FEATURE ARTICLE
Research

Preventing Nursing Back Injuries

Redesigning Patient Handling Tasks

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Abstract

The researchers identified nine patient handling tasks that place nursing staff at high risk for musculoskeletal injuries. An expert panel redesigned these tasks using new patient handling technologies and work practice controls. The key objective was to evaluate the biomechanical benefit of the redesigned tasks. Back and shoulder muscle activity, forces on the lumbar spine, shoulder joint moments, and perceived comfort were evaluated in a laboratory setting. Using objective and subjective data, 63 participants who performed the redesigned tasks were compared with 71 participants who used standard procedures. Objective data revealed significant improvement in five of the redesigned tasks, while staff subjectively rated four of the redesigned tasks as significantly improved. Nursing tasks can be redesigned to improve caregiver and patient safety using new patient handling technologies and work practice controls. Further study is needed to redesign other high risk tasks to promote safer work environments.

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Nursing personnel continue to have one of the highest job related injury rates of any occupation (Leighton, 1995; U.S. Department of Labor, 1999; U.S. Department of Labor, 2001). The problem is particularly severe in nursing homes, where the incidence rate of non-fatal occupational injuries in 2001 was 13.5 cases per 100 full time workers, the third highest rate among industries with 100,000 or more injuries and illnesses. The rate for hospitals (8.8 per 100 full time workers) was fourth highest (U.S. Department of Labor, 2002).

Efforts to significantly decrease the risks related to providing patient care have been largely unsuccessful during the past two decades. The four factors that most contribute to musculoskeletal injuries in nursing are:

- Characteristics of nursing professional doing lifting.
- Load lifted (i.e., patient).
- Work environment.
- Job tasks (Nelson, 1997).

Several strategies have been implemented to prevent musculoskeletal injuries in nursing. Those most frequently cited include education and training in body mechanics, use of standard mechanical lifting aids and equipment, and alterations in lifting techniques. Unfortunately, none of these strategies has been successful in isolation (Daltroy, 1997; Girling, 1988; Harper, 1987; Nelson, 1997). However, Ronald (2002) found a reduction in musculoskeletal injuries when using the next generation of equipment—overhead ceiling lifts. Additional preventive interventions are critically needed to control the hazards and economic burdens associated with performing patient handling and movement tasks (Genaidy, 1994).

BACKGROUND

The first step in redesigning high risk nursing tasks is to conduct a biomechanical evaluation of each task. The methods for collecting data have significantly improved over time. The few biomechanical evaluations in nursing practice conducted prior to the initiation of this study used data collection methods progressing from observation and still photography (Dehlin, 1975; St. Vincent, 1987) to two dimensional videotaping (Garg, 1992a; Garg, 1992b; Owen, 1991; Takala, 1987). The more a task is simplified to facilitate analysis, the more information is lost concerning the true stressors.

To date, biomechanical assessments of the spine have used static symmetrical sagittal plane stick figures to represent body postures. Such an approach has limited value in replicating and determining the true biomechanical stressors while performing a specific task. For example, because back injuries are cumulative in nature, subtle damaging motions such as twisting while lifting can have a dramatic, injury producing effect on the human musculoskeletal system over time.

To ensure capture of these subtle motions and to solve many of the limitations of previous biomechanical assessments of nursing practice, this study used the newest technology—a dynamic three dimensional (3-D) data collection and analysis system. The intent was this assessment technique would help to redefine the state of the art by introducing a powerful new tool for analyzing high risk patient care tasks in nursing.

The National Institute for Occupational Safety and Health [NIOSH] (Waters, 1993) provided the scientific basis for safe practices for lifting and handling in the United States by providing an equation setting the maximum recommended weight limit at 51 pounds under ideal conditions. It applies to virtually all men and 75% of women. Studies applying the NIOSH lifting guidelines to nursing practice found the estimates of compressive force to the L5/S1 disc were all above the limit permitted as safe (Owen, 1991; Nelson, 1996).

For nursing care, a number of the standard conditions of the NIOSH formula do not apply. For example, the trunk is rotated during several tasks, and spatial restrictions are often present in the health care setting because of crowded environments. Further, that the load (i.e., patient) may oppose or make unexpected movements is not taken into account. Therefore, the NIOSH lifting guidelines are not directly applicable to moving patients.

Experts do not agree on which lifting techniques are optimal in nursing (Owen, 1990; Venning, 1988). Owen (1985) identified discrepancies among experts in identifying effective lifting techniques. Recommended lifting techniques have often failed to consider one or more of the factors noted in the Sidebar.

This study adds to the body of knowledge in safe patient handling and movement in four significant ways:

- Inclusion of nursing tasks involving frequent bending and sustained awkward positions in addition to traditional lifting tasks.
- Evaluation and redesign of several “high risk” nursing tasks not previously studied.
- Expansion of redesign options beyond equipment use to include changes in postural techniques.
- Using newly developed 3-D electromagnetic tracking system to capture dynamic whole body postural data on the caregiver.

METHODS

Goal and Purpose

The goal of this study was to identify scientifically based patient handling and movement strategies reducing

Reasons Lifting Techniques May Fail

- Although mechanical loading associated with lifting primarily involves the lower back, other body parts, particularly the knees and the shoulders, are vulnerable and may be injured as a result of repeatedly lifting heavy loads. This is known as “transferring the overload to multiple other body parts” (Gagnon, 1987).
- Balance was virtually ignored when nurses were taught to lift loads from below the level of the knees in the position of flexed knees, with the back straight.
- Techniques have focused exclusively on lifting, yet many patient handling tasks do not involve vertical lifting (Owen, 1990). Investigations show 20% to 30% of the working time is spent in an erect static posture with a forwardly bent or twisted trunk during activities such as bathing or dressing and undressing patients (Nelson, 1996).
- Techniques have failed to consider lifting, turning, and repositioning patients often must be accomplished on a horizontal plane, using the weaker muscles of the arm and shoulder as primary muscles, rather than the stronger muscles of the legs.
- Patients are asymmetric, bulky, and cannot be held close to the body.
- Patient handling tasks are often unpredictable and can be complicated by patients who are uncooperative, combative, or severely contractured.

What Does This Mean for Workplace Application?

Engineering and administrative controls can dramatically reduce the risk of musculoskeletal injuries to nursing care staff. The perceived comfort of both the caregiver and patient during the performance of redesigned tasks is important to staff acceptance of the intervention. Transfer devices that reduce friction are a low cost way to redesign lateral patient transfer tasks. Because they are readily available, ceiling mounted lifts reduce the barrier to use and are superior to floor based lifts. In addition, they reduce more of the biomechanical load on the caregiver. Introduction of new lifting technology must be accompanied by training and competency evaluation in its correct use to maximize its benefits.

Table

Redesigned At Risk Tasks and Outcomes

#	Task	Control Group	Intervention Group	Findings Significant at $p < .01$
1	Bathing patient in bed.	Standard procedures used for bathing a patient in bed. No directions to adjust bed height.	Bed height adjusted according to caregiver's needs. Used new air mattress.	(See 1a and 1b below).
1a	(a) Top side.			Reduction in lumbar spine moment (60%).* Reduction in left shoulder moment (50%).* Reduction in lumbar force (59%).
1b	(b) Under side.			No significant improvement.
2	Making an occupied bed.	Standard procedures used for changing sheets No directions to adjust bed height.	Bed height adjusted according to caregiver's needs. Used new air mattress.	None significant.
3	Dressing a patient in bed.	Standard procedures used dressing a patient in pajamas. No directions to adjust bed height.	Bed height adjusted according to caregiver's needs. Used new air mattress.	None significant.
4	Transferring from bed to stretcher.	Transfer patient from bed to stretcher using draw sheet. Stretcher not height adjustable.	Evaluated chair that facilitates lateral transfers by converting from chair to stretcher. Friction reducing device used to minimize force requirements.	Redesigned task perceived by caregivers as more comfortable. External applied forces reduced 48%†. Erector spinae activity reduced 25%. Shoulder muscle activity reduced 33%.
5	Transferring from bed to wheelchair.	Transfer from bed to wheelchair using floor based powered full body sling lift.	Evaluated ceiling-mounted lift for this task. Assumed that sling was incorporated into patient clothing or bedding (new technology in development).	Intervention perceived by caregivers as more comfortable. Lumbar spine moment reduced by 54%.* Left shoulder moment reduced by 69%.* Right shoulder moment reduced by 45%.* Lumbar force reduced 58%.
6	Transfer from bed to geri-chair.	Transfer patient from bed to geri-chair using floor based mechanical full body sling lift.	Evaluated chair that facilitates lateral transfers by converting from chair to stretcher. Friction-reducing device used to minimize force requirements of the task.	Redesign perceived by caregivers as more comfortable. Lumbar spine forces reduced 36%. Erector spinae activity reduced 25%. Shoulder muscle activity reduced 45%.
7	Pulling up in chair.	Standard procedures used to pull a patient up in a standard geri-chair.	Tested recline and incline operation of occupied chair that converts to stretcher.	Redesign perceived by caregivers as more comfortable.
8	Pulling patient up to head of the bed.	Standard procedures used. No directions to adjust bed height.	Head of height adjustable bed tilted 10 degrees downward. Patient's knees bent. Use of innovative beds with shearless pivots would eliminate this task by preventing patients from sliding down in bed.	Shoulder moments reduced by 40% (average).* External applied force reduced by 31%.†
9	Applying anti-embolism stockings.	No directions to adjust bed height. Caregiver approached task from side of bed, requiring twisting.	Bed height adjusted according to caregiver's needs. Caregiver approached task from foot of bed, thereby improving body mechanics.	Lumbar moment reduced 23%.* Left shoulder moment reduced 29%.* Erector spinae activity reduced 20%. Shoulder muscle activity reduced 27%.

**Moment is a measure of the bending effect. The moment of a force about a point acts in a direction perpendicular to the plane on which both the point and the force lie. The magnitude of the moment of a force about a point is equal to the magnitude of the force times the shortest distance between the point and the line of action of the force.*
†Significance levels for external applied forces are not applicable because results were determined by laboratory testing, independent of each participant's performance.

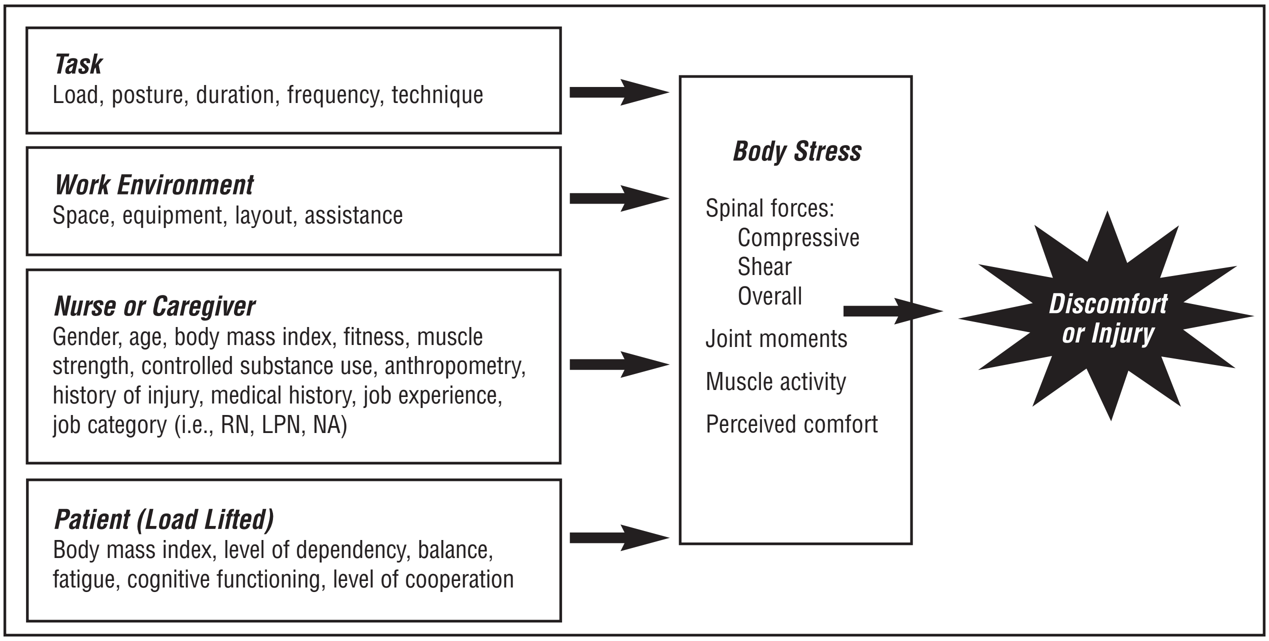

Figure 1. Conceptual model for redesigning patient handling tasks.

the incidence and severity of occupational musculoskeletal injuries in nursing. Nine high risk patient handling tasks involving vertical lifting, lateral transfers, frequent bending, or sustained awkward positions were identified. The purpose of the study was to conduct a laboratory based evaluation of the biomechanical benefit of the proposed ergonomic interventions.

Sample

Participants included registered nurses (RN), licensed practical nurses (LPN), and nursing assistants (NA), each with a minimum of 6 months' experience and a job description that included a minimum of 80% direct patient care responsibilities. Participants were required to be injury free for at least 1 year, as evidenced by a brief orthopedic examination and interview. All participants read and signed an informed consent prior to participating in the study.

No injuries were reported from study activities. A total of 134 participants, composed of 71 participants in the control group and 63 in the intervention group, completed this study. This sample presented a power of .9 to detect statistically significant differences between the intervention and control groups. The distribution of gender and job category (RN, LPN, NA) across the two groups was not significantly different. The mean functional reach of the intervention group was 30 mm greater than the control group, and the shoulder height was 50 mm more before adjustment for gender.

Although the groups were unequal in these two anthropometric measures, this did not compromise findings because the larger participants in the intervention group would generate larger internal moments as a function of their size. This means the intervention participants were, in fact, at a slight biomechanical disadvantage in performing tasks because the loads they moved or lifted were further from their centers of gravity (the L5/S1 spine).

HIGH RISK TASK IDENTIFICATION AND REDESIGN

A study conducted by Nelson (1996) identified 16 high risk nursing tasks. Nine of the most common and highest risk tasks were selected for inclusion. Surface electromyography (EMG) data collected on 15 nursing staff members compared muscle activity in participants while they performed each selected task. Based on these data, a set of cost effective controls for reducing the stress and injury potential was developed by an expert panel. Experts included occupational health nurses and physicians, ergonomists, biomechanists, and engineers who had published in the area. Interventions included engineering solutions (e.g., equipment) or administrative solutions (e.g., changes in work method) to reduce the level of exposure to a stressful task. Each high risk task and its redesign tested in the study, as well as significant findings, are displayed in the Table.

The conceptual model for this study is depicted in Figure 1 and was derived from the scientific literature (Institute of Medicine, 2001; National Institute for Occupational Safety and Health, 1997; U.S. Department of Labor, 1999; U.S. Department of Labor, 2000). The etiology of musculoskeletal discomfort and injury in nursing personnel is multifactorial, with host, agent, and environmental factors all playing a part. Host factors include personal characteristics of the caregiver, and agents include characteristics of the load lifted (e.g., level of cooperation), as well as the task performed (e.g., frequency, duration). Environmental factors include not only the physical layout of the patient care space, but also the amount of assistance available to the caregiver.

Data Collection Procedures

The biomechanics laboratory was configured to represent a typical patient room. To standardize the weight lifted, a mannequin was used instead of a patient. This

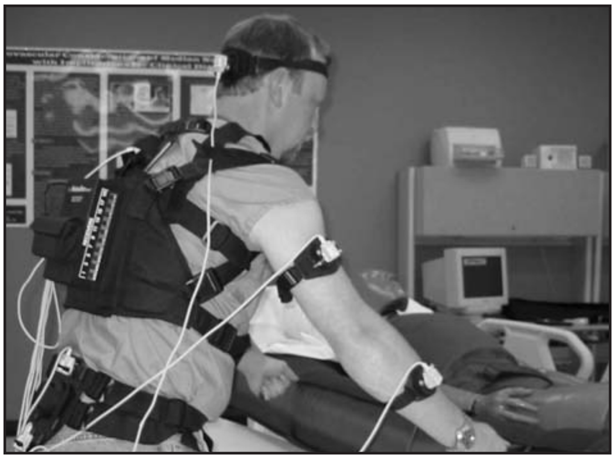

Figure 2. The study participant is performing a bed to stretcher lateral transfer task. Throughout execution of this task, postural demands were acquired through real-time measures of human motion using HumanTRAC (Gross, 1997).

helped reduce between subject variability by maintaining a constant weight of lift for each of the participants. The mannequin was filled with lead to equal the weight of a 90th percentile U.S. adult man (Open Ergonomics, Ltd., 1995) to generate stressful lifting conditions.

In this 3 year study, data were collected using a 3-D electromagnetic tracking system (HumanTRAC proprietary measurement technology) (Gross, 1997), surface EMG, and questionnaires to record demographic data, anthropometric measurements, and perceived comfort. Anthropometry is "the study of people in terms of their physical dimensions" (Kodak Ergonomics Group, 1986). The techniques used by the researchers to measure participant anthropometry were in accordance with guidelines set forth in the U.S. Army anthropometric survey measurer's handbook (Clauser, 1988).

Participants also completed a demographic questionnaire. A polychotomous options response scale (0 = extremely comfortable, 20 = extremely uncomfortable) was used to measure the caregivers' perceived comfort immediately following their performance of each patient handling task (Nunnally, 1994). The HumanTRAC system is a 3-D, whole body tracking technology allowing the researchers to track whole body movement dynamically, collecting data in real time on the computer (Gross, 1997). Key variables included biomechanical forces, joint moments, and postures required for each of the "high risk" tasks (see Figure 2).

Data Management and Analysis

Each of the objective data collection systems used in this study was computer based, facilitating automated data entry, thereby minimizing the possibility of human error. The researchers performed a statistical analysis of the absolute joint moments and forces between control and intervention tasks. An upper alpha level of .05 was used for all statistical tests as a minimum measure of statistical significance.

Independent samples *t* tests were performed on the means of all 18 continuous demographic and anthropometric variables to determine whether there were any statistically significant differences between the groups. Independent samples *t* tests also were performed on all biomechanical and EMG data to compare joint moments, forces, and muscle activity between control and intervention tasks among participants.

RESULTS

The numbers used in the following sections correspond to the numbers in the Table on page 128.

Perceived Comfort

Based on subjective comfort rating measures, the intervention group found the following redesigned tasks more comfortable than the control method:

- No. 4: Transferring from bed to stretcher using a friction reducing device.
- No. 5: Transferring from bed to wheelchair using a ceiling mounted lift.
- No. 6: Transferring from bed to a stretcher that converts to chair.
- No. 7: Pulling a patient up in a chair that converts to a stretcher.

Staff acceptance of new equipment and new methods for performing tasks is partially dependent on whether they view the new approach as advantageous. Because participants rated tasks using the ceiling mounted lift, friction reducing device, and stretcher that converts to a chair as more comfortable to perform than the associated control tasks, it is likely this equipment will have high acceptance and adoption. Of the five redesigned tasks deemed not improved by the nursing staff, the redesigns involved bed height adjustment and use of an air mattress.

The new air mattress actually made access to the patient more difficult, because the patient tended to sink down into the bed. This is an example of a redesign that benefited the patient (increased comfort and prevention of pressure ulcers) to the detriment of the nursing staff (limiting access to patient and making patient handling tasks more stressful to perform).

Lumbar Force

Lumbar force is "the pressure placed on the intervertebral discs due to forces generated during lifting or maintaining a posture" (Kodak Ergonomics Group, 1986). Biomechanical stresses exerted on the lumbar spine were calculated for the load assumption and compared between control and intervention tasks. Interventions resulted in significantly reduced lumbar forces for the following tasks ($p < .001$):

- No. 1a: Bathing patient in bed (top side).
- No. 5: Transferring from bed to wheelchair.
- No. 6: Transferring from bed to geri-chair.
- No. 7: Pulling up in chair.

Joint Moment

Joint Moment is a "force that produces or tends to produce rotation; quantified as the product of the perpendicular force times its distance from the axis of rotation" (Kodak Ergonomics Group, 1986). For objective measures of internal moments at the shoulders, the researchers found a significant improvement in the following redesigned tasks over the traditional method:

- No. 1a: Bathing patient in bed (top side) ($p < .001$).
- No. 5: Transfer to wheelchair ($p < .001$).
- No. 7: Pulling up in chair ($p = .001$).
- No. 8: Pulling patient up in bed ($p < .001$).
- No. 9: Applying anti-embolism stockings ($p = .001$).

For objective measures of internal moments at the lumbar spine, the researchers found a significant improvement in the following redesigned tasks over the traditional method.

- No. 1a: Bathing patient in bed (top side) ($p < .001$).
- No. 5: Transfer to wheelchair ($p < .001$).
- No. 7: Pulling up in chair ($p = .001$).
- No. 9: Applying anti-embolism stockings ($p < .001$).

Figure 3. Friction reducing device. (Photo courtesy of PHIL-E-SLIDE Inc., Salem, NH.)

External Applied Force

External applied force is force applied by the human operator on an external element. Ergonomic intervention for the tasks of "Pulling patient up in bed" and "Transfer to stretcher" resulted in a dramatic reduction (31% and 48%, respectively) in externally applied forces, which substantially contributes to the postural benefits recognized above as reductions in internal moments and forces.

Muscle Activity

Maximum voluntary capacity is "the largest force developed by a muscle or muscle group under a given set of conditions" (Kodak Ergonomics Group, 1986). Electromyographic measures of muscle activity take into account both postural demands and externally applied loads. Significant benefit was found for the following interventions:

- No. 1a: Bathing patient top side.
- No. 4: Transfer to stretcher.
- No. 6: Transfer to geri-chair.
- No. 9: Applying anti-embolism stockings.

DISCUSSION

All but tasks No. 2, "Making an occupied bed," and No. 3, "Dressing a patient in bed," were significantly improved in either biomechanical stress or perceived comfort, or both, as a result of combined technology and work practice interventions.

Task 1a: Bathing Patient in Bed, Top Side

The simple act of raising the bed to an appropriate working height and instructing the participant to minimize trunk rotation by moving along the side of the bed showed dramatic, significant ($p < .001$) improvement for this task (see Table on page 128).

Task 4: Transfer from Bed to Stretcher

Although the redesign did not afford any significant ($p < .001$) measurable reduction in internal forces and moments for the postural demands of this task, the researchers discovered external applied forces could be reduced by approximately 48% through correct operation of the friction reducing device instead of a standard draw sheet (see Figure 3). Furthermore, there was a significant reduction of muscle activity in participants. Nursing staff preferred the use of a friction reducing device, as evidenced by significant improvement in perceived comfort rating. The researchers anticipate this low cost technology solution will afford significant injury reduction potential to caregivers.

Task 5: Transfer from Bed to Wheelchair

The researchers were able to reduce internal moments generated in the lumbar spine and shoulders through the implementation of a ceiling mounted powered lift (see Figure 4). This lift significantly reduced postural demands over a floor based powered full body sling lift during the execution of this task ($p < .001$). Subjective comfort was also significantly improved through the availability of a ceiling lift for this task ($p = .001$). Ceiling mounted powered full body sling lifts afford a number of benefits over floor based powered or mechanical lifts. Consequently, the researchers feel incorporating ceiling mounted powered full body sling lifts into new structures and considering their installation into existing structures is justified from the perspective of both caregiver and patient safety. A cost–benefit analysis of this new technology is being evaluated in a separate study by the investigators.

Task 6: Transfer from Bed to Geri-chair

Forces generated at the lumbar spine were significantly reduced ($p < .001$). Findings for reduction in muscle activity were significant across participants ($p < .001$). Nursing staff preferred the use of a friction reducing device, as evidenced by the improved perceived comfort rating.

Task 7: Pulling a Patient up in Chair

The chair presented as an intervention for "Pulling up in chair" can be opened innovatively into a stretcher,

Figure 4. Ceiling mounted lift. (Photo used with permission of Guldmann, Inc., Tampa, FL.)

thereby permitting horizontal repositioning where the greater load is borne by the surface.

Task 8: Pulling a Patient up in Bed

Nursing perception was this redesign did not offer a significant improvement over the standard procedures. The researchers were able to reduce internal moments at the shoulders. Angling the bed surface and raising the patient's knees helped to reduce external applied forces associated with this task.

Task 9: Apply Anti-embolism Stockings

A reduction in lumbar moment and left shoulder moment were achieved by reducing torso twisting and excessive reaching. Furthermore, there was a comparable reduction in muscle activity at the erector spinae muscles and shoulders.

CONCLUSIONS

NIOSH Guidelines

During the execution of this study, the researchers discovered forces exerted on the lumbar spine during performance of high risk nursing tasks are predominately in the anterior-posterior shear plane, with a minor compressive component. This discovery proposes the etiology of back injuries for nursing activities differs from typical manufacturing and warehousing operations, where loads on the lumbar spine are predominantly compressive. Therefore, current NIOSH guidelines for safe lifting cannot be applied to nursing tasks.

User Error

User error can contribute to increased risk. Use of a friction reducing device for the lateral transfer of patients significantly reduced muscle activity for the spine and the shoulders. Although reduced muscle activity can reduce muscle fatigue, observation of intervention participants revealed the friction reducing device was not intuitive in its use, and despite training, participants did not realize the true capability of this ergonomic intervention. Training and competency programs to assure appropriate use are needed to fully benefit from patient care equipment.

Ceiling Mounted Patient Lifts

Mechanical lifting devices of any type have been shown to be far safer for both nurses and patients. However, several limitations interfere with lifting device use in practice, including difficulty using in confined spaces, extra time required, lack of accessibility or availability, difficulty using and storing, and poor maintenance (Fragala, 1993). Many of these barriers can be eliminated through the use of ceiling mounted lifts over each patient bed. Using a ceiling mounted lift decreased internal moments (i.e., the forces generated by posture) significantly when compared to operation of a floor based lift. Ceiling mounted patient lifts reduce the risk for musculoskeletal injuries in nursing staff.

Work Practice Controls

Administrative (i.e., work practice) controls can be implemented successfully to reduce risk. For example, applying anti-embolism stockings from the bottom of the bed where there is a pushing movement compared to applying stockings from the side where there is a combination of lifting and pulling significantly reduces caregiver muscle activity. Another example involves bathing a patient in bed. Bathing the patient's top side by setting the bed at the correct height and instructing the nurse or care giver to move up and down the side of the bed rather than twisting their torso resulted in a reduction in internal joint moments. A third example involves pulling a patient up in bed. During performance of the redesigned task of pulling the patient up in bed, internal moments increased for the back, but showed a significant reduction in the shoulders. (The 3% increase for the back was not statistically significant.) The improvement was attributed to the tilt of the bed and raising the patient's knees.

Patient Versus Staff Risk

Redesigned tasks need to integrate patient and staff risk. One redesigned task in this study used a special air mattress designed to reduce the risk of pressure ulcer development. However, rolling a patient toward the caregiver was made more difficult by the air mattress. Even in its fully inflated state, the air mattress was more easily compressed than a standard mattress. In this case, reducing risk for the patient increased risk for the staff member.

RECOMMENDATIONS

Minimize Lumbar Forces

Nurses should promote the development of recommendations applicable in nursing to minimize lumbar forces in the anterior-posterior and lateral shear planes. Unlike manufacturing operations, nursing tasks involve a predominant horizontal component to load transfer, which exerts shear stresses on the spine in the anterior-posterior and lateral planes. Shear forces are "applied tangentially to a surface" (Kodak Ergonomics Group, 1986). To describe their direction, shear forces acting internally may be referred to as anterior-posterior or lateral.

Anterior-posterior shear forces act from front to back of the operator, whereas lateral shear forces act side to side. An analogy can be drawn between the spine and a column of bricks—the column is able to withstand extraordinary forces directed along the length of the column. However, a minor force applied perpendicularly could cause the column to fail.

Similarly, shear forces in the anterior-posterior and lateral planes are the major contributor of back injuries among nursing professionals. Recommendations to minimize shear forces acting on the spine, without translating those forces to other planes or joints, are urgently required. The effective use of friction reducing devices for the lateral transfer of patients is an excellent example of a recommendation to minimize shear forces acting on the lumbar spine without translating those forces to other planes or joints. Using the traditional draw sheet technique, caregivers experience high internal compressive and anterior-posterior forces at the L5/S1 disk. Selection and effective use of a quality friction reducing technology can substantially reduce these forces without translation to other planes or joints.

Redesigned Tasks

- The simple act of raising the bed to an appropriate working height and instructing staff to minimize trunk rotation by moving along the side of the bed can reduce risk to caregivers when bathing a patient in bed.
- Applying anti-embolism stockings from the bottom of the bed allows for less effort by using a pushing movement compared to applying stockings from the side where there is a combination of lifting and pulling.
- Pulling a patient up in bed is made easier by tilting the head of the bed downward and raising the patient's knees.
- Friction reducing devices should be used whenever a dependent patient is transferred laterally. Such devices should be provided in sufficient number and in convenient locations to promote staff usage. Training in the correct use of any new device is imperative to successful implementation.
- Pulling a patient up in bed from the head of the bed should be eliminated through use of shearless pivot beds, which help prevent the patient from sliding down in bed.
- Ceiling mounted powered full body sling lifts afford a number of benefits over floor based powered or mechanical lifts and should be installed in high risk patient care units.
- Mattress purchasers must balance the risks to patients from pressure ulcers against the risks of back injuries to nursing staff.
- Geri-chairs could be eliminated and replaced with convertible stretcher chairs.

Redesign Tasks

Tasks may be redesigned for use in clinical practice. The Sidebar lists redesigned tasks the researchers recommend for use by caregivers.

Promote Safety

Nurses can develop competency checklists and tools to promote safe use of equipment in clinical practice. The maximum benefit of new patient handling technologies can be achieved only if caregivers use the device properly. Annual competency evaluation of staff in use of patient handling equipment facilitates safety for both the caregiver and the patient. The correct operation of all patient handling equipment is not intuitively obvious. During the study, many caregivers had difficulty using at least one piece of equipment, even after receiving instructions on its use.

Standardize Tasks

Algorithms can be developed to standardize high risk nursing tasks. A lack of standardization exists in how high risk patient handling tasks are performed. Variations in practice include techniques, deciding when to use a device versus performing a task manually, deciding when to ask for assistance or perform a task independently, and assessing how much assistance a patient can offer. Sufficient evidence and consensus of expert opinion are available to develop and implement algorithms to standardize the caregiver tasks and promote safer patient handling. Algorithms covering routine patient handling tasks have been developed by the Veterans Administration's Patient Safety Center and are available on the following website: http://www.patientsafetycenter.com.

Perform Research

Additional research is needed to reduce the risk and perceived stress in the application of anti-embolism stockings. Although a study demonstrating the cost–benefit of ceiling mounted lifts was completed in Canada (Spiegel, 2002), the cost–benefit of these devices in the United States needs to be established to convince administrators of their value. Finally, a randomized clinical trial is needed to evaluate the effectiveness of these ergonomic interventions in a clinical setting, as well as to assess patients' perception of their comfort, safety, and dignity. If patients do not accept these new technologies, nurses will avoid their use (Owen, 2000).

SUMMARY

Patient handling tasks are performed under unfavorable conditions and at significant risk to nursing staff. Recommendations based on the results of this study include:

- Using friction reducing devices for lateral transfers.
- Using ceiling mounted patient lifts.
- Making bed adjustments for height.
- Moving laterally along the bed instead of twisting.
- Applying anti-embolism stockings from the foot of the bed.

This study adds to the body of knowledge in safe patient handling and movement in four ways:

- Inclusion of nursing tasks involving frequent bending and sustained awkward positions in addition to traditional lifting tasks.
- Evaluation and redesign of additional high risk lifting tasks not previously studied.
- Expansion of redesign options beyond equipment use to include changes in postural techniques.
- Use of a newly developed 3-D Electromagnetic Tracking System to capture three-dimensional posture data of the whole body.

Further research is needed to examine other high risk nursing tasks.

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