transferring adult patients; 2) could not physically perform the transfers; and 3) a previous back injury that was "flaring up from time to time" (thus, in the candidate's best interest to not participate).

Subject testing time from entry into the biomechanics laboratory until exit was approximately 4 hours.

Analysis of participants' body's positioning, accelerations and velocities relative to the subjects transfer technique showed three distinct activities/stages in the floor-to-toilet transfer task.

•Stage 1. This was the positioning stage. A participant would enter the bathroom/testing area and position himself/herself in preparation to perform the transfer. No loading occurred in this stage.

•Stage 2. This was the vertical lift portion of the transfer. It began immediately after the frame/point where the participant gained control of the transfer belt handles and the wrist marker initiated a positive z-axis (i.e., vertical, increase/displacement in position).

•Stage 3. This was the horizontal repositioning portion of the transfer. It began immediately after the frame/point where the ratio of z-axis displacement divided by the resultant of the x and y axis displacement became less than one. Stage three continued until the dummy was stationary on the toilet with no load present on the hands due its weight.

As testing proceeded through each stage, body posture and force were continuously captured relevant to time by the lab's various data acquisition systems (Daynard, et al., 2001; Zhang & Chaffin, 1999; Zhang, Nussbaum & Chaffin, 2000). Statistical tests conducted on the resulting data included balanced ANOVA and paired t-test. Tests were performed at a significance level of 0.05. In addition to testing each stage, the entire transfer (i.e., the event) and loading stages (i.e., combining stages 2 and 3) were tested. Detailed results for each of the four dependent measures are explained in the following sections.

Time

The difference in the average time required for lifting in unrestricted as opposed to restricted space was found to be significant using a paired t-test for both the vertical lifting stage ($p = .036$) and the combined stages 2 and 3 ($p = .049$). For the stage 2 vertical lift, time increased 28.20% from 2.357 seconds to 3.022 seconds, when the space was restricted. When examining the combination of the two stages, time was found to increase 14.02% from 5.313 seconds to 6.058 seconds when space was restricted.

Table 3

Participating Nurses Average Responses

Participating nurses average responses to "user perception" questions.

Trial/ study	Question	Yes (%)	Borg scale response (out of 6)		
			Unrestricted trials	Restricted trials	All trials
Trial	I believe the transfer was correctly performed.	68%	4.1	3.8	3.9
Trial	I performed the transfer as I planned.	73%	4.4	4.2	4.3
Trial	The transfer was difficult.	73%	4.1	4.6	4.4
Trial	The transfer was representative real life.	80%	3.9	4.3	4.1
Trial	The transfer was more difficult in real life.	90%	4.3	3.9	4.1
Trial	The transfer took more time in real life.	30%	2.9	2.9	2.9
Trial	The transfer belt was beneficial in perform the transfer.	80%	5.0	4.7	4.9
Study	When space is restricted, transfers take more time.	100%	---	---	5.4
Study	When space is restricted, transfers are more difficult.	100%	---	---	5.3
Study	When space is restricted, transfers place more stress on the body.	90%	---	---	4.8
Study	When space is restricted, transfers place more stress on the back.	90%	---	---	5.0
Study	This study was representative of the real world.	90%	---	---	4.9

Posture

Postural differences were found to be significant in one of the two postural analysis tools used when comparing restricted to unrestricted transfers. REBA showed significant differences using a paired t-test to analyze the horizontal repositioning (p = .002), stage 3. During the horizontal repositioning of the dummy, the REBA composite score decreased 19.70% from 5.33 to 4.28 when the space was restricted. Hence, REBA scoring is the lower the score, the better the posture. However, both scores are considered to be a "medium" risk factor, where "action was necessary" to reduce the risk level is recommended.

Testing using OWAS did not yield any statistically significant results. However, it was used in a slightly different way in this experiment. The normal application of OWAS is to classify position of the entire body. However, this team's focus was limited to evaluation of the back. Therefore, only the distributions of the thousand category ranges (i.e., back position) and the percentage of time the task was loaded during that category were charted and analyzed.

While there were no significant results, the charting provided insight into the manipulation and loading of the spine required to complete the patient transfer. Table 1 shows the average distribution of OWAS classifications, by restriction, for a patient transfer from the floor to toilet.

Joint Moment

Peak moment about the L5 vertebra of the spine was not found to be significantly different based on restriction in the floor-to-toilet transfer. However, the average peak load was approximately 2,880 N of compressive stress on average, which is substantial considering the "gold standard" is to not exceed 3,400 N (Marras, 2005). This conclusion is also based on the fact that this study was designed to be the best-case scenario with the transfer dummy weighted at the level of a fifth percentile female. Table 2 shows the Utah Back Compressive Force Equation's average peak estimated moment about the L5 vertebra for both static and dynamic loads.

Additionally, in three individual trials, shock/spring loading of the transfer occurred when the participant generated momentum prior to the beginning of the vertical lift (i.e., jerking motion) (Commissaris & Toussaint, 1997). In at least one case, the moment predicted about the L5 vertebra was greater than two times the gold standard, which has the potential to cause an acute low back injury. However, this result is only preliminary due to sample size not having sufficient statistical power.

User Perception

Participants' opinions were collected via survey after each trial, then again after all trials were completed. Results for individual trials showed that only 68% of the time did participants believe that they performed the transfer correctly during the trial and 73% of the time did they believe the transfer was performed the way they planned to do it. Further, 73% of the time they believed that the transfer was difficult, but 90% of the time they still believed real-life transfers were more difficult than the trials. Time to complete the task was considered to be consistent with real life, receiving 2.9 out of 6.0 on a scale using the verbal anchors "took more time in real life" and "took less time in real life." Overall, it was believed that 80% of trials were realistic compared to the real world with a combined effectiveness rating of 4.1 out of 6.0.

For the study, 90% believed both body and back stress increased when space was restricted. Additionally, 100% of participating nurses stated they believed restricting the space made the transfer more costly in terms of time to complete and difficulty. Other results showed that 90% of participants believed the study was representative of real life,

Of the nurses who participated, 100% stated that restricting the space made the transfer more costly in terms of time to complete and more difficult. In addition, 9 of 10 participants felt the overall study was a good representation of real life.

giving it an overall effectiveness rating of 4.9 out of 6.0. Table 3 (p. 43) gives the average ratings and responses to each question.

Discussion

The goal of this study was to evaluate the effects of restricted space on a patient transfer that involved moving a patient from the floor to a toilet while in the main bathroom or shower. Responses examined included the time to complete the lift, body posture and joint moment about the L5 vertebra.

Of these, time was the most affected, showing an increase of 28.20% for the vertical lifting stage and a 14.02% increase during both vertical and horizontal loaded stages combined. This was particularly important since these are the two stages of the transfer that the nurse was lifting/carrying a load. Hence, the obvious implication is that working in a restricted space such as a bathroom substantially increases the time during which the person (nurse) executing the transfer is exposed to an associated high-risk posture while lifting/carrying a heavy load.

For posture, results showed that the REBA posture score improved slightly overall for the horizontal repositioning when space was restricted. However, it is believed that this improvement was due to the restriction limiting the ranges of motion of the participant's body. Further, neither score for restricted nor unrestricted transfers was found to be below a medium risk level, which is considered to be an "action necessary" level for REBA. Additionally, both the average restricted and unrestricted transfer scores for the vertical lift stage were at the high risk level, an "action necessary soon" level. Figure 3 illustrates the average REBA postural score by time for both restricted and unrestricted transfers with defined risk levels.

REBA is able to account for most joint angles and body positions required when transferring a patient. Its ability to provide a single composite score for each individual video frame captured made it ideal for use in a biomechanical laboratory setting.

The final physical component based on task time, posture, and force was a measure of the stress on the low back. Since back injuries were the most prevalent injury seen among nurses in statistical reports and literature (BLS, 2005), the moment about the L5 vertebra was evaluated. However, no significant difference in back moment was found when comparing the restricted and unrestricted transfers, but this was not the only goal. The goal was to determine the moment under the best-case scenario, then analyze for differences.

The average combined peak moment at the L5 was estimated by the Utah Back Compressive Force Equation at approximately 2,880 N. This level of moment is considered to be substantial, since the transfer weight was only 113.7 lb. Since most American males weigh at least 1.5 times this amount, it is reasonable to conceive that the 3,400 N limit would be exceeded in a typical patient transfer. In addition, this moment does not include estimations of spring/shock loading, which could help a nurse perform a transfer but could more than double the normal stress/moment on the low back.

An overall assessment for the physical characteristics was performed by examining the postural results in stages over time for both restricted and unrestricted transfers. The purpose was to examine events such as the participant's posture when loading was initiated. In Figure 3, vertical event lines are used to show the beginning and ending of each transfer stage.

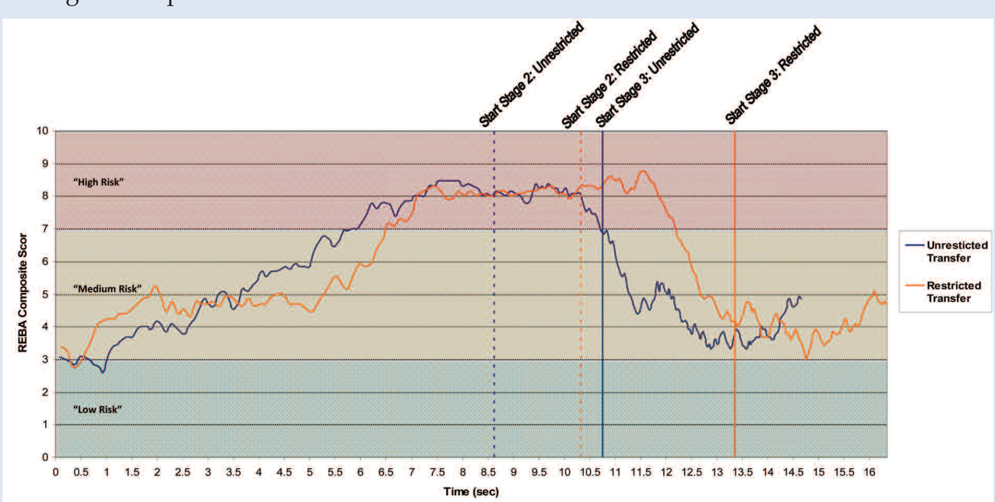
Analysis of this graph shows initial loading (i.e., stage 2 vertical lift) begins with the participant in the worst posture given the event. For the unrestricted transfer, the participant quickly transitions from the stage 2 vertical lift into the stage 3 horizontal repositioning before resuming a more upright posture. This event can be seen by examining the intersection of the start stage 3 unrestricted event line and the unrestricted transfer, which is at the top of the declining slope.

Further, this gives insight into why time was significant. Specifically, if the participants were not allowed (due to space or other restriction) to transition to the horizontal repositioning as they normally would before being required to come to a complete upright position, then additional time would be required to complete the stage 2 vertical lift, accounting for the significant time difference. This comparison can be seen visually in the figure by comparing the slope intersection point of "start stage 3" event lines with the corresponding REBA line plot. However,

Figure 3

REBA Postural Score

Average REBA postural score for both restricted and unrestricted transfers.



given the estimated average moment present during the loaded stages, it is believed that neither floor-to-toilet transfer tested here would be capable of producing an L5 moment less than the 3,400 N limit, while transferring a person of average (50% percentile) height and weight.

Finally, user perception of this study was found to be positive. In general, participants believed time to perform the task was consistent with real life. However, laboratory simulations were still believed to be less difficult due to the weight transferred, a comment stated by most participants during the study debriefing. The transfer belt was viewed as beneficial by 9 of 10 participants when performing the floor-to-toilet transfer, but 90% believed both body and back stress increased when space was restricted.

Additionally, as noted, 100% of participating nurses stated that restricting the space made the transfer more costly in terms of time to complete and more difficult. However, results only show that time to complete the task increased, but difficulty remained statistically constant. Thus, the true reasoning for this response is unknown, but speculation suggests that it could possibly be attributed to psychosocial factors related to nursing or that it is a conditioned response based on education and/or experience. Also as noted, 80% found each individual trial to be realistic. Further, 9 of 10 participants felt the overall study was a good representation of real life, giving an effectiveness rating of 4.9 out of 6.0.

Potential Limitations

Restriction in workspace is normally categorized as an environmental situation or condition that affects work being performed both from a worker safety and efficiency perspective. While this study focused on the effects of restricting space when performing a patient transfer, many other industries have similar tasks for which restricted, confined or congested space is a known problem.

However, no published literature was found for a comparison or basis that attempted to quantify this condition. This absence in literature is likely due to the large number of variables that must be controlled in order to get valid, reliable research data. Some of the variables are spring/shock loading of the transfer, directional forces generated from brushing, hitting or leaning on an obstruction such as a wall or handrail, unilateral and/or unbalanced lifting, feet/foot not being completely on the forceplate, etc.

For this study, efforts were made to design and build a high-fidelity representation of an actual hospital bathroom. Protocols and procedures were developed to ensure uniform instruction in order to minimize the number of confounding variables. However, as with all laboratory studies, there is a limit to what can be recreated from real life.

A limitation of the study was that a weighted dummy was used for transfer and not an actual person. The dummy met desired criteria including skin texture, weight, weight distribution and proper joint movement and range. However, given the weight, the dummy was taller than desired, and its stature was that of a medium-build male.

Another limitation was based on experience from pilot trials. There was no way to ensure participants would keep their foot/feet completely on the forceplate for the duration of a transfer. Therefore, the recently published revised Utah Back Compressive Force Equation was used to estimate the peak moment about the L5. The research team believed, based on the literature, the equation would provide accurate moment estimates for the study, as well as, allow for an external validation of the equation itself. However, the choice to use the equation meant losing the ability to measure dynamic spring/shock loading, since it is a static predictor.

Conclusion

Methods that nurses in Alabama use to handle patients are substantially influenced by several factors, and these factors facilitate either positive or negative perceptions of job duties/tasks. One negative perception is that the floor-to-toilet transfer is the most difficult of the patient-handling transfers due to the conditions and restrictions that dictate the task. Consequently, they also regard the location of the transfer as important, perceiving bathrooms as the most undesirable area for a transfer.

Despite these negative perceptions, the study participants were asked to perform a series of floor-to-toilet transfers in order to quantify the effects of restricted space. Results showed that restricting the space, as it occurs in a hospital environment, does not place any significant additional moment on the low back. It does, however, alter how the nurse moves when transferring a patient, thus significantly increasing the transfer time during the loaded portions of the transfer.

The time needed for a restricted transfer increased by an average of 14% when compared to the unrestricted. In this context, this is 14% more time in a medium- to high- risk postural position for which the best-case scenario estimates the moment on the low back at an average of 2,880 N. Simply put, space restriction increases exposure to a high-risk event known to cause injury in literature. Hence, the negative perceptions nurses have of this transfer seem to be justified.

Information presented here comprises only one set of variables relating to one transfer performed in one location. Additional studies of this type are needed before valid multilevel recommendations can be made. Results of this study suggest that few real-world floor-to-toilet transfers would produce low back stress (i.e., a peak L5 moment, less than the 3,400 N limit). Therefore, mechanical assistance should be required for this transfer.

Unfortunately, this is a statement made all too often, since it is both understood and accepted among nurses, administration and professionals that patient handling is a complex problem that will not be solved simply by one catch-all solution. Advances will only occur when the problem is defined from

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the perspective of those performing the job. Thus, it is up to administrators, nurses, healthcare professionals and engineers to contribute time and knowledge to quantify factors for integration into models and equipment designs to provide more options in patient transfer situations (Nelson, 2003).

Future Research

This study has shown that the conditions and restrictions of the job environment play a large role in the selection of methods nurses use to perform patient-handling tasks. The results quantified the effects of restricting space on one of the two transfers regularly performed in a hospital bathroom. This suggests that if the second transfer could be quantified in future research, an overall risk factor could be developed based on the unrestricted transfer, which could ultimately lead to understanding how risk changes when work areas are increased or decreased. ■

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