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Field, Biomechanical, and Psychophysical Evaluation of Manual and Mechanical Patient/Resident Handling Methods in Nursing Homes

by

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ABSTRACT

Low back pain in nursing personnel is a common and well documented event that is associated with a variety of their work activities. One of the more commonly implicated activities is patient/resident handling. In brief, the problem is that the loads they handle (people) are heavy, they move unpredictably, and the nursing personnel cannot drop the load if it gets out of control. This leads to both overexertion and sudden movement induced back injuries. One recommended control measure for this problem is the use of a mechanical handling device to lift and move the people. This study, which was conducted in a laboratory, investigated the biomechanical loading associated with the traditional manual and mechanical device methods of patient/resident handling. The study also investigated the psychophysical responses of the nursing personnel to the different handling methods. Finally, the laboratory portion of the research studied the biomechanical and psychophysical aspects of using the traditional drawsheet and a mechanical method of raising a person up in bed.

The research also included a field study in which some of the mechanical devices were placed in a nursing home for four months for evaluation by the home's nursing personnel.

Based on the literature and interviews with nursing personnel, moving a person from bed to chair was selected as the research task. Two elderly female adults were used as simulated patients/residents, and nine people currently employed as nursing assistants in nursing homes were used as the subjects who performed the resident handling work. Ten commercially available mechanical devices, (five sling lifts, four stand-up lifts, and a sliding board) were evaluated. All of the participating nursing personnel were trained by representatives of the devices' manufacturers prior to their use of a device. Biomechanical loading was

determined using force platforms, a motion analysis system, and a computerized biomechanical model. Psychophysical response was determined using interviews and likert scale based questionnaires. The field study evaluation was based on interviews with the nursing personnel and observation of the nursing personnel using the devices.

The results revealed that the use of the mechanical lifting devices eliminated more than half of the lifting exposure, and reduced the magnitude of biomechanical loading during times of lifting exposure. They also showed that the nursing personnel perceived the use of the devices to be less stressful than the traditional manual methods of patient/resident handling.

The pilot study results showed a reduction in low back pain complaints, a reduction in the work related fatigue experienced by the nursing personnel, and a general acceptance of the devices by the nursing personnel, and by the nursing home residents and management.

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ACKNOWLEDGMENTS

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INTRODUCTION

There were 630,000 lost workday back injuries in the United States in 1979 (Jensen, 1990b) and approximately 19 percent of all workers' compensation claims are coded as back sprains or strains (Klein et al., 1984). The financial cost of back injuries is estimated to be billions of dollars each year (Brigham and Harris, 1990). These figures explain why the National Institute for Occupational Safety and Health (NIOSH) ranked work-related musculoskeletal injuries and illnesses second on the list of leading occupational injury and illness problem areas in the United States (Millar, 1988).

Comparisons of back injury rates from workers' compensation data ranked nursing aides and garbage collectors first or second in each state (Jensen, 1987). Other studies have shown that nursing professionals have both a high prevalence rate of back pain (Biering-Sorensen, 1985) and a high incidence rate of workers' compensation claims for back injuries (Klein et al., 1984; Personick, 1990). The Bureau of Labor Statistics reported that in 1987, nursing and personal care employees had an average injury rate of 13.9 injuries per 100 full-time employees (Bureau of Labor Statistics, 1989).

Patient-handling tasks have been identified to be the main cause of back injury to nursing personnel (Bell et al., 1979; Owen, 1987). The stresses that are associated with these handling tasks are presumed to be the cause of the injuries. The purpose of this study was to evaluate a number of methods of performing two resident-handling tasks: (transferring residents from bed to a chair and lifting residents up in bed) to determine their comparative stress levels.

LITERATURE SUMMARY

Health care personnel have been the subject of considerable accident/injury research (Jensen et al., 1989; Owen, 1989a; Mostardi et al., 1989; Videman, 1989; Jensen, 1990a; Personick, 1990). Klein (1984) found that nurse's aides and licensed practical nurses ranked fifth and ninth in the top nine occupations with the largest ratio of claims for back sprains or strains. Cust (1972) compared female nurses with female teachers and found that low back pain (LBP) which started at work or was perceived to be because of work was significantly more frequent in nurses (19.9 percent) than in teachers (12.8). Harber et al. (1985) compared professional and licensed practical nurses with unit coordinators/clerks in a hospital and found that 52 percent of the nursing personnel and 20 percent of the unit coordinators had experienced LBP within the past year.

According to a survey of 3912 nurses by Stubbs et al. in 1983, 43 percent of the nursing population in England and Wales suffered back pain at least once a year. Stubbs also estimated that 40,000 nurses in the British National Health System (BNHS) suffered from back pain each year and over three quarters of a million working days were lost annually from back pain.

Owen (1989a) reported that 38 percent of her random sample of 503 nurses had experienced at least one incidence of occupational low back pain or injury. Nearly 20 percent of these nurses had made at least one transfer to a different unit, position, or employment setting because of LBP.

Back pain experienced by nursing personnel is greater than published statistics indicate (Owen, 1989a). The reasons are that the magnitude of the LBP is often estimated from the workers' compensation data or incident report data and it is noted that many nursing personnel do not report their LBP. For instance, 66 percent of the nurses who stated they had occupational LBP never filed any incident report (Owen, 1989a).

The direct costs of work-related low back pain among U.S. employees for 1986 was estimated at $11.1 billion (Liberty Mutual Ins, Webster, 1990). The mean cost per claim was $6807 and the median cost was $391. Back injuries alone account for 32 percent of compensable injuries and 42 percent of compensation costs.

Lifting has, perhaps incorrectly, been identified as the prime cause of back pain. Unfortunately, in many cases, lifting is not a well defined task, and health care is one of these cases.

Patient-handling tasks often involve asymmetric lifting, two person lifts, twisting motions, and sudden movements. Some people have researched these difficulties in lifting, but to date, no guidelines have been established to incorporate all aspects of lifting tasks (Yates & Karwowski, 1987; Oriet & Dutta, 1989; Johnson & Lewis, 1989). NIOSH's work practices guide and Snook's psychophysical lifting guidelines have probably helped reduce the incidence of back injuries in general industries, but unfortunately, the tasks performed in a hospital or nursing home are highly variable, not standardized, and poorly modeled by the guidelines.

Control strategies in any industry include employee selection, training, and job design. Within health care settings, the focus for corrective action has been on training. The previously cited statistics speak to the ineffectiveness of this approach. This leaves us with job design based on ergonomic principles as the best control strategy. This is true in most work settings, and particularly so in health care. Ultimately, if our goal is to control musculoskeletal injuries and illnesses, we have to reduce people's exposure to the conditions and situations which are known to cause injuries and illnesses. In the case of health care personnel, this can be done by eliminating as many patient/resident handling activities as possible. One way of doing that is with the use of assistive devices which lift and carry people, and this study evaluated a number of commercially available assistive devices to determine their effect on physical stress, their acceptability, and their general design utility.

METHODOLOGY

This section describes the experimental procedures which were used to accomplish this research. Tasks to be performed in this study were selected based on a literature review and an analysis of injury records from two nursing homes.

The literature suggests that maneuvering residents in bed was the most frequently cause of back pain. The physical actions of lifting, pulling, or sliding a resident up in bed was the most difficult maneuvering action. Other problems cited were transferring a resident from toilet to wheelchair, wheelchair to toilet, chair to bed, and transferring the resident from bed to chair.

The injury records reviewed at the nursing home indicated that most injuries were due to transferring residents from one place to another (bed to/from wheelchair and wheelchair to/from toilet) and lifting resident up in bed.

The following two tasks were selected for this laboratory study: 1) lifting residents up in bed; and 2) transferring residents from bed to chair. The task of transferring a resident from bed to chair was standardized in this study and defined as transferring a resident from a supine position in the bed to an upright position in a chair. Table 1 summarizes the tasks and assistive devices used in the study.

Table 1 Tasks and Methods of Performing Them

Task One - Transferring Residents Bed to Chair	Task Two - Lifting Residents up in Bed
Baseline Method (2-person no device	Baseline Method (2-person drawsheet)
Waling Belt (2 person)	Magic Sheet
Basket-sling Lift #1	
Basket-sling Lift #2	
Basket-sling Lift #3	
Basket-sling Lift #4	
Overhead Lift	
Stand-up Lift #1	
Stand-up Lift #2	
Stand-up Lift #3	
Stand-up Lift #4	
Sliding Board	

A review of the literature relating to assistive devices for use with these resident-handling tasks indicates that a limited number of devices are available and are limited to the following: hoists, sliding boards, belts, slings, and turntables (Owen, 1988 Garg, 1990; Bell, 1984; Lloyd et al., 1987). A questionnaire administered to nursing personnel showed that the most frequently used devices were gait belts, bathtub lifts, hoists, and lift sheets (Owen, 1989b). According to the literature, 85 percent of patient transfers in nursing homes were being performed manually (Bell et al., 1979). The reasons nurses gave for not using lifting assistive devices are as follows: too time consuming, lack of staff knowledge and experience, inadequate staffing, and lack of availability (Owen & Garg, 1990). Bell (1984) found nursing personnel reluctant to use assistive devices because they did not understand how to use them.

The criteria for selecting assistive devices evaluated in this study were: 1) the product was designed for commercial use rather than for home use; 2) lifting devices could be lowered to lift residents from the floor in a seated or lying position; 3) lifting devices could be equipped with scales to weigh totally dependent residents; and 4) lifting devices were not prone to tipping over while transporting residents in previous laboratory evaluations. Assistive devices evaluated by other researchers were not selected for further testing in this study.

The assistive devices selected for this study are described below.

ASSISTIVE DEVICES

The walking belt is a four inch wide belt that is wrapped around the resident's abdomen-hip area. It provides handles for nursing assistants to grasp during a transfer. An early model of the walking belt was evaluated by Garg and colleagues (1991a, 1991b) and as a result of that study, the manufacturer added ergonomically designed handles and an adjustable strap to provide a better fit and to prevent the belt from riding up on a resident's back. This new model (Figure 1) was evaluated in this study.

The basket-sling lift is battery powered and quite mobile. The resident is placed in the sling, centered over the sling base, and gently raised. A scale is integrated into some designs so that residents can be weighed while they are suspended in the sling. This type of lift is designed for both totally and partially dependent residents. Four brands of this type of lift were evaluated. Figures 2 to 5.

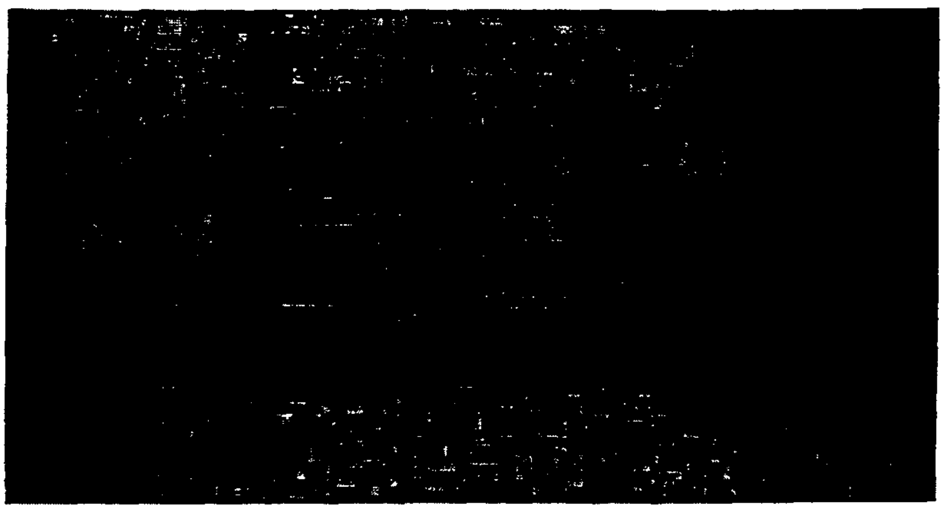

Figure 1 Walking Belt

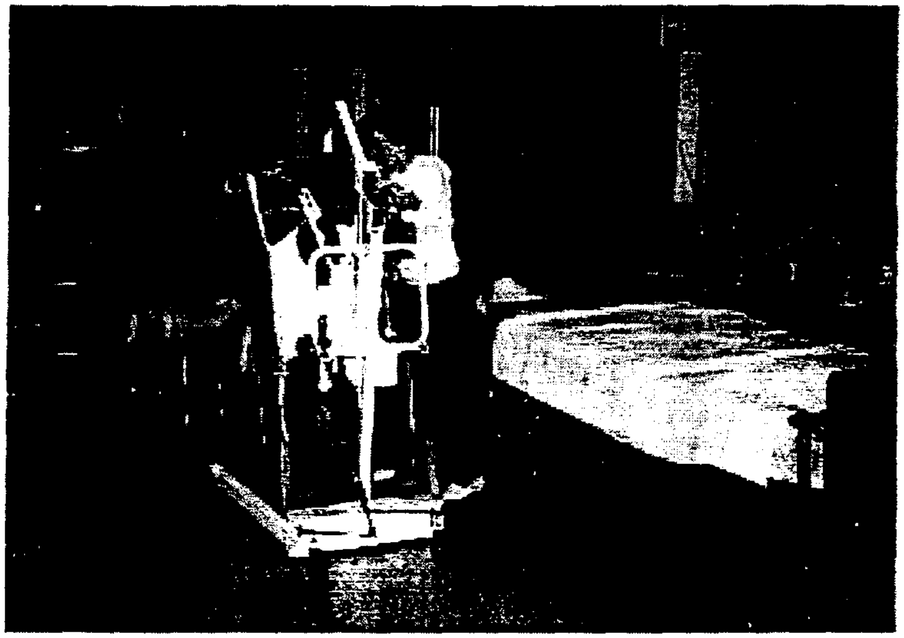

Figure 2 Basket-sling Lift #5

Figure 3 Basket-sling Lift #6

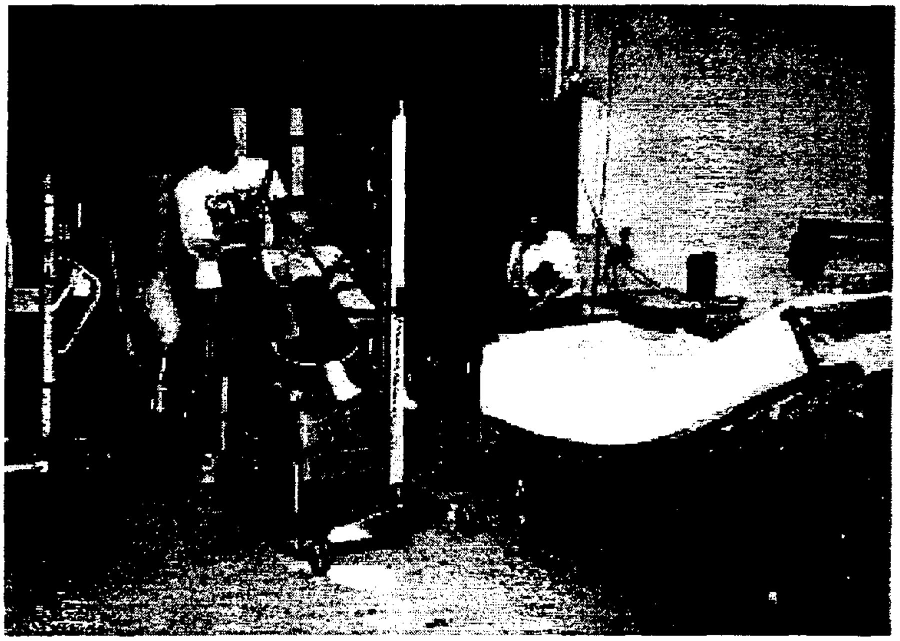

Figure 4 Basket-sling Lift #7

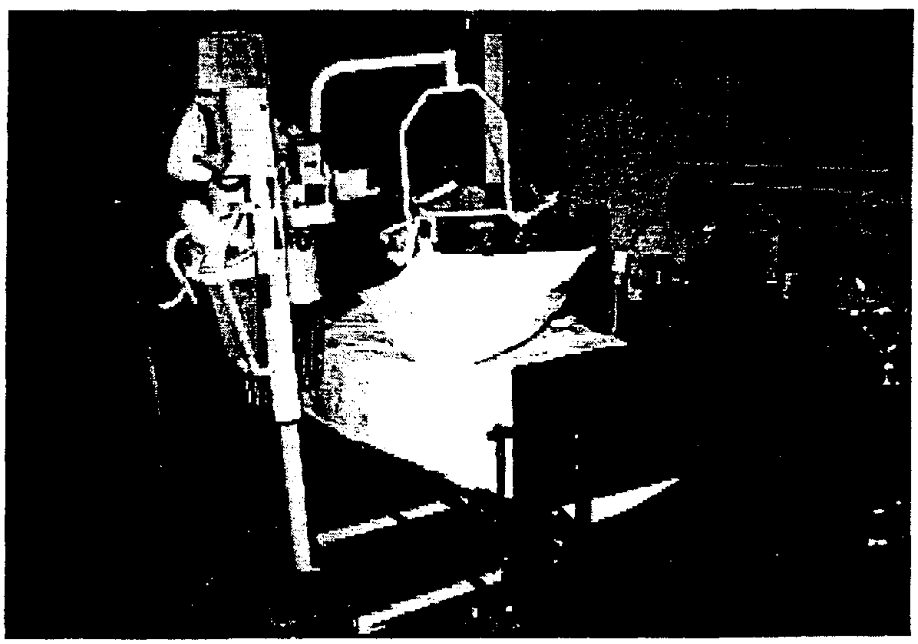

Figure 5 Basket-sling Lift #8

The overhead lift is a basket-sling type of lift that is attached to a ceiling-mounted track and is battery powered. It is designed for both totally and partially dependent residents. One model of this type of lift (Figure 6) was tested.

The standup lift is similar to a basket-sling lift. The resident places his/her feet on a foot-plate, bends the knees, and rests them against a soft knee-pad support. A belt-sling is placed under the arms and around the resident's back to support him/her in a near standing position. This type of lift is only designed for partially dependent residents. Four brands of this type of lift were evaluated. Figures 7 to 10.

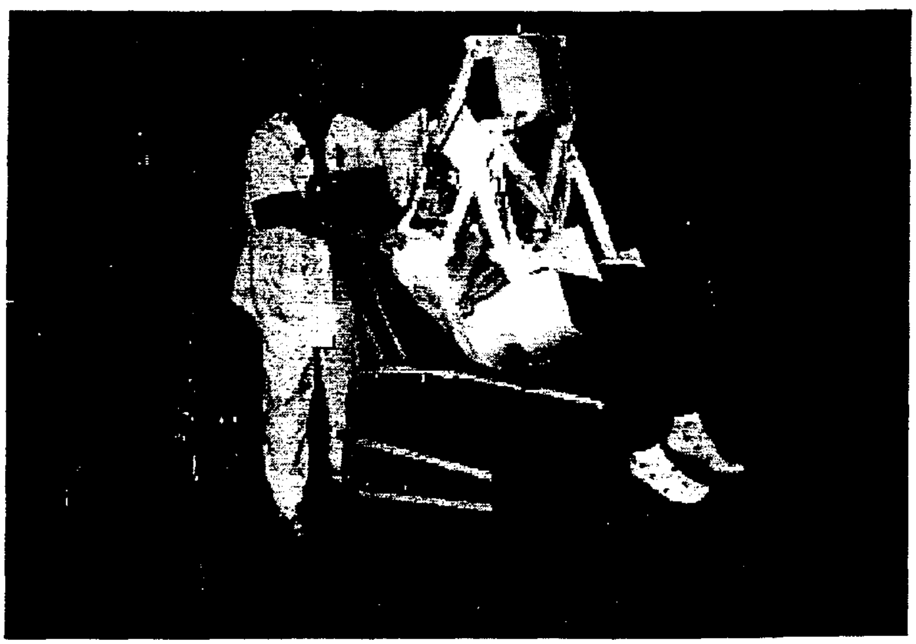

Figure 6 Overhead Basket-sling Lift #9

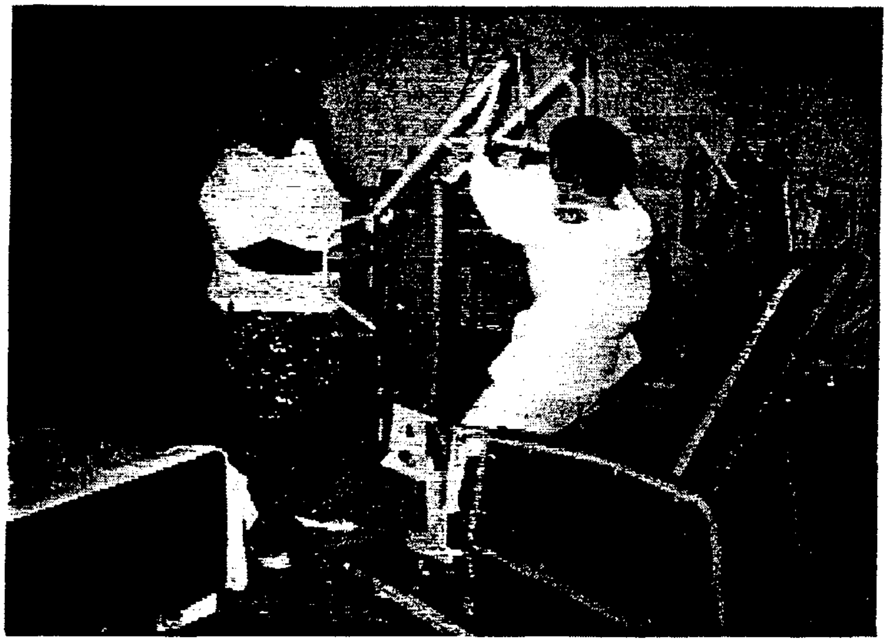

Figure 7 Stand-up Lift #1

Figure 8 Stand-up Lift #2

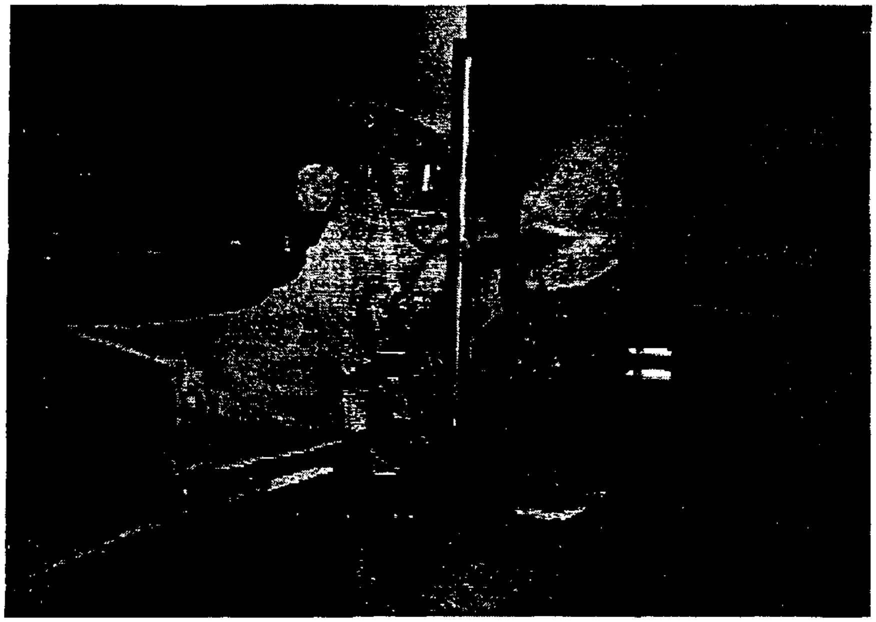

Figure 9 Stand-up Lift #3

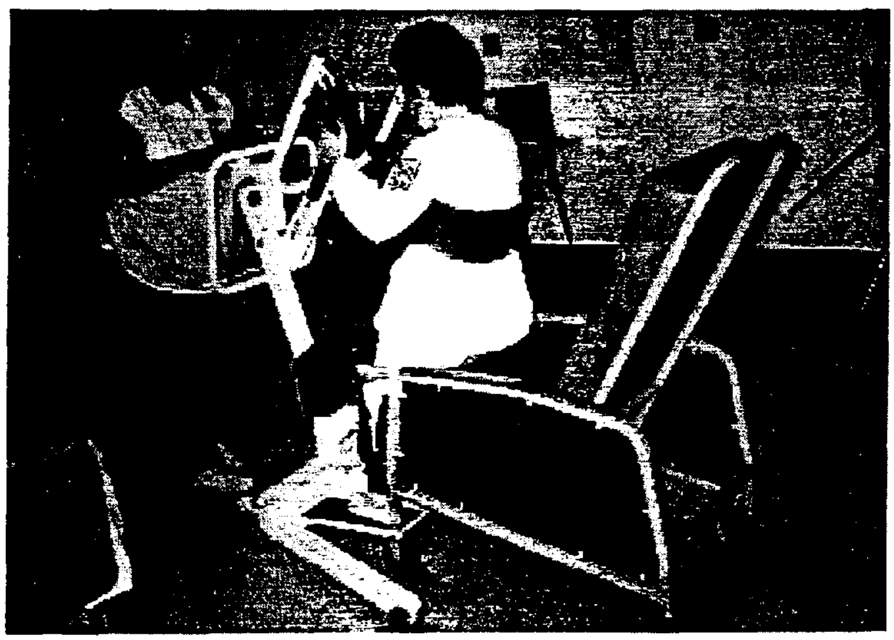

Figure 10 Stand-up Lift #4

The _sliding board_ tested in this study was 40 inches long and 12 inches wide with a one-half-inch thick seat which slides on a one inch thick board. The unit weighs 6.5 pounds. This sliding board (Figure 11) is a somewhat different way to accomplish transfers to and from wheelchair, bed, auto, commode, etc., with ease and dignity.

The _Magic Sheet_ is an assistive device for lifting residents up in bed. It is made of Gortex, and weighs 30 pounds. The Magic Sheet is adaptable to most hospital beds, and allows one person to move a patient up and down in bed. The Magic Sheet is illustrated in Figure 12.

The commonly used _manual methods_ were selected to serve as a comparative baseline for the other methods manual transfer of residents from bed to chair (Figure 13) and the drawsheet method of lifting residents up in bed (Figure 14).

Figure 11 Sliding Board

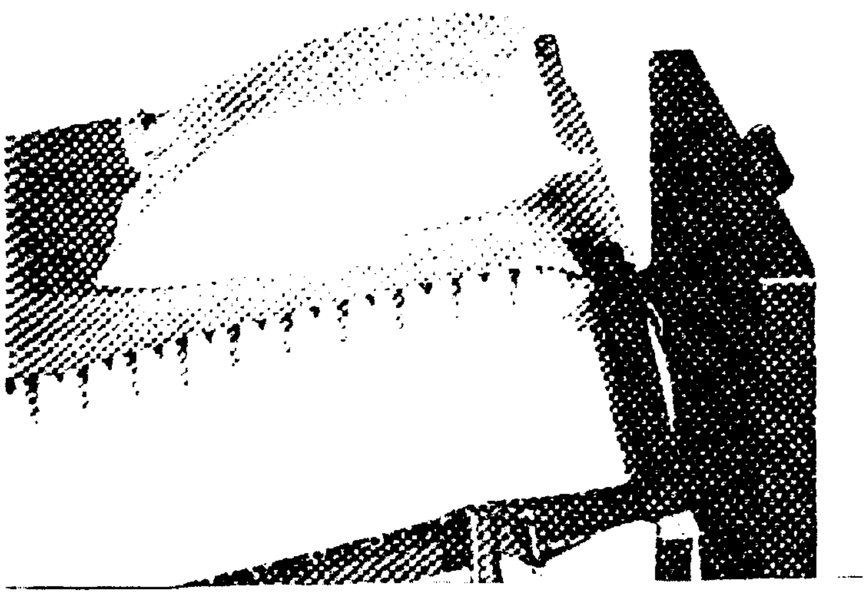

Figure 12 Magic Sheet

Figure 13 Baseline Transfer Method

Figure 14 Drawsheet Technique

Subjects

There were two types of subjects in this study: nursing assistants and residents. Each nursing assistant performed all resident-handling methods on all residents, thus allowing the estimation of inter-nursing assistant variation.

Nine nursing assistants (two males and seven females) were recruited from local nursing homes. The following criteria were used to select the nursing assistants:

1) performance of resident-handling tasks as part of their work activity;
2) willingness to learn how to use the resident-transferring devices;
3) lack of back injury or pain within the last year, or chronic episodic back pain that had been experienced within the last three years;
4) passing of a medical screening exam

The nursing assistants' mean age, height, and body weight were 45.8 years (range = 20 - 69 years), 168 cm (157 - 183 cm) and 76.2 kg (45.5 - 132.3 kg), respectively. Their mean experience as a nursing assistant was 33.2 months (2 - 71 months).

The "Consent to Voluntarily Participate in a Research Study" forms and fact sheets were explained to the nursing assistants and residents who were then asked to sign a consent form. They were permitted to stop participation in the study at any time without penalty.

Two elderly female volunteers agreed to serve as residents for the study. Females were used because they are the most common residents of nursing homes and conversations with nursing home personnel indicated females were generally more difficult to transfer. Elderly subjects were selected because the residents in nursing homes are generally older than the general population. Their perception of the comfort and security provided by the assistive devices is probably different from that of younger people. A medical screening exam was conducted to insure that the residents were healthy in both mind and body.

One resident was 51 years old, 152 cm tall and weighed 58.2 kg. The other resident was 67 years old, 160 cm tall and weighed 77.3 kg.

This section briefly describes how the two resident-handling tasks were performed by the nursing assistants with the methods selected for this study.

Transferring Residents from Bed to Chair

Handling Tasks. In this study, the bed to chair transfers were classified into six categories: baseline (no device), walking belt, basket-sling lift, overhead lift, stand-up lift, and sliding board. The residents were instructed to be passive at all times during a transfer.

Baseline Method. The baseline manual transfer method required two nursing assistants. First the nursing assistants adjusted the height of the bed to the level they perceived to be the most appropriate height for them to perform the task. This height was recorded for each assistant and used throughout the study. The resident was then raised to a near sitting position using the adjustable portion of the bed. Both nursing assistants were on the same side of the bed. The assistant nearest the head of the bed placed his/her right arm around the resident's shoulders and grasped the resident's upper arm with the left arm. The other nursing assistant placed both arms under the resident's knees. On the count of three, the resident was rotated slowly and smoothly toward the side of the bed to assume a sitting position on the edge. If the resident's feet did not reach the floor, the bed was lowered. Each nursing assistant then stood in front of and to either side of the resident. The assistants' outer hands were positioned to the side and back of the resident, while their inner hands were placed under the axilla (armpit) of the resident. On the count of three, both assistants helped the resident to a standing position, and then helped the resident move until the chairfront touched the back of the resident's legs. Finally, the nursing assistants lowered the resident into the chair.

Walking Belt. The walking belt also required two nursing assistants. First, they assisted the resident to a sitting position in the same manner as the baseline method. The nursing assistants then snugly fastened the walking belt around the resident's lower abdomen-hip area. Each nursing assistant grasped one handle with their inner hands. In synchrony, the resident was rocked back and forth and, on the count of three, pulled the resident to a standing position. When the resident was stabilized in a standing position, one nursing assistant instructed the resident to pivot her feet and back up to the seat of the chair. The nursing assistants likewise moved their feet to avoid twisting their backs. While still grasping the handles of the belt, the nursing assistants lowered the resident into the chair. They then removed the walking belt.

Basket-sling and Overhead Lift. The first activity of the basket-sling and overhead lift transfer methods required one nursing assistant to roll the residents (in the bed) on their side, fold the sling in half, and place it behind the resident's back. The resident was rolled back onto the sling and over slightly in the opposite direction to bring out the folded part of the sling. The nursing assistant then moved the lift next to the bed and connected the shoulder straps of the sling to the lift. The leg pieces were brought under the thighs and connected to the lift. The resident was lifted and positioned for transfer, moved over the chair, lowered into it, and then pulled back into the chair. When the resident's body weight was fully supported by the chair, the sling straps were disconnected and the lift pushed away. The sling was then removed from under the resident.

For the stand-up lift, the nursing assistant first raised the upper body of the resident, to a near sitting position. Next, the nursing assistant placed the arm nearest the head of the bed around the resident's shoulders and the other arm under the resident's knees. The resident was then rotated slowly and smoothly toward the side of the bed until a sitting position was assumed on the edge of the bed. The stand-up lift was then brought up to the resident, the resident's feet were positioned on the footrest, and the brakes applied. The sling was then placed around the resident's back, and straps were attached to the support arms on the lift's frame. A safety strap was used to assist in supporting the resident in the sling during the lifting procedure. The device's support arms were raised to elevate the resident to a near standing position, with their feet supported on the footrest and their knees by the padded knee brace. The nursing assistant then released the brakes and transferred the resident to the chair. The legs of the stand-up lift were opened to fit around the chair. The resident was lowered into the chair and pulled back into the seat in a seated position. The nursing assistant then released the safety strap, unhooked the sling, and moved the lift away from the resident.

Sliding Board. The sliding board was used by assisting the resident to a sitting position on the side of the bed as previously described. The nursing assistant placed a walking belt snugly around lower abdomen/hips of the resident, leaned the resident as far as possible to the side opposite of that on which the transfer is to be made, the lead leg was lifted and crossed over the trailing leg, and the seat was placed under the resident. Using a countdown such as "1-2-3 GO", the nursing assistant simply glided the resident slowly across the board. The resident finished with her back against the back of the chair. The board was then pulled out from under the resident.

Drawsheet/Magic Sheet. The nursing assistants used the drawsheet by rolling each side of the drawsheet close to the resident's body and grabbing the rolled edges of the drawsheet. The resident was asked to flex the knees and brace her feet firmly on the bed. On the count of three, both assistants lifted and slid the resident toward the head of bed.

When using the magic sheet, one nursing assistant turns the crank handle which moves the sheet and resident up in bed.

EVALUATIONS

Equipment Evaluation. The equipment was evaluated based on ergonomic criteria. Both objective (biomechanical) and subjective (psychophysical) evaluations were used. They were performed as described below.

Objective Evaluations. The compressive force on the L5/S1 disc of the nursing assistants was estimated using the 3D Static Strength Prediction Program™ (The University of Michigan, 1993). The body posture and angle input data were estimated using a three-dimensional video motion analysis system, Peak® Performance System (Peak Performance Technologies Inc., 1992). The nursing assistants' hand forces (lifting, pushing, and pulling) were measured using two force platforms. The hand force direction was determined from the xyz force vectors measured by the force platform.

Subjective Evaluations. The nursing assistants' ratings of perceived exertion on the lower back, upper back, shoulder, and whole body were determined using the Borg scale. The ease of using each method was determined with a five-point Likert scale. The nursing assistants' preference of methods was obtained by asking the assistants to rank the methods from the most preferred method to the least preferred method. Functional outcome measures, such as task performance and nursing assistant work time, were determined from the video tapes.

Issues relating to the safety and comfort of the residents were assessed subjectively by having each resident rate each method/nursing assistant/resident weight combination on a 5 point Likert scale.

Laboratory Facility. The layout of the laboratory facility is shown in Figure 15. This figure shows the location of the key equipment such as the camera, the bed, the force plates, the computer, etc.

Instructions to Subjects. Nursing assistants were instructed in the proper use of the assistive devices by the manufacturers' representatives. This allowed the representatives to fully explain all the features of their devices to the nursing assistants. It also assured that the representatives could train the assistants to use their products in the manner suggested by the manufacturers. To reinforce the initial training, further training was provided by review of the manufacturer's written instructions and video tapes. Prior to performing each transfer, the nursing assistants were asked to practice the techniques, with feedback from the researchers, until both the researchers and the nursing personnel were satisfied that transfers were done as directed by the manufacturers.

Objective Evaluations. Objective data include the hand forces associated with maneuvering lift devices, pulling/lifting force associated with the basket-sling lift, force platform data, video tapes for resident-handling activities, and bed height.

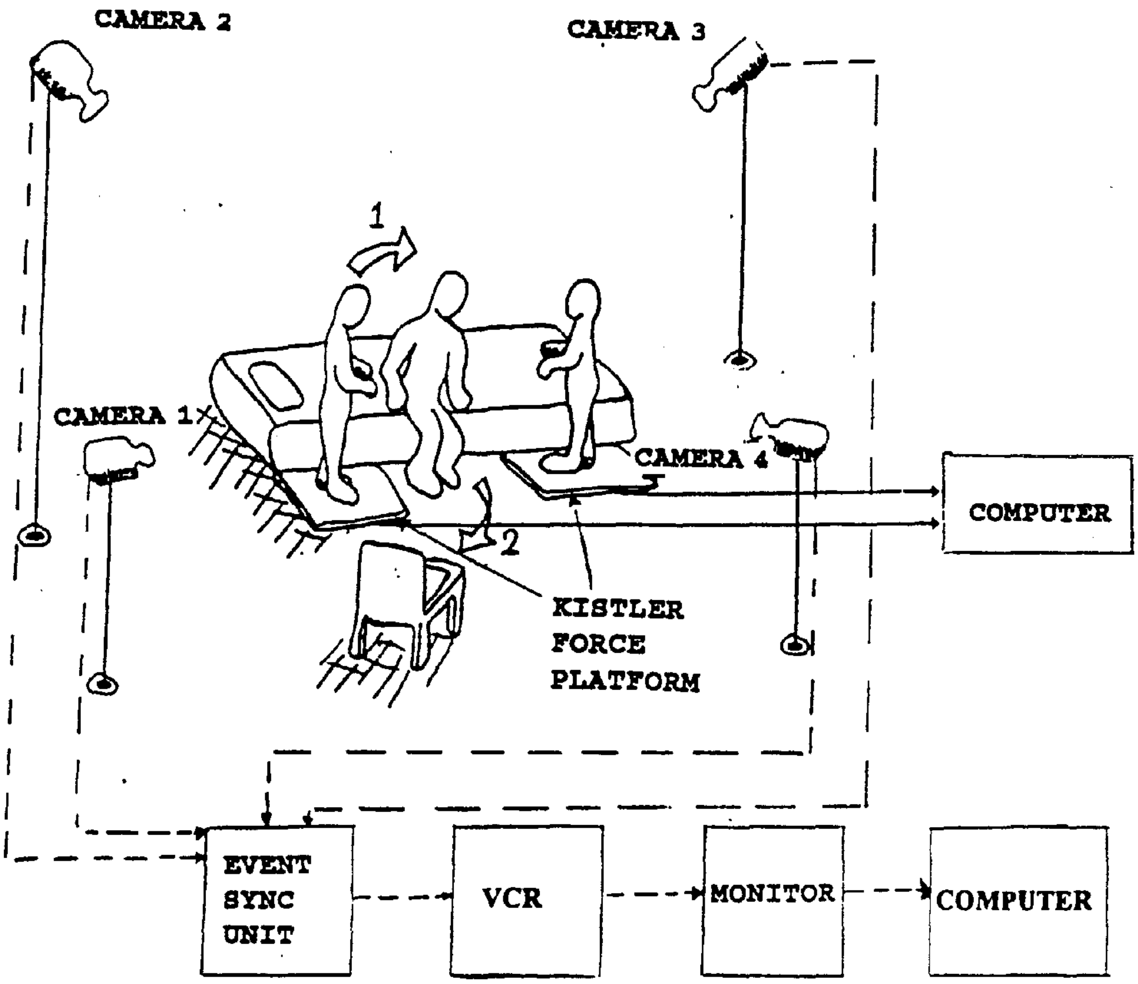

Figure 15 Layout of Laboratory

Lift Device Movement Hand Forces. During practice time, nursing assistants were asked to stand on a force platform and push and turn each lift device with a resident in the sling. This activity was used to quantify the maneuvering forces required by each lift device. One trial was undertaken for each combination of nursing assistant, resident, and lift device.

Basket Sling Lift Pull/Lift Forces. The nursing assistants needed to pull a handle on the back of the slings of the basket-sling lift to seat the resident in an upright position in the chair. Figure 16 illustrates this pulling activity. During practice time, the nursing assistants were also asked to stand on a force platform and pull a handle on lifts equipped with them to lower and seat the resident in an upright position in the chair.

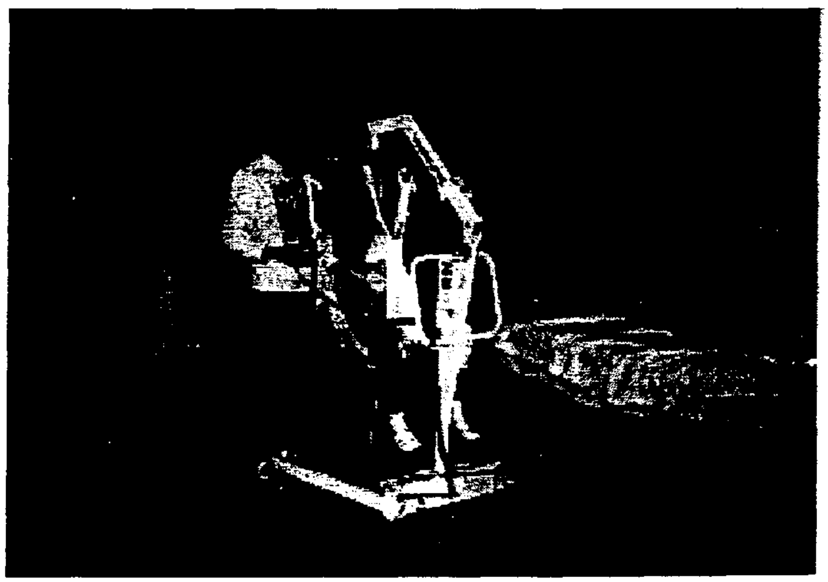

Figure 16 Pulling a Handle on the Sling to Situate the Resident in an Upright Position in the Chair

This activity was used to quantify the lifting forces required by the basket-sling lift device. One trial was collected for each combination of nursing assistant, resident, and basket-sling lift.

Resident Handling Biomechanical Data. When the nursing assistants were ready to perform the resident-handling tasks, markers were placed on them. The subjects were then asked to adjust the height of the bed to the level they perceived to be the most appropriate for them in performing the resident-handling tasks. The bed height was electrically adjusted. Then they were asked to perform each technique.

The resident-handling activities were videotaped with four cameras. Each nursing assistant stood on a force platform, which was synchronized with the video taping. For the baseline transfer method, force platform data and video tapes were collected when the resident was rotated to a sitting position on the edge of the bed (activity #1) (see Figure 13) and then lifted to a standing position (activity #2) (see Figure 17).

Figure 17 Helping the Resident to a Standing Position

For the walking belt, the same biomechanical data (force plate and video tape) were collected when the resident was rotated to a sitting position on the edge of the bed (activity #1) and then pulled to a standing position (activity #2) (see Figure 18).

For the basket-sling and overhead lifts, biomechanical data were recorded when nursing assistant rolled a resident on her side in the bed (activity #1). This activity is illustrated in Figure 19. Biomechanical data for the stand-up lift and sliding board were collected when the resident was rotated to a sitting position on the edge of the bed (activity #1). This activity is shown in Figure 20.

Two replications were recorded for each of the above activities associated with transferring residents from bed to chair.

For the task of lifting residents up in bed, biomechanical data were recorded only for the drawsheet technique. Force platform data and video tapes were collected when the resident was lifted up in bed (see Figure 14). Two replications were collected for lifting residents up in bed as well.

Biomechanical measures of physical demands of resident-handling tasks were then calculated using the University of Michigan biomechanical model.

Figure 18 Pulling the Resident to a Standing Position with the Walking Belt

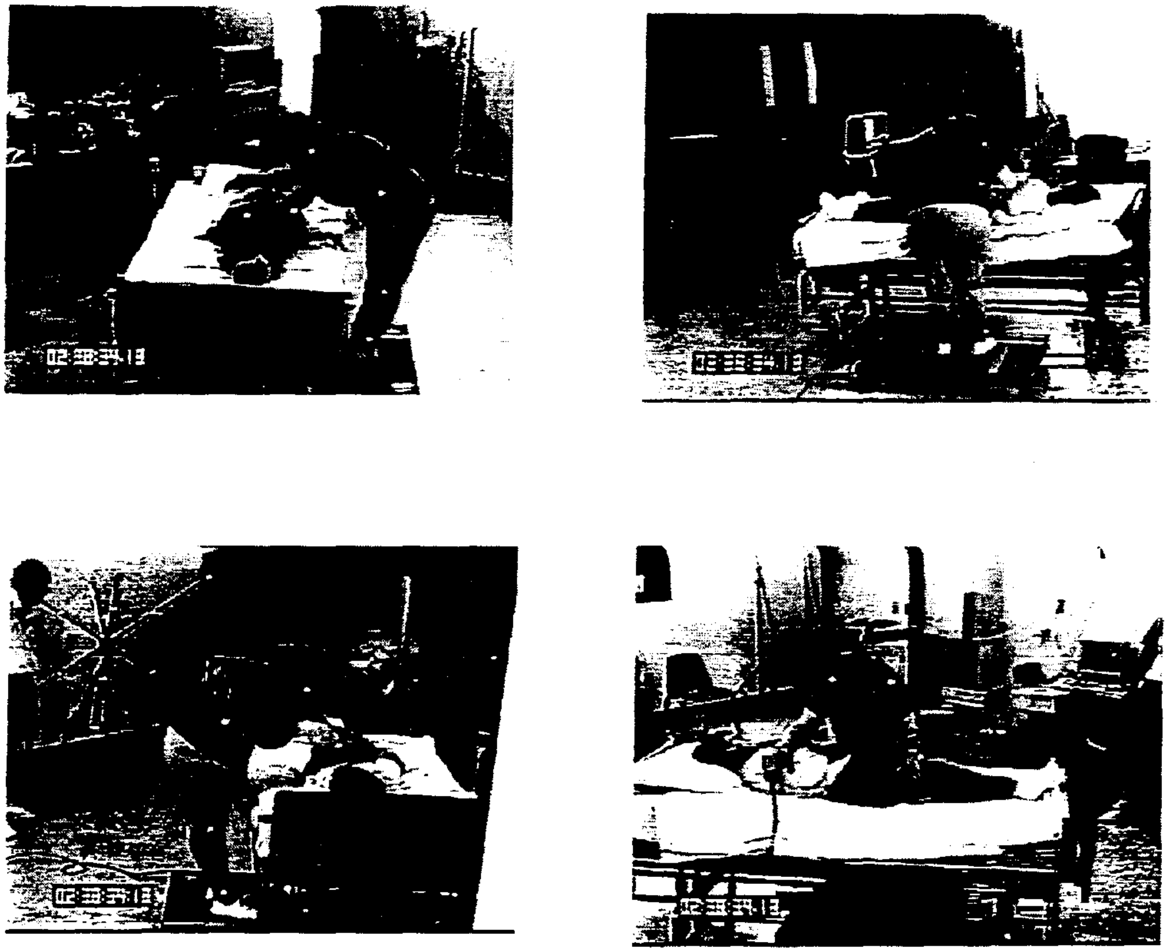

Figure 19 Turning the Resident toward the Assistant

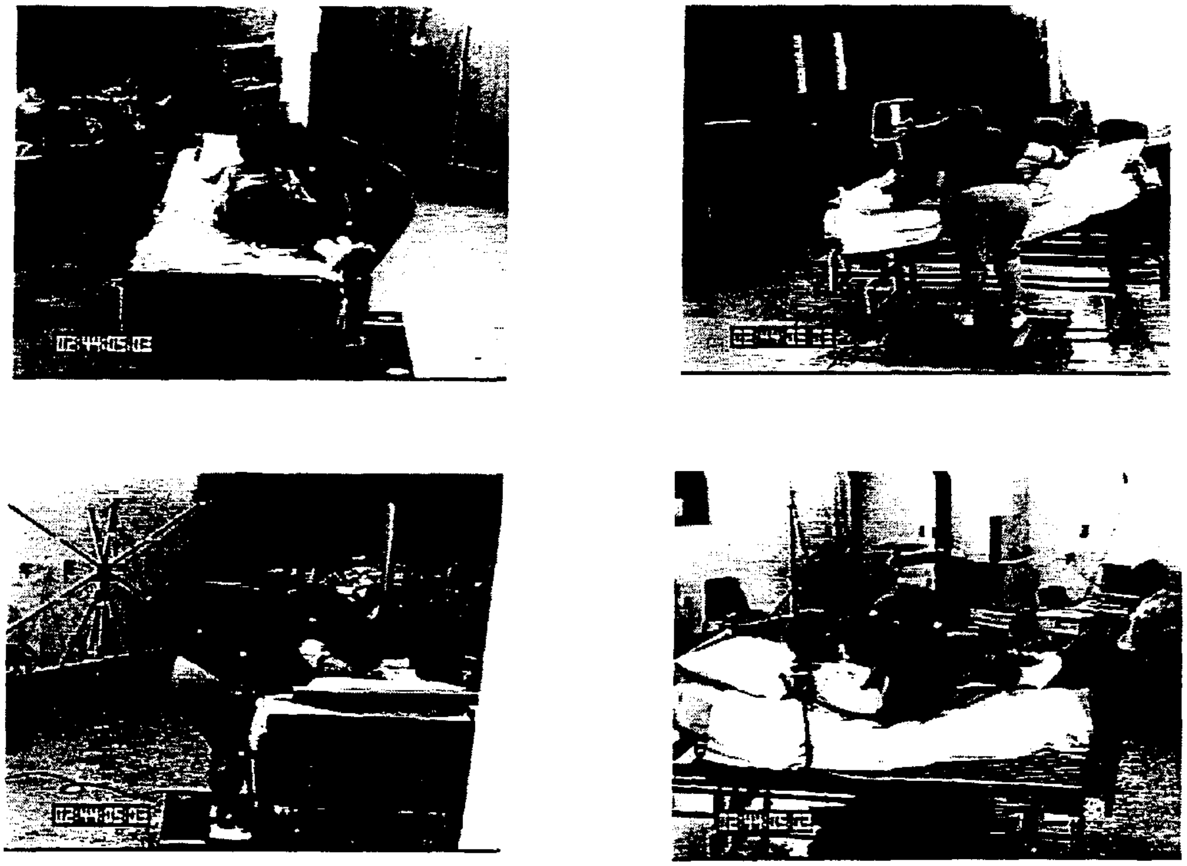

Figure 20 Rotating the resident to a sitting position
On the edge of the bed by one assistant

Preference. Bed heights preferred by the nursing assistants for completing resident-handling tasks were measured. Task performance and nursing assistant work times for the resident-handling tasks (for each of the appropriate assistive devices) were determined from the video tapes.

Subjective Data Collection. After completing each task, the nursing assistants were asked to rate the exertion/stress felt for their shoulders, upper backs, lower backs, and whole body using the Borg scale. When using the RPE scale, the subjects were asked to state, "In general, how hard the specific task feels in terms of physical difficulty." They were also asked to rate "how easy each handling method was to perform" on a five-point Likert scale (0=extremely easy and 5=extremely difficult). They were also asked for any other comments they had about each resident-handling technique. After nursing assistants had performed all of the transfer techniques on both residents, they were asked to rank their preference of the methods.

The residents were asked to rate how comfortable and how secure they felt while being transferred on a five-point Likert scale (0=extremely comfortable and 5=extremely uncomfortable; 0=extremely secure and 5=extremely insecure). They were also asked for any comments they had about each resident-handling technique.

STATISTICAL DESIGN

Methods of resident transfer were treated as a main factor in this study. Resident weight was also considered as a main factor, but it was confounded with resident participant.

The subjective and objective data were collected on a sample of nine nursing assistants. Two replications of biomechanical data were recorded. Only one trial of psychophysical data was collected. The nine nursing assistants were organized into five pairs. The fifth pair was formed with the ninth nursing assistant and one of the first eight. They performed each task using the selected methods specified for that task on each resident. The task presentation order was randomized for each resident/nursing assistant combination in each test session. This design yielded an a x b x c (a=number of nursing assistants, b=number of residents/weight levels, and c=number of methods) split-plot design with one replication at each factor level combination for the subjective rating data (two replications for the biomechanical data). The structure of this design is illustrated in Figure 21.

The linear model for the split-plot design is:

$$y_{ijk} = \mu+\tau_i+\beta_j + (\tau\beta)_{ij} + \gamma_k + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \epsilon_{(ijk)l}$$

where I=1,...,a; j=1,...,b; k=1,...,c; l=1,...,n; τ_i, β_j, and $(\tau\beta)_{ij}$ represent the whole plot and correspond respectively to blocks (factor S), main treatments (factor W), and whole plot error (SW); while γ_k, $(\tau\gamma)_{ik}$, $(\beta\gamma)_{jk}$, and $(\tau\beta\gamma)_{ijk}$ represent the subplot and correspond respectively to the subplot treatment (factor M), the SM and WARREN R. MYERS interactions, and the subplot error; and $\epsilon_{(ijk)l}$ represents the random errors. Sums of squares for these factors are computed as in the three-way analysis of variance. Biomechanical data were analyzed with the above linear model. Psychophysical data were analyzed with the same model without the random error term.

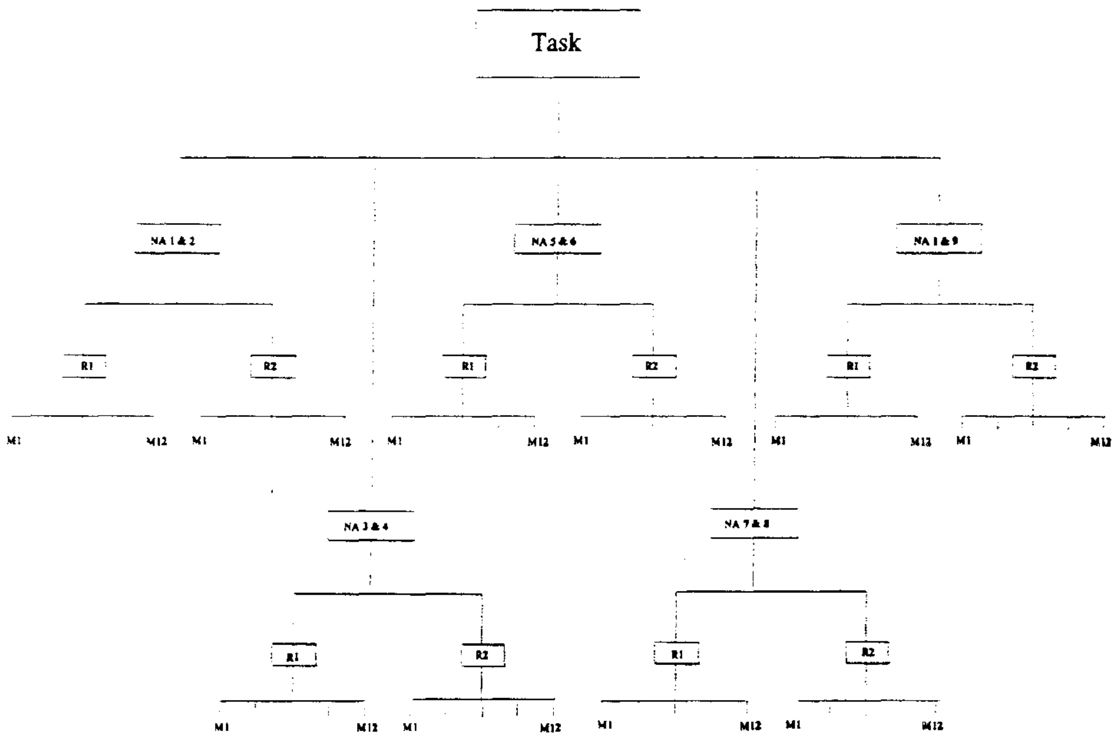

Figure 21 Illustration of a Split-Plot Design (NA=Nursing Assistant, R=Resident, and M=Method)

Analysis of variance was performed on both subjective and objective data for each task. Table 2 outlines the ANOVA table for the biomechanical data with 12 methods for transferring residents from bed to chair. The number of nursing assistants is nine, i.e., a=9 and the number of residents/weight levels is two, i.e., b=2. Thus, the degree of freedom for these two factors are 8 and 1. The number of replications is two, i.e., n=2. Table 3 outlines the ANOVA table for the psychophysical data with "c" number of methods for each task. The different methods of transferring residents are considered as fixed factors since these methods are the items of interest (Montgomery, 1984). The resident weight factor and nursing assistant blocks are also treated as fixed factors for the same reason. The expected mean squares for this split-plot design are derived in Table 4.

Duncan's Multiple Range test (Montgomery, 1984) was performed to compare means and detect significant differences between the manual procedure and the other methods. It was also used to compare and detect significant differences between any two resident transfer methods and between the weight levels of the two residents. All of the statistical analyses performed on these data were done using the Standard Analysis System (SAS).

Table 2 ANOVA Table for Biomechanical Data

Sources	degree of freedom
Whole plot	
Nursing Assistants (S)	8
Resident Weight (W)	1
S x W	8
Subplot	
Method (M)	6
S x M	48
W x M	6
S x W x M	48
Errors	102
Total	227

Table 3 ANOVA Table for Psychophysical Data

Sources	degree of freedom
Whole plot	
Nursing Assistants (S)	8
Resident Weight (W)	1
S x W	8
Subplot	
Method (M)	(c-1)
S x M	8(c-1)
W x M	(c-1)
S x W x M	8(c-1)
Errors	(not estimable)
Total	c x 9 x 2 - 1

Note: The "c" value varies with different data set. For both the psychophysical stress rating data and the comfort and security data, "c" is equal to 12 for the transferring task and 2 for the task of lifting residents up in bed.

Table 4 Expected Mean Square Derivation for the Split-Plot Design

	a	b	c	1	
	F	F	F	R	
Factors	I	j	k	l	Expected Mean Square
Whole plot					
τ_i (S)	0	b	c	1	$\sigma^2 + bc\Sigma\tau_i^2/(a-1)$
β_j (W)	a	0	c	1	$\sigma^2 + ac\Sigma\beta_j^2/(b-1)$
$(\tau\beta)_{ij}$ (SW)	0	0	c	1	$\sigma^2 + c\Sigma\Sigma(\tau\beta)^2_{ij}/[(a-1)(b-1)]$
Subplot					
γ_k (M)	a	b	0	1	$\sigma^2 + ab\Sigma\gamma_k^2/(c-1)$
$(\tau\gamma)_{ik}$ (SM)	0	b	0	1	$\sigma^2 + b\Sigma\Sigma(\tau\gamma)^2_{ik}/[(a-1)(c-1)]$
$(\beta\gamma)_{jk}$ (WARREN R. MYERS)	a	0	0	1	$\sigma^2 + a\Sigma\Sigma(\beta\gamma)^2_{jk}/[(b-1)(c-1)]$
$(\tau\beta\gamma)_{ijk}$ (SWM)	0	0	0	1	$\sigma^2 + \Sigma\Sigma\Sigma(\tau\beta\gamma)^2_{ijk}/[(a-1)(b-1)(c-1)]$
$e_{(ijk)l}$ (Errors)	0	0	0	1	σ^2 (not estimable for subjective data)

RESULTS

The results of this research are summarized in this section. The results are divided into two sections, one for the biomechanical analyses and one for the psychophysical analyses. The results consistently demonstrate that the use of assistive devices results in a reduction in the total force required to complete a resident lift, and the perceived effort required to complete a resident lift.

BIOMECHANICAL ANALYSES

The biomechanical model input parameters were trunk flexion angle, trunk lateral bending angle, trunk rotation angle, and hand force magnitude. Nursing assistant specific anthropometric data were used as biomechanical model input model. Output was back compressive force and percentage of population capable of performing the task. Three percentages, based on torso strength, hip flexor/extensor strength, and the minimum of all body joints, are reported.

The biomechanical model input data were measured during the research. Body joint angle data were obtained from the video tapes using the motion analysis system. Hand force data were obtained from the force platforms and anthropometric data were obtained by measuring the subjects in the laboratory.

The input data were summarized by transfer method in Table 5 using group data for all nursing assistants and both residents. The mean, standard deviation, and range for trunk flexion angle, trunk lateral bending angle, trunk rotation angle, and the nursing assistants' hand forces are presented in the table. The significant findings about these input parameters are described below.

Trunk Flexion Angle - The largest mean trunk flexion angle (52°) occurred during activity #2 when the nursing assistants were using the baseline method to help the residents to a standing position. The second largest mean trunk flexion angle (50°) also occurred during activity #2 when the nursing assistants used the walking belt to pull the residents to a standing position. These two means (52° and 50°) were significantly larger than the mean trunk flexion angles for other methods and were not significantly different from each other. The smallest mean trunk flexion angle (35°) was associated with rolling the residents toward the nursing assistants (activity #1).

Trunk Rotation Angle - The largest mean trunk rotation angle of 20° occurred when a single nursing assistant rotated the residents to the edge of the bed while preparing them for transfer with the stand-up lift or sliding board. The mean angle during this activity was significantly larger than the mean trunk rotation angles associated with other transfer methods.

Trunk Lateral Bending Angle - The largest mean trunk lateral bending angle (21°) occurred as a nursing assistant (working alone) rotated a resident to the edge of the bed in preparation for transfer with a stand-up lift or sliding board. The smallest and the second smallest mean trunk lateral bending angles occurred when the residents were rolled toward the nursing assistants (5°) and when the residents were rolled away from the assistants (7°). These two means were significantly smaller than any other mean trunk lateral bending angles.

Table 5 Input Data for Biomechanical Analyses of Resident Transfer (Both Residents)

ACTIVITY #1 - Rotating/Rolling the Resident to Prepare for Transfer					
	Baseline method and walking belt (two-person)		Basket-sling lift and overhead lift (one-person)		Stand-up lift and sliding board (one-person)
Variables	Lifting torso (N=20)[1]	Lifting legs (N=20)	Rolling toward (N=36)	Rolling away (N=36)	Rotating resident (N=36)
Trunk flexion angle (°)	43±5[2] 35-50[3]	38±11 20-62	35±6 25-50	37±9 17-55	42±9 26-57
Trunk lateral bending (°)	12±6 4-26	10±7 0-21	5±5 0-15	7±5 0-15	21±9 3-38
Trunk rotation angle (°)	10±5 0-20	12±7 0-25	7±5 0-20	9±5 2-17	20±10 1-37
Hand force (N)	139±28 89-173	174±42 113-262	83±21 44-120	102±25 54-147	194±58 58-315
Group label[5]	C	B	E	D	A

ACTIVITY #2 - Help/Pull the Resident to a Standing Position					
Variables	Baseline method (N=40)	Walking belt (N=40)	Basket-sling lift[5]	Overhead lift[5]	Stand-up lift and sliding board[5]
Trunk flexion angle (°)	52±11 33-75	50±9 29-69	NA	NA	NA
Trunk lateral bending (°)	13±5 5-24	12±5 0-21	NA	NA	NA
Trunk rotation angle (°)	10±6 2-25	13±5 6-25	NA	NA	NA
Hand force (N)	129±41 53-209	114±36 48-195	NA	NA	NA
Group label[4]	C	D			

1 Number of observations ("a" nursing assistants x 2 residents x 2 replications).
2 Mean (43) and standard deviation (5) of N observations.
3 Range of observations.
4 Mean hand forces with the same group label are not significantly different ($p > 0.01$).
5 During this activity, the nursing assistants used the handset control to operate the lift devices to lift the resident out of the bed and lower into the chair. No significant lifting was involved.

Hand Force - The largest mean hand force of 194 Newtons (N) (range = 58 - 315 N) occurred when a single nursing assistant rotated the resident to the edge of the bed in preparation for a stand-up lift or sliding board transfer. This force was significantly greater than the hand forces associated with the other methods. The smallest mean hand force of 83 N (range = 44 - 120 N) occurred when a resident was being rolled toward the nursing assistants. It was significantly smaller than any other mean hand force.

The mean hand force was smaller for lifting a resident off of the bed (129 N) than the mean hand forces associated with lifting the resident's legs (139 N) or torso (174 N) while rotating the individual. The main reason is that the nursing assistants only helped the resident to a standing position as compared to lifting the total weight of the resident as in a nursing home environment. In addition, although the simulated residents were told to be passive, they provided some assistance by supporting their own weight. In a nursing home, there are many residents who cannot do this, but still must be transferred. It was impossible for the simulated resident not to help when the resident was lifted or pulled to a standing position.

In summary, transferring residents from bed to chair with the stand-up lift or sliding board required the most trunk rotation and trunk lateral bending. The largest hand force was also associated with the preparation for the stand-up lift or sliding board transfer. Rolling a resident in bed and lifting a resident's legs as two nursing assistants rotated the resident to a sitting position on the edge of the bed required the most trunk flexion.

Back Compressive Force. The biomechanical data are summarized by transfer method in Table 6 using the group data for all nursing assistants and both residents. The mean, standard deviation, and range for percentage of population capable of performing the task and back compressive force are presented. The population percentage and back compressive force are summarized based on the nursing assistant specific anthropometric data.

While raising the resident up in bed, the two-person baseline transfer method resulted in an average back compressive force of 3,487 N (range = 2391 - 4999 N). This mean compressive force exceeded the action limit (3,400 N) established by the National Institute for Occupational Safety and Health (NIOSH, 1981, 1991) and was significantly larger than the mean back compressive forces generated by all of the other methods except the transfer utilizing the stand-up lift which is a similar activity.

While standing the person up, the baseline transfer method resulted in an average back compressive force of 2,703 N (range = 1641 - 3573 N). The average back compressive force, while helping a resident off of the bed, was smaller than the mean back compressive forces associated with lifting the legs or torso while rotating the resident. The main reason is that the nursing assistants only helped the resident to a standing position as compared to lifting the total weight of the resident. The residents could remain passive during the first activity but could not during the second activity. In practice, it is impossible for simulated residents not to use their

Table 6 Summary of Biomechanical Measures for Resident Transfer (Both Residents)

ACTIVITY #1 - Rotating/Rolling the Resident to Prepare for Transfer					
	Baseline method and walking belt (two-person)		Basket-sling lift and overhead lift (one-person)		Stand-up lift and sliding board (one-person)
Variables	Lifting torso (N=20)[1]	Lifting legs (N=20)	Rolling toward (N=36)	Rolling away (N=36)	Rotating resident (N=36)
% Capable[2] (Torso)	78±22[3] 26-95[4]	84±13 53-97	84±15 38-97	87±13 44-96	74±16 41-97
% Capable[2] (Hip)	46±30 11-88	58±24 12-85	64±22 16-91	72±19 19-92	32±25 4-93
% Capable[2] (Minimum)	38±26 7-77	53±27 12-85	56±25 9-91	70±20 19-92	23±25 1-93
Compressive force (N)[2]	3487±614 2391-4999	3150±482 2298-4089	2951±503 2094-4367	2698±582 1804-4745	3454±571 2436-4618
Group label[5]	A	B	C	D	A

ACTIVITY #2 - Help/Pull the Resident to a Standing Position					
Variables	Baseline method (N=40)	Walking belt (N=40)	Basket-sling lift[6]	Overhead lift[6]	Stand-up lift and sliding board[6]
% Capable[2] (Torso)	85±14 45-97	87±12 48-97	NA	NA	NA
% Capable[2] (Hip)	58±26 7-93	61±27 5-90	NA	NA	NA
% Capable[2] (Minimum)	50±30 2-91	54±28 5-90	NA	NA	NA
Compressive force (N)[2]	2703±437 1641-3573	2660±639 1570-4203	NA	NA	NA
Group label[5]	D	D			

1 Number of observations ("a" nursing assistants x 2 residents x 2 replications).

2 Using the specific height, body weight and gender of the nursing assistants as model input.

3 Mean (78) and standard deviation (22) of N observations.

4 Range of observations.

5 Mean compressive forces with the same group label are not significantly different ($p > 0.01$).

6 During this activity, the nursing assistants used the handset control to operate the lift devices to lift the resident out of the bed and lower into the chair. No significant lifting was involved.

legs to support themselves as they are pulled to a standing position, and this reduces the force required to lift them to a standing position.

While standing the person up, the baseline transfer method resulted in an average back compressive force of 2,703 N (range = 1641 - 3573 N). The average back compressive force, while helping a resident off of the bed, was smaller than the mean back compressive forces associated with lifting the legs or torso while rotating the resident. The main reason is that the nursing assistants only helped the resident to a standing position as compared to lifting the total weight of the resident. The residents could remain passive during the first activity but could not during the second activity. In practice, it is impossible for simulated residents not to use their legs to support themselves as they are pulled to a standing position, and this reduces the force required to lift them to a standing position.

Back compressive force while using the walking belt was essentially the same as for the baseline method.

The average back compressive force was 2,951 N (range = 2094 - 4367 N) when the resident was rolled toward an assistant and 2,698 N (range = 1804 - 4745 N) when the resident was rolled away from the assistant.

The average back compressive force was 3,454 N (range = 2436 - 4618 N) when a single assistant rotated the resident to the edge of the bed. This mean compressive force also exceeded the NIOSH action limit (3,400 N) and was statistically larger than the mean back compressive forces associated with all of the other activities except lifting the resident's torsos.

In summary, the average back compressive forces associated with preparing a resident for transfer using the basket-sling lift and overhead lift were smaller than the forces associated with the baseline method and the NIOSH recommended action limit. Thus, the basket-sling and overhead lifts can significantly reduce the biomechanical loading on the nursing assistants' backs during the transfer of residents. Also, if the stand-up lift is used for a transfer, the lifting during the second phase of the manual lifting technique (activity #2) can be eliminated and biomechanical loading on nursing personnel can be reduced.

POPULATION STRENGTH CAPABILITY

The percentage of the population capable of performing a task is based on a comparison between the externally induced torque at a joint and the functional muscle group force available at the joint. The comparison is reported as the percent capable for that muscle group. It should be noted that the percent NOT capable (1 - percent capable) are at risk of musculoskeletal injury due to their inadequate strength. Three percentages of population capable of performing the task (torso strength, hip flexor/extensor strength, and the minimum of all body joints) were calculated in the biomechanical analyses. The mean, standard deviation, and range for percentages are presented in Table 6. Which shows that the range of population percentages capable was quite wide. This is primarily due to the individual nursing assistant anthropometry. Large nursing assistants create large biomechanical loads. This in turn results in a small percent of the population - only the very strong - being capable of performing the task. A close examination of those observations with small percentages of the population capable also revealed that relatively large hand forces were a significant factor.

Torso. When using the baseline transfer method, the average percentage of the population capable of performing the activity of lifting the resident's torso when two nursing assistants rotated the resident to a sitting position on the edge of the bed was 78 percent (range = 26% - 95%). The average percentage was 84 percent (range = 53% - 97%) when lifting the legs of the resident when two nursing assistants rotated the resident to a sitting position on the edge of the bed.

When rolling the resident, the average percentage of the population capable was 84 percent (range = 38% - 97%) when the resident was rolled toward the assistants and 87 percent (range = 44% - 96%) when the resident was rolled away from the assistants.

For the stand-up lift, the average percentage of the population capable of rotating a resident to the edge of the bed was 74 percent (range = 41% - 97%). This average percentage was significantly smaller than average percentages associated with other activities.

When using the baseline transfer method, the average percentage capable was 46 percent (range = 11% - 88%). This mean percentage was significantly smaller than the average percentages capable with the other transfer methods, except the transfer utilizing the stand-up lift and sliding board. The average percentage was 58 percent (range = 12% - 85%) for the activity of lifting the legs of the resident when two nursing assistants rotated the resident to a sitting position on the edge of the bed.

The average percentage capable was 64 percent (range = 16% -

91%) when the resident was rolled toward the assistants and 72 percent (range = 19% - 92%) when the resident was rolled away from the assistants.

For the stand-up lift, the average percentage of the population capable of rotating a resident to the edge of the bed was 32 percent (range = 4% - 93%). This average percentage was significantly smaller than average percentages associated with other activities.

Resident Effect. The biomechanical data were also analyzed by the resident and transfer method to determine the resident effect. The input data were summarized by the resident using group data for all nursing assistant and transfer method combinations in Table 7. The input data were further summarized by method using group data for all nursing assistants for each resident in Tables 8 and Table 9.

Table 7 shows that there was no significant difference in trunk flexion angle, trunk lateral bending, and trunk rotation angle between the heavier resident and the lighter resident. The mean hand force, required to transfer the heavier resident, was significantly larger than the mean hand force required to transfer the lighter resident with the corresponding transfer method.

The biomechanical measures based on the nursing assistant specific anthropometric data are summarized by the resident in Table 10 using group data for all nursing assistant and transfer method combinations. The biomechanical measures are further summarized by method using group data for all nursing assistants for each resident in Tables 11 and 12.

Table 7 Input Data by the Resident

Variables	Heavier Resident (N=114)[1]	Lighter Resident (N=114)	Significant Differences[2]
Trunk flexion angle (°)	43±11[3] 17-69[4]	44±11 20-75	No
Trunk lateral bending (°)	12±8 0-38	11±7 0-34	No
Trunk rotation angle (°)	12±8 0-37	11±6 0-35	No
Hand force (N)	146±59 44-315	114±40 44-231	Yes

[1] Number of observations ("a" nursing assistants x 2 residents x 2 replications).

[2] Means for the heavier and the lighter resident are significantly different ($p < 0.01$).

[3] Mean and standard deviation of N observations.

[4] Range of Observations.

Table 8 Input Data for Biomechanical Analyses for Transferring the Heavier Resident

ACTIVITY #1 - Rotating/Rolling the Resident to Prepare for Transfer					
	Baseline method and walking belt (two-person)		Basket-sling lift and overhead lift (one-person)		Stand-up lift and sliding board (one-person)
Variables	Lifting torso (N=10)[1]	Lifting legs (N=10)	Rolling toward (N=18)	Rolling away (N=18)	Rotating resident (N=18)
Trunk flexion angle (°)	41±5[2] 35-50[3]	41±12 26-62	35±7 25-50	36±11 17-50	44±9 26-57
Trunk lateral bending (°)	13±6 8-26	8±7 0-21	5±5 0-14	6±5 0-15	23±10 3-38
Trunk rotation angle (°)	12±7 0-20	12±6 4-21	7±6 0-20	9±5 2-17	23±11 4-37
Hand force (N)	150±27 93-173	188±52 113-262	89±19 44-120	109±27 62-147	227±54 134-315
Group label[4]	C	B	E	D	A

ACTIVITY #2 - Help/Pull the Resident to a Standing Position					
Variables	Baseline method (N=20)	Walking belt (N=20)	Basket-sling lift[5]	Overhead lift[5]	Stand-up lift and sliding board[5]
Trunk flexion angle (°)	50±11 33-65	49±10 29-69	NA	NA	NA
Trunk lateral bending (°)	14±4 5-24	12±6 0-21	NA	NA	NA
Trunk rotation angle (°)	10±6 2-25	14±5 6-25	NA	NA	NA
Hand force (N)	153±42 53-209	126±39 48-195	NA	NA	NA
Group label[4]	C	D			

1 Number of observations ("a" nursing assistants x 2 residents x 2 replications).
2 Mean (41) and standard deviation (5) of N observations.
3 Range of Observations.
4 Mean hand forces with the same group label are not significantly different ($p > 0.01$).
5 During this activity, the nursing assistants used the handset control to operate the lift devices to lift the resident out of the bed and lower into the chair. No significant lifting was involved.

Table 9 Input Data for Biomechanical Analyses for Transferring the Lighter Resident

ACTIVITY #1 - Rotating/Rolling the Resident to Prepare for Transfer					
	Baseline method and walking belt (two-person)		Basket-sling lift and overhead lift (one-person)		Stand-up lift and sliding board (one-person)
Variables	Lifting torso (N=10)[1]	Lifting legs (N=10)	Rolling toward (N=18)	Rolling away (N=18)	Rotating resident (N=18)
Trunk flexion angle (°)	44±4[2] 35-50[3]	36±10 20-51	36±5 29-46	37±8 25-55	41±8 32-55
Trunk lateral bending (°)	11±6 4-20	12±7 0-21	6±5 0-15	8±4 0-15	20±9 7-34
Trunk rotation angle (°)	9±4 4-15	11±9 0-25	7±3 2-13	8±5 2-16	17±8 1-35
Hand force (N)	128±27 59-168	159±21 120-196	76±21 44-120	95±21 54-129	162±42 58-231
Group label[4]	B	A	D	C	A

ACTIVITY #2 - Help/Pull the Resident to a Standing Position					
Variables	Baseline method (N=20)	Walking belt (N=20)	Basket-sling lift[5]	Overhead lift[5]	Stand-up lift and sliding board[5]
Trunk flexion angle (°)	54±10 40-75	51±9 30-63	NA	NA	NA
Trunk lateral bending (°)	12±5 5-24	12±4 5-20	NA	NA	NA
Trunk rotation angle (°)	11±5 4-20	13±4 6-22	NA	NA	NA
Hand force (N)	106±23 67-151	102±28 53-160	NA	NA	NA
Group label[4]	C	C			

[1] Number of observations ("a" nursing assistants x 2 residents x 2 replications).

[2] Mean (44) and standard deviation (4) of N observations.

[3] Range of observations.

[4] Mean hand forces with the same group label are not significantly different ($p > 0.01$).

[5] During this activity, the nursing assistants used the handset control to operate the lift devices to lift the resident out of the bed and lower into the chair. No significant lifting was involved.

Table 10 Biomechanical Measures for Resident Transfer by the Resident

Variables	Heavier Resident (N=114)[1]	Lighter Resident (N=114)	Significant Differences[2]
% Capable[3] (Torso)	81±16[4] 26-97[5]	85±14 36-97	Yes
% Capable[3] (Hip)	53±28 4-92	60±26 7-93	Yes
% Capable[3] (Minimum)	46±30 1-92	54±28 5-93	Yes
Compressive force (N)[3]	3102±677 1570-4999	2818±567 1641-4397	Yes

1 Number of observations ("a" nursing assistants x 2 residents x 2 replications).

2 Means for the heavier and the lighter resident are significantly different ($p < 0.01$).

3 Using the specific height, body weight and gender of the nursing assistants as model input.

4 Mean and standard deviation of N observations.

5 Range of Observations.

Table 11 Summary of Biomechanical Measures for Transferring the Heavier Resident

ACTIVITY #1 - Rotating/Rolling the Resident to Prepare for Transfer					
	Baseline method and walking belt (two-person)		Basket-sling lift and overhead lift (one-person)		Stand-up lift and sliding board (one-person)
Variables	Lifting torso (N=10)[1]	Lifting legs (N=10)	Rolling toward (N=18)	Rolling away (N=18)	Rotating resident (N=18)
% Capable[2] (Torso)	77±23[3] 26-93[4]	83±13 53-93	83±17 38-96	85±16 44-96	71±16 41-93
% Capable[2] (Hip)	43±33 11-82	59±25 18-85	64±22 16-88	71±21 19-92	26±21 4-73
% Capable[2] (Minimum)	37±30 11-77	51±29 15-85	54±25 16-88	70±21 19-92	19±20 1-73
Compressive force (N)[2]	3676±572 2977-4999	3216±517 2298-3085	3081±531 2407-4367	2786±708 1881-4745	3635±639 2436-4618
Group label[5]	A	B	B,C	D	A

ACTIVITY #2 - Help/Pull the Resident to a Standing Position					
Variables	Baseline method (N=20)	Walking belt (N=20)	Basket-sling lift[6]	Overhead lift[6]	Stand-up lift and sliding board[6]
% Capable[2] (Torso)	83±15 45-96	86±14 48-97	NA	NA	NA
% Capable[2] (Hip)	50±26 7-80	57±28 5-89	NA	NA	NA
% Capable[2] (Minimum)	41±30 2-80	49±29 5-89	NA	NA	NA
Compressive force (N)[2]	2919±434 1838-3573	2768±703 1570-4203	NA	NA	NA
Group label[5]	C,D	D			

1 Number of observations ("a" nursing assistants x 2 residents x 2 replications).
2 Using the specific height, body weight and gender of the nursing assistants as model input.
3 Mean (77) and standard deviation (23) of N observations.
4 Range of Observations.
5 Mean compressive forces with the same group label are not significantly different ($p > 0.01$).
6 During this activity, the nursing assistants used the handset control to operate the lift devices to lift the resident out of the bed and lower into the chair. No significant lifting was involved.

Table 12 Summary of Biomechanical Measures for Transferring the Lighter Resident

ACTIVITY #1 - Rotating/Rolling the Resident to Prepare for Transfer					
	Baseline method and walking belt (two-person)		Basket-sling lift and overhead lift (one-person)		Stand-up lift and sliding board (one-person)
Variables	Lifting torso (N=10)[1]	Lifting legs (N=10)	Rolling toward (N=18)	Rolling away (N=18)	Rotating resident (N=18)
% Capable[2] (Torso)	79±23[3] 36-95[4]	85±13 59-97	86±13 48-97	88±10 63-96	78±16 45-97
% Capable[2] (Hip)	50±28 17-88	57±25 12-84	65±22 21-91	73±17 31-91	37±28 7-93
% Capable[2] (Minimum)	40±24 7-77	55±25 12-84	58±26 9-91	70±20 31-91	27±29 5-93
Compressive force (N)[2]	3299±625 2391-4397	3085±462 2585-3806	2822±452 2094-3904	2610±424 1804-3438	3273±439 2470-3990
Group label[5]	A	A	B	C	A

ACTIVITY #2 - Help/Pull the Resident to a Standing Position					
Variables	Baseline method (N=20)	Walking belt (N=20)	Basket-sling lift[6]	Overhead lift[6]	Stand-up lift and sliding board[6]
% Capable[2] (Torso)	86±14 46-97	87±11 58-97	NA	NA	NA
% Capable[2] (Hip)	65±26 8-93	64±25 15-90	NA	NA	NA
% Capable[2] (Minimum)	60±27 8-91	59±26 14-90	NA	NA	NA
Compressive force (N)[2]	2487±448 1641-3187	2552±566 1706-3528	NA	NA	NA
Group label[5]	C	C			

1 Number of observations ("a" nursing assistants x 2 residents x 2 replications).
2 Using the specific height, body weight and gender of the nursing assistants as model input.
3 Mean (79) and standard deviation (23) of N observations.
4 Range of observations.
5 Mean compressive forces with the same group label are not significantly different ($p > 0.01$).
6 During this activity, the nursing assistants used the handset control to operate the lift devices to lift the resident out of the bed and lower into the chair. No significant lifting was involved.

CONSISTENCY OF NURSING ASSISTANT PERFORMANCE

There were 114 data points for each replication. The mean and standard deviation of the back compressive forces for the first replication were 2947.1 and 629.8 N, and 2973.6 and 645.1 N for the second replication. The mean and standard deviation of the hand forces for the first replication were 129.3 and 52.2 N, and 130.8 and 52.7 N for the second replication. In both cases, a T test showed that there was no significant difference between replications one and two. As a group, the nursing assistants were quite consistent when performing resident transfers.

STATISTICAL MODEL VERIFICATION

The R^2 for the statistical model used to analyze the back compressive force data is 0.94. The F-statistic for the model is 15.67 (P = .0001). The predicted back compressive force and the residual values are plotted against the observed back compressive force in Figures 22 and 23. The residuals are normally and randomly distributed. The residual values range from -532 to 532 N and remain constant throughout the range of the observed back compressive force. In addition, the mean of the residual values is equal to zero. All of these statistics indicate that the statistical model is adequate.

The R^2 for the statistical model used to analyze the hand force data is 0.94. The F-statistic for the model is 16.31 (P = .0001). The predicted hand force and the residual values are plotted against the observed hand force in Figure 24 and 25. The residuals are normally and randomly distributed. The residual values range from -40 to 40 N and remains constant throughout the range of the observed hand forces. In addition, the mean of the residual values is equal to zero. All these statistics also indicate that the statistical model for analyzing the hand force data is adequate.

Basket-sling Lift Pulling Force. When residents are transferred to a chair, they must be placed so that they sit upright. The nursing assistant does that by positioning the sling over the chair seat and pulling on a handle located at the back of the sling while lowering it. If done correctly, no repositioning is necessary. The ease with which this activity is done is important both in reducing the physical stress on nursing assistants and for resident comfort and acceptance of the lifting devices. The hand forces required to complete this activity were measured while the nursing assistants stood on a force platform and pulled the resident to an upright position in the chair. The hand force data are presented in Appendix I for all combinations (nursing assistant - resident - device) of transfer, and are summarized in Table 13. The sling handle on lift #5 required the largest mean force of 174 N (range = 53 - 263 N), which was significantly larger than the mean pulling forces associated with other basket-sling lifts.

The design of the sling, the sling handle, the handle position, and frame of the lift are the primary factors that cause the differences in the pulling forces between different lifts. The handle on some slings is positioned too low, and is not easily grasped. This resulted in an awkward posture while pulling.

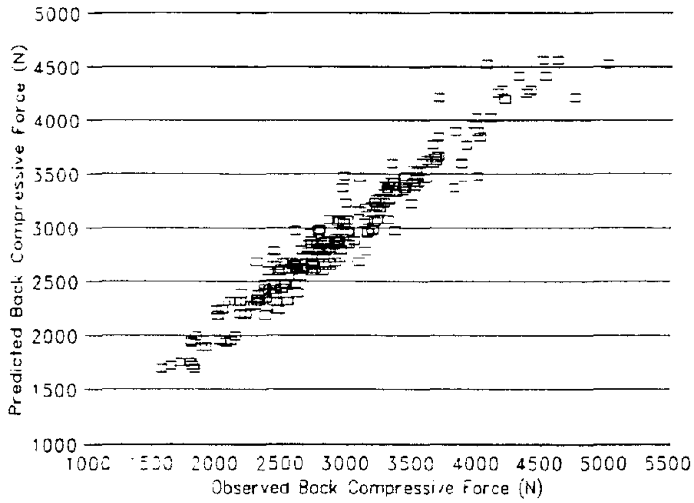

Figure 22 Predicted back Compressive Force
Vs. Observed Back compressive force

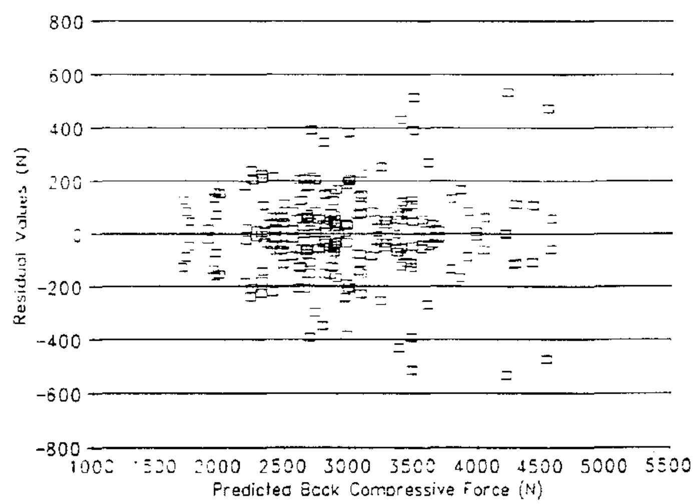

Figure 23 Residual Values vs. Predicted
Back Compressive Force

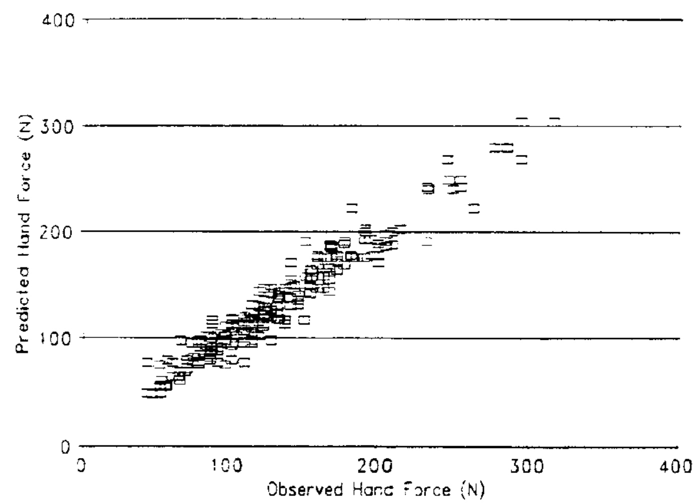

Figure 24 Predicted Hand Force vs.
Observed Hand Force

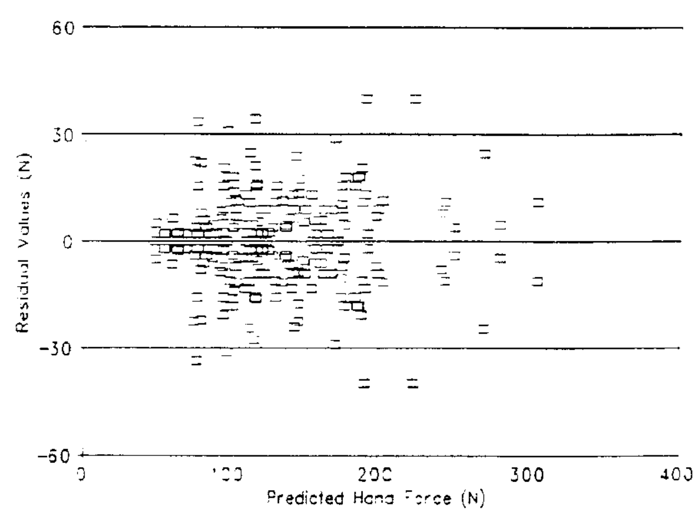

Figure 25 Residual Values vs. Predicted
Hand Force

The average pulling force was 160 N when the heavier resident was positioned in the chair and 134 N when the lighter resident was seated. This difference was significant, indicating resident size as an important factor in determining the physical stress associated with this aspect of patient handling.

RESIDENT/DEVICE MANEUVERING FORCES

Three other activities associated with bed to chair transfers are pushing and turning the lift while residents was being supported in the sling, and gliding the residents across the sliding board.

The pushing and turning forces are further summarized by device for both residents in Table 14.

Lift #6 required the largest mean pushing force (44 N; range = 32 - 57 N). Lift #8 required the smallest mean pushing force (24 N; range = 15 - 38 N). The sliding board required the largest mean turning force (81 N) which was significantly larger than the mean turning forces associated with the lift devices.

When statistical analysis was performed on the basket-sling lift data, the mean pushing force for lift #5 was significantly smaller than those mean pushing forces for lifts #6 and 7. There were no statistical differences in the mean turning forces among the basket-sling lifts.

Table 13 Pulling Force Required by the Basket-sling Lift

Method	Mean (N)	Group label	Standard deviation	Range
	Both Residents (N=18)			
Lift #5	174	A	60	53-263
Lift #6	143	B	40	85-209
Lift #7	121	C	45	36-196
Lift #8	152	B	49	53-240
Lift #9	145	B	45	80-240
	The Heavier Resident (N=9)			
Lift #5	191	A	67	67-263
Lift #6	171	A	35	120-209
Lift #7	122	B	48	49-196
Lift #8	163	A,B	52	67-240
Lift #9	152	A,B	45	93-214
	The Lighter Resident (N=9)			
Lift #5	157	A	49	53-214
Lift #6	114	B	21	85-147
Lift #7	121	B	41	36-174
Lift #8	140	A,B	45	53-209
Lift #9	137	A,B	45	80-240

Notes: 1) The pulling force is associated with the activity of pulling a handle on the back of the sling while lowering the resident into the chair in an upright position;

2) Mean pulling forces with the same group label (A or B) are not significantly different ($p > 0.05$).

Table 14 Resident/Device Maneuvering Forces (N=18 for both residents and N=9 for each resident)

Method	Mean[1] (N)	Group label[2]	Standard deviation	Range	Mean Heavy[3]	Mean Light[3]
Pushing Force						
Lift #1	37	C,D	7	28-53	39	35
Lift #2	35	D	6	25-44	38	32
Lift #3	36	C,D	6	25-44	38	33
Lift #4	37	C,D	10	15-59	41	32
Lift #5	39	B,C	6	25-55	42	28
Lift #6	44	A	7	32-57	47	56
Lift #7	43	A	6	35-54	44	42
Lift #8	24	E	6	15-38	25	23
Lift #9	42	A,B	7	30-53	45	39
Turning Force						
Sliding board	81	A	40	38-163	89	74
Lift #1	31	B	7	20-42	32	29
Lift #2	27	B,C	4	20-34	28	27
Lift #3	27	B,C	10	8-47	28	26
Lift #4	29	B,C	6	21-43	29	29
Lift #5	29	B,C	5	20-39	30	28
Lift #6	31	B	6	23-41	31	31
Lift #7	31	B	8	10-52	31	30
Lift #8	24	C	5	16-34	26	23
Lift #9	32	B	7	20-45	32	32

[1] The mean maneuvering force is associated with the activity of pushing and turning the lift to the chair while the resident is supported in the sling;
[2] Mean pushing or turning forces with the same group label (A or B) are not significantly different ($p > 0.05$);
[3] Mean pushing or turning forces for the each resident.

When statistical analysis was performed on the stand-up lift data, the mean pushing forces for lifts #2 and 3 were statistically smaller than the mean turning force for lift #1. No statistical differences in the mean turning forces were found among the stand-up lifts.

The data for the basket-sling and stand-up lifts for each of the four manufacturers were averaged and compared in Table 15.

Pushing and turning forces were further summarized by type of lift (basket-sling vs. stand-up lifts) in Table 16. The average pushing force was 42 N for the basket-sling and 36 N for the stand-up lift. The average turning force was 31 N for the basket-sling and 19 N for the stand-up lift. Statistical differences were found in the mean pushing forces or turning forces between the basket-sling and stand-up lifts.

Table 15 Resident/Device Maneuvering Forces by the Manufacturer (N=18)

Method	Mean (N)	Group label	Standard deviation	Range
Pushing Force				
Manufacturer 1	38	A	6	28-52
Manufacturer 2	40	A	5	33-50
Manufacturer 3	39	A	4	33-48
Manufacturer 4	39	A	8	26-55
Turning Force				
Manufacturer 1	30	A	5	22-40
Manufacturer 2	29	A	7	19-41
Manufacturer 3	29	A	5	16-43
Manufacturer 4	31	A	5	22-40

Notes: 1) The maneuvering force is associated with the activity of pushing and turning the lift to the chair while the resident is supported in the sling;
2) Mean pushing or turning forces with the same group label (A or B) are not significantly different ($p > 0.05$).

Table 16 Resident/Device Maneuvering Forces by the Type of Lift (N=72)

Method	Mean (N)	Group label	Standard deviation	Range
Pushing Force				
Basket-sling lift	42	A	7	25-57
Stand-up lift	36	B	7	15-59
Turning Force				
Basket-sling lift	31	A	7	10-52
Stand-up lift	29	B	7	8-47

Notes: 1) The maneuvering force is associated with the activity of pushing and turning the lift to the chair while the resident is supported in the sling;
2) Mean pushing or turning forces with the same group label (A or B) are not significantly different ($p > 0.05$).

The design of the wheels, width and length of the lift base, shape of the lift base, and locations of the pushing frame are the primary factors that cause the differences in pushing and turning forces between different lifts. Some lifts have six wheels and some have four. Some manufacturers used a single wheel castor while others used double castors. An inappropriate pushing frame position may force the nursing assistants to use awkward postures which aggravate the effect of large pushing or turning forces.

In summary, the sliding board is the most difficult and lift #8 is the easiest to maneuver. There were some differences in pushing or turning forces between lifts, and there was a significant difference in pushing force between the heavier than the lighter residents. The basket-sling lift required greater forces to push or turn than the stand-up lift. Pushing the lift while the resident is being supported in a sling is more stressful than turning the lift.

PSYCHOPHYSICAL ANALYSIS

Ratings of Perceived Exertion. The RPE ratings for the 12 transfer methods are summarized in Table 17. For all but lift #9, the lower back was perceived as the most stressed.

Shoulder - The baseline method had the largest mean shoulder RPE (9.8). Lifts #5 and #9 had the second largest mean shoulder RPE (9.7), and Lift #2 had the smallest shoulder RPE (7.7).

Upper Back - The largest mean upper back RPE rating (9.8) occurred when using lift #5, and the second largest (9.6) was associated with the baseline method. Although this difference was statistically significant, it probably has limited practical significance.

Lower Back - The largest mean lower back RPE (10.4) occurred when using the sliding board, and the second largest (10.3) was associated with the baseline transfer method and lift #5. Transfers using lift #2 were again rated the least stressful with a mean of 8.0.

Whole Body - The largest mean whole body rating (10.1) was associated with the use of the baseline transfer method and the sliding board. The next largest mean whole body RPE (9.8) was associated with lift #5. Moving residents with lift #2 was again observed to have the smallest mean rating (8.0).

Table 17 Ratings of Perceived Exertion for Resident Transfer by Method (N=18[1])

Method	Ratings of perceived exertion			
	Shoulder	Upper back	Lower back	Whole body
Baseline method (2)[3]	9.8±2.0[2] 7-13[4] (A)	9.6±2.2 6-13 (A)	10.3±2.0 7-13 (A)	10.1±2.0 7-13 (A)
Walking belt (2)	8.5±1.6 6-12 (DC)	8.3±1.9 6-12 (BCD)	9.0±1.7 7-11 (BC)	8.7±1.6 7-12 (BC)
Sliding board (1)	9.2±2.2 7-15 (ABC)	9.2±1.9 7-13 (ABC)	10.4±1.9 7-13 (A)	10.1±2.3 7-14 (A)
Lift #1 (1)	8.4±1.9 6-12 (DC)	8.2±2.0 6-13 (DC)	8.7±1.8 6-12 (BC)	8.4±1.8 6-12 (BC)
Lift #2 (1)	7.7±1.1 6-10 (D)	7.6±1.2 6-10 (D)	8.0±1.4 6-11 ©	8.0±1.2 6-10 ©
Lift #3 (1)	8.4±1.5 6-11 (DC)	8.5±1.4 6-11 (BCD)	8.8±1.5 6-11 (BC)	8.5±1.3 6-10 (BC)
Lift #4 (1)	8.2±1.7 6-13 (DC)	8.2±1.8 6-12 (DC)	8.4±2.0 6-13 ©	8.3±1.6 6-12 (BC)
Lift #5 (1)	9.7±1.7 7-13 (AB)	9.8±1.8 7-13 (A)	10.3±1.8 7-13 (A)	9.8±1.8 7-13 (A)
Lift #6 (1)	8.8±1.5 7-12 (ABC)	8.2±1.2 6-10 (CD)	8.7±1.3 7-11 (BC)	8.4±1.2 7-11 (BC)
Lift #7 (1)	8.4±1.4 6-11 (DC)	8.3±1.3 6-11 (BCD)	8.7±1.6 6-11 (BC)	8.6±1.5 6-11 (BC)
Lift #8 (1)	8.7±1.4 7-13 (BCD)	8.9±1.5 7-12 (ABC)	9.6±2.0 7-13 (AB)	9.2±1.9 7-12 (AB)
Lift #9 (1)	9.7±2.3 6-13 (A)	9.3±2.3 6-15 (AB)	9.5±1.8 7-13 (AB)	9.7±2.1 7-13 (A)

[1] N=20 for the baseline and walking belt methods.
[2] Mean and standard deviation of nine nursing assistants and two residents.
[3] # of nursing assistants required by the transfer method.
[4] Range of ratings.
[5] Column means with the same group label are not significantly different (p > 0.05).

In summary, some devices received psychophysical stress ratings as high as the baseline transfer method. The high stress ratings for some devices were caused by the postural stresses which result from sub-tasks such as placing and removing slings from underneath the patient, attaching slings to the lift, maneuvering and steering the lift to the chair, etc. The mathematical differences between scores have limited meaning, but there was a consistent difference in the patterns meaning that a given method was consistently <u>perceived</u> as causing a different stress level than another method. The psychophysical ratings indicated that the use of the sliding board and lift #5 did not result in a reduction in perceived stress to the shoulders, upper back, lower back, or whole body of the nursing assistants. The use of the assistive devices including the walking belt generally resulted in significantly less perceived stress to all four body areas evaluated. This conclusion is generally consistent with the conclusion generated from the biomechanical evaluation.

Analysis by Method Group. The RPE data are summarized by the transfer method group in Table 18. There were four designs of basket-sling lifts and four designs of stand-up lifts. There was only one design in each of the other four method groups.

At the shoulder, the baseline transfer method was the most stressful. The walking belt and stand-up lift had significantly lower ratings than the baseline method.

At the upper back, the baseline transfer method was again the most stressful, and the walking belt and stand-up lift had significantly lower ratings than the baseline method. In addition, the mean upper back rating for the stand-up lift was significantly lower than that for the sliding board.

The nursing assistants consistently rated the lower back as the most highly stressed part of the body. The largest mean lower back RPE (10.4) occurred when the sliding board was used. The second largest mean RPE was 10.3 when the baseline transfer method was used. These two mean ratings were statistically higher than the other mean ratings with the exception of the transfer utilizing the overhead lift. There were no significant differences in the mean ratings for the lower back among the basket-sling lift, stand-up lift, and walking belt.

The nursing assistants were directed to complete the ease of use rating by evaluating all aspects of device use <u>except</u> physical exertion. This was rated separately, and this point was reinforced during each rating period.

The ease of use ratings for each transfer method are summarized in Table 19. The smallest mean ease of use rating (1.4) was observed with lift #2, while Lift #5 received the largest mean ease of use rating (2.9).

Table 19 indicates that the minimum rating for every transfer method was 1 (extremely easy) and the maximum rating varied with method. The sliding board and lift #5 had a maximum rating of 5 (extremely difficult). This pattern suggests that there is a great deal of individual variability in the perception of difficulty of use of equipment. This variability probably reflects the differences in size, strength, flexibility, and experience of the nursing assistants.

Table 18 Ratings of Perceived Exertion for Resident Transfer by Method Group

Method group	Ratings of perceived exertion			
	Shoulder	Upper back	Lower back	Whole body
Baseline method (2)[2]	9.8±2.0[1] (7-13)[3] (A)	9.6±2.2 (6-13) (A)	10.3±2.0 (7-13) (A)	10.1±2.0 (7-13) (A)
Walking belt (2)	8.5±1.6 (6-12) (B)	8.3±1.9 (6-12) (BC)	9.0±1.7 (7-11) (BC)	8.7±1.6 (7-12) (C)
Basket-sling lift (1)	9.2±1.8 (6-13) (AB)	8.9±1.8 (6-15) (ABC)	9.3±1.7 (6-13) (BC)	9.1±1.8 (6-13) (BC)
Overhead lift (1)	8.7±1.4 (7-13) (AB)	8.9±1.5 (7-12) (ABC)	9.6±2.0 (7-13) (AB)	9.2±1.9 (7-12) (ABC)
Stand-up lift (1)	8.2±1.6 (6-13) (B)	8.1±1.6 (6-13) (C)	8.5±1.7 (6-13) (C)	8.3±1.5 (6-12) (C)
Sliding board (1)	9.2±2.2 (7-15) (AB)	9.2±1.9 (7-13) (AB)	10.4±1.9 (7-13) (A)	10.1±2.3 (7-14) (AB)

1 Mean and standard deviation of nine nursing assistants and two residents.
2 No. of nursing assistants required by the transfer method.
3 Range of the ratings.
4 Column means with the same group label are not significantly different ($p > 0.05$).

The mean whole body RPE for the baseline transfer method (10.1) was significantly higher than all other method means, except for the sliding board.

In summary, the assistive device other than the sliding board consistently resulted in less perceived stress to the nursing assistants.

Table 19   Ease of Use Ratings by Method

Method	N	Mean rating[1]	Standard deviation	Range
Baseline method	20	$1.8^{D,E}$	0.6	1-3
Walking belt	20	$1.9^{C,D,E}$	1.0	1-4
Sliding board	18	2.7^{A}	1.0	1-5
Lift #1	18	$2.2^{B,C}$	0.6	1-3
Lift #2	18	1.4^{E}	0.6	1-3
Lift #3	18	$1.9^{C,D}$	0.7	1-3
Lift #4	18	1.5^{E}	0.6	1-3
Lift #5	18	2.9^{A}	1.1	1-5
Lift #6	18	$1.9^{C,D}$	0.8	1-4
Lift #7	18	$2.0^{C,D}$	0.7	1-3
Lift #8	18	$2.6^{A,B}$	1.2	1-4
Lift #9	18	$2.6^{A,B}$	0.9	1-4

[1] The nursing assistants rated from 1 for extremely easy to 5 for extremely difficult; and mean ratings with the same group label (A, B, etc.) are not significantly different ($p > 0.05$).

The ease of use ratings for resident transfer methods are further summarized by the method group in Table 20. The stand-up lift and the baseline transfer method had the smallest mean rating of 1.8 and the mean for the walking belt method was 1.9. The reason the mean ratings for the walking belt and stand-up lift were low is that their operating procedures were simple. The sliding board had the largest mean rating of 2.7. The mean ease of use rating for the basket-sling lift was 2.3.

Table 20 Ease of Use Ratings by Method Group

Method group	N	Mean rating[1]	Standard deviation	Range
Baseline method	20	1.8[B]	0.6	1-3
Walking belt	20	1.9[B]	1.0	1-4
Basket-sling lift	72	2.3[A]	0.9	1-5
Overhead lift	18	2.6[A]	1.2	1-4
Stand-up lift	72	1.8[B]	0.7	1-3
Sliding board	18	2.7[A]	1.0	1-5

[1] The nursing assistants rated from 1 for extremely easy to 5 for extremely difficult; and mean ratings with the same group label (A, B, etc.) are not significantly different ($p > 0.05$).

The nursing assistants used the baseline transfer method in their jobs, thus their ease-of-use ratings for this technique were low (easy) as expected. The data show that the assistants indicated that using the walking belt and stand-up lift were as uncomplicated as the baseline transfer method.

RATINGS OF SLING, FRAME, AND MANEUVERING

The ease-of-use ratings for the sling are summarized by the device in Table 21 for weight bearing residents and in Table 22 for non-weight bearing residents.

The ease-of-use ratings for the frame or spreader bar are summarized by device in Table 23 for weight bearing residents and in Table 24 for non-weight bearing residents. The ease of maneuvering ratings are summarized by device in Table 25 for weight bearing residents and in Table 26 for non-weight bearing residents.

Within the classification of weight bearing and non-weight bearing residents, the residents are also classified into five different types: normal, combative, heavy, contracted, and with medical devices. When the nursing assistants were asked to rate the ease of using the sling, frame, or ease of maneuvering of the lifts, they were told that normal residents were considered simulated residents in this lab study. A combative resident is considered as one who does not cooperate in transferring or repositioning, suddenly resists movement, tries to grasp or hit the nursing assistants, etc. Residents whose body weights are over 91 kg (200 lbs) are considered as heavy residents. Residents with contracted knee, elbow, or other body joints are considered contracted residents. A contracted body joint limits the range of motion for the adjacent body segments. Residents with medical devices are those who have had surgery or need intensive care so that devices, such as heart and glucose monitors, are attached to certain parts of their bodies. Residents with any of these four attributes may pose additional difficulty in using lift devices.

Table 21 Ease of Use Ratings for the Sling (Weight Bearing)

	Resident Characteristics				
Method	Normal	Combative	Heavy	Contracted	With equipment
Lift #1	2.2±1.0[1] 1-4[2] 9[3]	3.9±0.9 3-5 7	3.9±0.7 1-5 7	4.0±0.7 3-5 5	3.6±1.0 2-5 7
Lift #2	1.4±0.5 1-2 9	2.7±0.8 2-4 7	2.6±0.9 2-4 8	3.0±1.0 2-4 5	3.0±1.4 1-5 7
Lift #3	2.1±1.1 1-4 9	3.7±0.8 3-5 7	3.1±1.1 2-5 8	3.6±0.9 3-5 5	3.3±1.1 2-5 7
Lift #4	1.7±0.7 1-3 9	3.1±1.1 2-5 7	2.8±0.9 2-4 8	3.0±0.7 2-4 5	2.9±0.7 2-4 7
Lift #5	2.2±1.0 1-4 9	3.3±0.9 2-5 8	3.3±1.4 1-5 9	3.4±1.0 2-5 7	3.3±1.3 1-5 8
Lift #6	1.7±0.7 1-3 9	2.5±1.1 1-4 8	2.4±1.1 1-4 9	2.7±1.0 1-4 9	2.8±1.3 1-5 8
Lift #7	1.9±0.8 1-3 9	2.6±0.9 1-4 8	2.7±0.9 1-4 9	2.3±0.9 1-4 9	2.6±0.9 1-4 8
Lift #8	2.3±0.7 2-4 9	3.9±0.8 3-5 8	3.6±1.1 2-5 9	3.4±0.9 2-5 9	3.5±0.8 2-4 8
Lift #9	2.0±0.7 1-3 9	2.8±1.2 1-4 8	2.7±1.3 1-5 9	2.8±1.1 2-5 9	2.9±1.0 2-5 8

1 Mean and standard deviation of nine nursing assistants and two residents.

2 Range of the ratings on five-point Likert scale.

3 The number of nursing assistants believed that the method was going to work for the type of residents.

Table 22 Ease of Use Ratings for the Sling (Non-Weight Bearing)

	Resident Characteristics				
Method	Normal	Combative	Heavy	Contracted	With equipment
Lift #1	3.3±1.0[1]	4.0± .	5.0± .	N/A	4.5±0.7
	2-4[2]	4-4	5-5	N/A	4-5
	4[3]	1	1	0	2
Lift #2	2.3±1.5	N/A	3.0± .	N/A	4.0± .
	1-4	N/A	3-3	N/A	4-4
	3	0	1	0	1
Lift #3	2.3±1.5	N/A	3.0± .	N/A	4.0± .
	1-4	N/A	3-3	N/A	4-4
	3	0	1	0	1
Lift #4	2.3±1.5	N/A	3.0± .	N/A	4.0± .
	1-4	N/A	3-3	N/A	4-4
	3	0	1	0	1
Lift #5	2.2±1.0	3.4±0.9	3.3±1.4	3.4±1.0	3.3±1.3
	1-4	2-5	1-5	2-5	1-5
	9	8	9	7	8
Lift #6	1.7±0.7	2.5±1.1	2.3±1.0	2.7±0.9	2.6±1.3
	1-3	1-4	1-4	2-4	1-5
	9	8	9	9	8
Lift #7	1.8±0.7	2.6±0.9	2.4±1.0	2.3±0.9	2.4±0.9
	1-3	1-4	1-4	1-4	1-4
	9	8	9	9	8
Lift #8	2.6±0.9	3.4±0.8	3.4±1.2	3.2±0.7	3.4±0.9
	2-4	3-5	2-5	2-4	2-4
	9	7	9	9	8
Lift #9	2.0±0.7	2.6±1.1	2.4±1.0	2.7±1.0	2.9±1.0
	1-3	1-4	1-4	2-5	2-5
	9	8	9	9	8

1 Mean and standard deviation of nine nursing assistants and two residents.
2 Range of the ratings.
3 The number of nursing assistants believed that the method was going to work for the type of residents.

Table 23 Ease of Use Ratings for the Lift Frame (Weight Bearing)

	Resident Characteristics				
Method	Normal	Combative	Heavy	Contracted	With equipment
Lift #1	2.7±1.0[1] 1-4[2] 9[3]	4.0±1.0 2-5 7	3.7±1.4 1-5 7	3.6±0.5 3-4 5	3.1±0.9 2-4 7
Lift #2	2.1±0.8 1-3 9	2.7±1.4 1-5 7	2.4±1.3 1-4 8	3.2±1.5 1-5 5	2.6±1.3 1-5 7
Lift #3	2.2±1.0 1-4 9	3.1±0.9 2-4 7	3.0±1.3 1-5 8	3.8±0.8 3-5 5	3.1±1.2 2-5 7
Lift #4	1.7±0.7 1-3 9	3.1±1.3 1-5 7	2.5±1.2 1-4 8	3.4±0.9 2-4 5	2.6±1.3 1-4 7
Lift #5	2.1±1.1 1-4 9	2.5±1.2 1-4 8	2.4±1.3 1-4 9	2.4±1.1 1-4 7	2.6±1.2 1-4 8
Lift #6	1.8±0.4 1-2 9	2.8±1.3 1-5 8	2.6±1.3 1-5 9	2.6±1.0 1-4 9	2.6±1.1 1-4 8
Lift #7	2.2±1.0 1-4 9	3.3±1.7 1-5 8	2.7±1.2 1-4 9	2.6±1.1 1-5 9	2.5±0.9 1-4 8
Lift #8	3.0±1.3 1-5 9	3.8±1.3 2-5 8	3.7±1.4 1-5 9	3.3±1.1 2-5 9	3.3±1.0 2-5 8
Lift #9	2.0±1.0 1-4 9	3.3±1.7 1-5 8	2.7±1.1 1-4 9	2.4±0.9 1-4 9	2.5±0.9 1-4 8

1 Mean and standard deviation of nine nursing assistants and two residents.

2 Range of the ratings.

3 The number of nursing assistants believed that the method was going to work for the type of residents.

Table 24 Ease of Use Ratings for the Lift Frame (Non-Weight Bearing)

	Resident Characteristics				
Method	Normal	Combative	Heavy	Contracted	With equipment
Lift #1	3.0±1.4[1] 2-5[2] 4[3]	5.0± . 5-5 1	4.0± . 4-4 1	N/A N/A 0	4.0±0.0 4-4 2
Lift #2	2.0±1.0 1-3 3	N/A N/A 0	2.0± . 2-2 1	N/A N/A 0	4.0± . 4-4 1
Lift #3	2.0±1.0 1-3 3	N/A N/A 0	2.0± . 2-2 1	N/A N/A 0	4.0± . 4-4 1
Lift #4	2.0±1.0 1-3 3	N/A N/A 0	2.0± . 2-2 1	N/A N/A 0	4.0± . 4-4 1
Lift #5	2.1±1.1 1-4 9	2.5±1.2 1-4 8	2.3±1.2 1-4 9	2.3±1.1 1-4 7	2.4±1.3 1-4 8
Lift #6	1.7±0.5 1-2 9	2.6±1.4 1-5 8	2.4±1.4 1-5 9	2.3±1.1 1-4 9	2.4±1.3 1-4 8
Lift #7	2.3±1.0 1-4 9	3.4±1.6 1-5 8	2.8±1.2 1-4 9	2.8±1.2 1-5 9	2.5±1.1 1-4 8
Lift #8	3.0±1.3 1-5 9	3.9±1.3 2-5 7	3.6±1.5 1-5 9	3.4±1.1 2-5 9	3.1±1.1 1-4 8
Lift #9	2.0±1.0 1-4 9	3.3±1.7 1-5 8	2.7±1.2 1-4 9	2.6±1.0 1-4 9	2.4±1.1 1-4 8

1 Mean and standard deviation of nine nursing assistants and two residents.
2 Range of the ratings.
3 The number of nursing assistants believed that the method was going to work for the type of residents.

Table 25 Ease of Maneuvering Ratings (Weight Bearing)

	Resident Characteristics				
Method	Normal	Combative	Heavy	Contracted	With equipment
Lift #1	2.1±1.0[1] 1-4[2] 9[3]	2.7±1.3 2-5 7	3.0±0.8 2-4 7	2.2±1.3 1-4 5	2.6±1.3 1-4 7
Lift #2	1.8±0.7 1-3 9	2.9±0.7 2-4 7	2.8±0.9 1-4 8	2.2±1.3 1-4 5	2.4±1.0 1-4 7
Lift #3	2.1±0.8 1-4 9	3.1±0.7 2-4 7	2.9±0.6 2-4 8	2.6±1.1 1-4 5	2.6±1.0 1-4 7
Lift #4	1.9±0.6 1-3 9	2.3±0.5 2-3 7	2.8±0.5 2-3 8	2.6±0.9 1-3 5	2.6±1.0 1-4 7
Sliding board	2.3±1.4 1-5 9	4.7±0.5 4-5 6	4.4±0.8 3-5 7	4.0±0.8 3-5 7	3.9±1.1 2-5 7
Lift #5	2.0±1.0 1-4 9	2.5±0.8 2-4 8	2.8±1.0 2-4 9	1.9±0.9 1-3 7	2.4±1.3 1-4 8
Lift #6	2.2±0.8 1-3 9	2.9±1.0 2-4 8	3.0±1.0 2-4 9	2.4±0.9 1-4 9	2.6±0.9 1-4 8
Lift #7	2.0±0.7 1-3 9	2.5±0.9 1-4 8	2.7±1.0 1-4 9	2.1±0.9 1-4 9	2.3±1.0 1-4 8
Lift #8	2.2±1.1 1-4 9	3.4±1.2 2-5 8	3.3±1.3 1-5 9	2.6±1.2 1-4 9	2.6±1.3 1-4 8
Lift #9	2.4±0.9 1-4 9	2.8±0.9 2-4 8	3.2±0.8 2-4 9	2.6±1.0 1-4 9	2.8±1.0 1-4 8

1 Mean and standard deviation of nine nursing assistants and two residents.

2 Range of the ratings.

3 The number of nursing assistants believed that the method was going to work for the type of residents.

Table 26 Ease of Maneuvering Ratings (Non-Weight Bearing)

	Resident Characteristics				
Method	Normal	Combative	Heavy	Contracted	With equipment
Lift #1	2.0±0.8[1] 1-3[2] 4[3]	2.0± . 2-2 1	3.0± . 3-3 1	N/A N/A 0	3.0±0.0 3-3 2
Lift #2	2.0±1.0 1-3 3	N/A N/A 0	2.0± . 2-3 1	N/A N/A 0	3.0± . 3-3 1
Lift #3	2.3±0.6 2-3 3	N/A N/A 0	2.0± . 2-2 1	N/A N/A 0	3.0± . 3-3 1
Lift #4	2.3±0.6 2-3 3	N/A N/A 0	2.0± . 2-2 1	N/A N/A 0	3.0± . 3-3 1
Sliding board	2.6±1.3 1-5 9	4.8±0.4 4-5 7	4.6±1.1 2-5 7	4.3±0.8 3-5 6	4.0±0.8 3-5 7
Lift #5	2.0±1.0 1-4 9	2.6±0.7 2-4 8	2.9±0.9 2-4 9	2.0±1.0 1-3 7	2.5±1.3 1-4 8
Lift #6	2.2±0.8 1-3 9	3.0±1.1 2-4 8	3.0±1.0 2-4 9	2.3±0.9 1-4 9	2.5±0.9 1-4 8
Lift #7	2.0±0.7 1-3 9	2.5±0.9 1-4 8	2.7±1.0 1-4 9	2.1±0.9 1-4 9	2.1±1.0 1-4 8
Lift #8	2.3±1.0 1-4 9	3.4±1.3 2-5 7	3.3±1.1 2-5 9	2.9±1.2 1-4 9	3.0±1.2 1-4 8
Lift #9	2.3±0.7 1-3 9	2.6±0.7 2-4 8	2.9±0.8 2-4 9	2.4±0.9 1-4 9	2.6±0.9 2-4 8

[1] Mean and standard deviation of nine nursing assistants and two residents.

[2] Range of the ratings.

[3] The number of nursing assistants believed that the method was going to work for the type of residents.

The nursing assistants did not use the lifts on these types of residents. They did, however, have considerable experience with caring for and transferring these types of people. They were asked to draw on their experiences with these types of people and their experience with the lifting devices to estimate the ease/difficulty with which these people could be transferred with devices. While these estimations are subjective, they still provide valuable insights into the potential utility of lift devices.

Table 21 shows that all nine nursing assistants thought that all lift devices could be effectively used on normal weight bearing residents. For combative residents, however, seven of the nine felt the stand-up lifts (1-4) would be effective, and eight of the nine felt the sling lifts (5-9) would be effective. The same nursing assistant said no in both cases, and her concerns were the combative residents will be resistive to these devices and may hurt themselves or the assistants.

For heavy residents, seven of the nine felt the stand-up lifts (1-4) would be effective, and all nine nursing assistants felt the sling lifts (5-9) would be effective. There were two nursing assistants felt lift #1 could not be used on heavy residents because they were not sure the sling could hold/support the heavy residents.

For contracted residents, five of the nine felt the stand-up lifts (1-4) would be effective, and all nine nursing assistants felt the sling lifts (6-9) would be effective. There were two nursing assistants who did not think that lift #5 could be used on contracted residents.

Seven of the nine assistants believed that lifts #1 through 4 could be used on weight bearing residents with medical devices attached to them. Eight of the nine assistants believed that lifts #5 through 9 could be used on the residents with equipment attached to them. The basket-sling lifts have greater flexibility in resident-handling than the stand-up lifts.

Weight bearing residents - The statistical analysis of the rating data for weight bearing and normal residents is presented in Table 21.

For weight bearing residents with the other four characteristics, the mean ease of maneuvering rating for the sliding board was significantly higher than the mean ratings for other lift devices.

TRANSFER METHOD PREFERENCE

The transfer method data are summarized in Tables 27 and 28. The 12 transfer methods were divided into three groups: the baseline transfer method and the walking belt were in group one; group two consisted of the sliding board and the stand-up lifts; while the basket-sling and overhead lifts made up group three. These group classifications were determined by the similarities in the transfer procedures.

Table 27 indicates that in group one the nursing assistants did not strongly prefer one method over the other. Five nursing assistants preferred the walking belt and four preferred the baseline transfer method.

Table 27 Summary of Nursing Assistants' Method Preference (N=9)

Method	Group ranking Mean	Standard deviation	Range	Median
Group One				
Baseline method	1.6^{A}	0.5	1-2	2
Walking belt	1.4^{A}	0.5	1-2	1
Group Two				
Sliding board	4.7^{A}	1.0	2-5	5
Lift #1	3.9^{A}	0.8	2-5	4
Lift #2	1.6^{C}	1.0	1-4	1
Lift #3	2.9^{B}	0.6	2-4	3
Lift #4	2.0^{C}	0.9	1-3	2
Group Three				
Lift #5	3.1^{B}	1.4	1-5	4
Lift #6	2.0^{C}	1.3	1-4	1
Lift #7	2.3^{B,C}	1.0	1-3	3
Lift #8	4.9^{A}	0.3	4-5	5
Lift #9	2.7^{B,C}	0.9	2-4	2

Note:
In group one, 1 = the most preferred method, 2 = the least preferred method.
In groups two and three, 1 = the most preferred method, 5 = the least preferred method.
Mean group rankings in each group with the same label (A, B, etc.) are not significantly different ($p > 0.05$).

Table 28 Summary of Nursing Assistants' Overall Method Preference (N=9)

Method	Overall Ranking			
	Mean[1]	Standard deviation	Range	Median
Baseline method	9.6[A]	4.2	1-12	12
Walking belt	9.2[A]	3.0	3-11	11
Sliding board	10.1[A]	1.4	7-12	10
Lift #1	8.0[A,B]	2.1	5-12	8
Lift #2	4.0[C,D]	2.1	2- 8	3
Lift #3	6.4[B,C]	2.1	3-10	6
Lift #4	5.1[C,D]	2.1	1- 8	6
Lift #5	5.4[C,D]	3.1	1- 9	7
Lift #6	3.0[D]	2.8	1- 9	2
Lift #7	3.2[D]	1.9	1- 7	3
Lift #8	9.3[A]	2.0	5-12	9
Lift #9	4.6[C,D]	1.9	2- 7	4

[1] 1 = the most preferred method;
12 = the least preferred method;
and mean rankings with the same group label (A, B, etc.) are not significantly different ($p > 0.05$).

The differences were quite pronounced in group two where the means ranged from 1.6 to 4.7. The range reflects the large perceived differences in the use of the devices. A similar pattern was found in group one.

Table 28 summarizes the overall ranking of all twelve devices. There, they were asked to rank from 1 for the most preferred method to 12 for the least preferred method. Transfer methods with a mean overall ranking above 9.0 were significantly less preferred by the nursing assistants than the methods with a mean overall ranking below 6.5. The nursing assistants' preferences are further summarized by method group based on the overall data in Table 29. No significant preference ranking differences were found between the baseline, walking belt, sliding board, and overhead lift method groups. Overall, the assistants preferred the basket-sling lift and stand-up lift to any other method.

Table 29 Summary of Nursing Assistants' Overall Method Preference by Method Group

Method group	Mean ranking[1]	Standard deviation	Range
Baseline method	9.6[A]	4.2	1-12
Walking belt	9.2[A]	3.0	3-11
Basket-sling lift	4.1[B]	2.6	1- 9
Overhead lift	9.3[A]	2.0	5-12
Stand-up lift	5.9[B]	2.5	1-12
Sliding board	10.1[A]	1.4	7-12

[1] The nursing assistants ranked from 1 for the most preferred method to 12 for the least preferred method; and mean rankings with the same group label (A, B, etc.) are not significantly different ($p > 0.05$).

WORK TIME CONSIDERATIONS

Task Performance Time and Nursing Assistant Work Time. A transfer procedure must be practical if nursing personnel are to use it. A key aspect of practically is the amount of time required to use the procedure, and in fact during interviews, the researchers found the excessive time required by older style devices was the main reason they were not used.

Task performance time and nursing assistant work time required for transferring residents from bed to chair are summarized in Table 30. The mean task performance time was 63 seconds (range = 28 - 118 seconds) using the baseline transfer method and 132 seconds (range = 103 - 182 seconds) using the walking belt. The mean performance time was 176 seconds (range = 106 - 240 seconds) using the sliding board. There were significant differences among these three means (63, 132, and 176 seconds). The three means involved significantly shorter times than those required by other methods. Lift #8 hand the longest mean task performance time (324 seconds; range = 260 - 393 seconds). Lift #4 had the shortest mean task performance time (207 seconds; range = 123 - 287 seconds). There were no significant differences in the mean task performance times between lifts #2, 3, and 4. No significant differences in the mean task performance times were found among lifts #5, 6, 7, and 9.

Table 30 Task Performance Time and Nursing Assistant Work Time (N=18[1])

Method	Task performance time (seconds)	Group label[2]	Nursing assistant work time (seconds)	Group label[3]
Baseline method (2)[5]	63±28[4] (28-118)[6]	G	126±56 (56-236)	F
Walking belt (2)	132±27 (103-182)	F	264±54 (206-364)	B
Sliding board (1)	176±39 (106-240)	E	176±39 (106-240)	E
Lift #1 (1)	235±51 (132-325)	C	235±51 (132-325)	C
Lift #2 (1)	214±52 (134-292)	D	214±52 (134-292)	D
Lift #3 (1)	213±40 (121-288)	D	213±40 (121-288)	D
Lift #4 (1)	207±43 (123-287)	D	207±43 (123-287)	D
Lift #5 (1)	258±45 (175-315)	B	258±45 (175-315)	B
Lift #6 (1)	264±57 (182-380)	B	264±57 (182-380)	B
Lift #7 (1)	257±44 (180-330)	B	257±44 (180-330)	B
Lift #8 (1)	324±40 (260-393)	A	324±40 (260-393)	A
Lift #9 (1)	265±44 (201-350)	B	265±44 (201-350)	B

1 N = 10 for the baseline and walking belt methods.
2 Mean task performance times with the same group label are not significantly different ($p > 0.05$).
3 Mean nursing assistant work times with the same group label (A, B) are not significantly different ($p > 0.05$).
4 Mean and standard deviation of nine nursing assistants and two residents.
5 Number of nursing assistants required by the transfer method.
6 Range of task performance time.

Since the baseline transfer method and the walking belt technique required two nursing assistants, the assistant work times were double the task performance time, or 126 and 264 seconds. The remaining methods required only one nursing assistant; thus, the task performance time is equal to the nursing assistant work time for those methods. There were no significant differences in the mean task performance times between lifts #5 through 7, lift #9, and the walking belt.

The task performance time and nursing assistant work times are further summarized by method group in Table 31. The longest mean task performance time, 324 seconds (range = 260 - 393 seconds), was associated with the overhead lift. The mean task performance times for all six method groups were significantly different from each other.

The baseline method takes less actual transfer time and less nursing assistant time, but the numbers are somewhat misleading to be done with reasonable safety, the baseline method requires 2 people whereas the device based transfers require only one. In practice, these are many times when the second person is not readily available - and the person who is working alone attempts the transfer alone. This is "injury prime time". In addition, although the transfer to chair is quicker with the baseline, a transfer to the bathing area, the dining area, etc. will be much quicker with a device. Finally, during a transfer, there is generally some time spent socializing with the residents around the transfer time. The time spent preparing for a device transfer can be used for socializing, while time spent socializing before or after a baseline transfer is theoretically lost. (Socializing with the residents should be encouraged whenever possible.)

Thus, while it appears that a baseline transfer takes less time, when one examines a number of transfer parameters, the truth is that the actual time spent to work with either method type is nominally the same.

Table 31 Task Performance Time and Nursing Assistant Work Time by Method Group

Method group	Task performance time (seconds)	Group label[1]	Nursing assistant work time (seconds)	Group label[2]
Baseline method (2)[4]	63±28[3] (28-113)[5]	F	126±56 (56-236)	E
Walking belt (2)	132±27 (103-182)	E	264±53 (206-364)	B
Basket-sling lift (1)	261±47 (175-380)	B	261±47 (175-380)	B
Overhead lift (1)	324±40 (260-393)	A	324±40 (260-393)	A
Stand-up lift (1)	217±47 (121-325)	C	217±47 (121-325)	C
Sliding board (1)	176±39 (106-240)	D	176±39 (106-240)	D

[1] Mean task performance times with the same group label (A, B, etc.) are not significantly different ($p > 0.05$).
[2] Mean nursing assistant work times with the same group label (A, B, etc.) are not significantly different ($p > 0.05$).
[3] Mean and standard deviation of nine nursing assistants and two residents.
[4] Number of nursing assistants required by the transfer method.
[5] Range of task performance time.

Correlation analysis was performed to see whether the bed height preferred by the nursing assistants correlated with the biomechanical and psychophysical measures. No significant correlations were found.

Correlation analysis was also performed to see whether the bed height preferred by the nursing assistants correlated with the height, shoulder height, elbow height, hip height, and knee height of the nursing assistants. No significant correlations were found.

When the nursing assistants were questioned about their referred height, it became clear that unless the existing height was grossly difficult to use, no adjustments were made. This was probably due to their daily experience with varying uncomfortable bed heights.

COMFORT AND SECURITY

The residents' comfort and security ratings are summarized by the transfer method in Table 32, where a lower rating means greater comfort and security.

Comfort - The mean comfort ratings for the baseline method was 2.7. The comparative comfort ratings for the standup lifts ranged from 1.7 to 3.7, with two being more comfortable and two being less comfortable. A similar pattern was observed for the basket lifts where the ratings varied from 2.2 to 3.9 with three being lower and two being higher. The walking belt had a rating of 1.9 and the sliding board had a rating of 3.1. Clearly, there is no pattern here. The residents comfort was very dependent on the individual characteristics of the lifting devices. These characteristics are discussed later.

Table 32 Ratings of Comfort and Security from the Resident during Transfer (N=18[1])

Method	Comfort			Security		
	Mean[2]	Standard deviation	Range	Mean	Standard deviation	Range
Baseline method	$2.7^{C,D}$	0.8	1-4	$2.1^{E,F}$	0.6	1-3
Walking belt	$1.9^{E,F}$	0.6	1-3	1.9^{F}	0.6	1-3
Sliding board	$3.1^{B,C}$	0.9	2-5	$2.7^{A,B}$	0.6	2-4
Lift #1	$3.1^{B,C}$	0.9	2-4	$2.1^{E,F}$	0.3	2-3
Lift #2	1.7^{F}	0.5	1-2	1.9^{F}	0.6	1-3
Lift #3	3.4^{B}	0.9	2-5	$2.3^{C,D,E}$	0.6	1-3
Lift #4	$1.9^{E,F}$	0.5	1-3	$2.1^{E,F}$	0.5	1-3
Lift #5	3.9^{A}	0.8	2-5	$2.6^{B,C,D}$	0.8	2-4
Lift #6	$3.1^{B,C}$	0.6	2-4	$2.3^{D,E}$	0.5	2-3
Lift #7	$2.2^{E,F}$	0.5	1-3	$2.7^{B,C}$	1.0	1-4
Lift #8	$2.4^{D,E}$	0.6	2-4	$2.6^{B,C,D}$	0.7	2-4
Lift #9	$2.4^{D,E}$	0.8	1-4	3.1^{A}	0.9	2-4

[1] N = 10 for the baseline and walking belt methods.
[2] 1 = extremely comfortable, 5 = extremely uncomfortable; 1 = extremely secure, 5 = extremely insecure; and column mean ratings with the same group label (A, B, etc.) are not significantly different ($p>0.05$).

Security - The mean security rating for the baseline transfer method was 2.1. The comparative security ratings for the standup lifts varied from 1.9 to 2.3, with one being lower and one being higher. The basket lifts consistently had a worse rating than the baseline; they ranged from 2.3 to 3.1. The walking belt was slightly more secure with a rating of 1.9 while the sliding board was somewhat worse at 2.7. Here again, the specifics of the device were critical to the ratings. The consistently low ratings of the basket lifts were apparently due to the "insecure feeling" that is associated with being suspended in the air from four chains. One has no feeling of control in this situation.

Subjects' Comments. The nursing assistants' and the residents' comments about the transfer methods are briefly discussed below.

Nursing Assistants. Baseline Method - Nursing assistants felt comfortable with the baseline method because it was quick and easy, and because they were familiar with it.

Walking Belts. The nursing assistants liked the handles on the walking belt and believed that a rocking motion made the transfer easier. They did not like the buckle on the walking belt because it was hard to use and the belt might cause tissue shearing when pulling it to lift residents.

Sliding Board. The board was quick and useful for certain situations. It moved smoothly, was light, and not as easy to use as some other methods. The nursing assistants felt the device would benefit a resident with good upper body strength. The board worked better for light-weight people; removing the board from under the residents was difficult. It was hard to properly position a resident on the board. The board caused tissue shearing when it was removed. The simulated residents found the board scary because there was nothing for them to hold onto; as a result, they tended to grab the assistants. Real residents would find it even more intimidating. The assistants felt that they had to be extremely careful with this particular device because of the possibility of tearing the resident's skin. The subjects also did not feel comfortable with the board because it was cumbersome to use, i.e., placing a patient on the board and then moving them.

Lift #1 - Generally, lift #1 was liked because it was easy to use. The problems identified are described below. The knee pads need to be closer to the lifting column so the resident can be correctly positioned back far enough in a chair. Support arm bars were too narrow and handle grips were not comfortable for residents to grasp. The two arm supports were so close that when the residents were lifted up, the sling caused undue pressure on their back and sides. The sling that went around the resident did not have a safety belt. This is a serious safety concern. Nursing assistants felt the sling was not effective because a resident that goes limp or moves their arms may fall. Attaching the Velcro belt to and from the knee pads was awkward, and was also difficult to remove because the assistants needed to bend down and reach behind the legs to fasten or release it. The Velcro straps needed to go around both legs and were difficult to fasten correctly. The bed was too close to the legs to fit the Velcro in between then, making the leg straps very difficult to fasten. It would be better if the strap or straps fastened in front of the legs. One nursing assistant did not like the way the lift raised or lowered residents. Residents were raised straight up in the air. The lift speed was slow due to the combined effect of low motor speed and the long travel distance of the support arms. The residents felt very uncomfortable hanging in the air for the relatively long period of time. Some assistants felt the lift was hard to push and that hooking up the sling to the machine was difficult to accomplish due to the poorly designed support arms.

Lift #2 - The nursing assistants felt lift #2 was easiest to use. The waist belt made it safe for the resident. The loops made it quick to hook up the sling to the support arms. Little force was needed to perform a good, safe transfer. All assistants liked the sling and the way it lifted the resident. The lift was quite mobile and worked smoothly and rapidly. Nursing assistants liked the blue sling but not the open weave one. The sling may be too long for a skinny resident, but too short for a large resident. Assistants had to lean a resident forward to attach and detach sling straps when the sling was not long enough. The lift did not seat a resident far enough back in the chair. The hard metal edge around the foot rest may injure a resident. If the lift got close to the residents' toes, the toes would catch under that hard metal area of the foot rest. Nursing assistants felt the surface of the foot rest should be plastic without the hard edge on it, or that rubber or a foam piece be placed around it. The footplate needed to have the ridge removed so one's feet did not drag with it as the machine was pulled away. Assistants felt they could hurt their backs due to the force required to use the handle to open the legs of the lift base.

Lift #3 - This lift was quick, easy to operate, and mobile. The support arms were too narrow and too close to the resident's face. The arms appeared to be coming straight at the resident's face and were frightening. The machine lowered residents too quickly leading to a feeling of insecurity. Some assistants felt the sling attachments were bad because they had to bend too much to place the sling around residents. The safety belt swung too freely when putting it over a resident's head and at times accidently hit the resident in the head and face. This swinging belt created problems, as the belt was attached to the machine and it was difficult to attach and release the belt when the resident was seated. The safety belt was hard to fasten when the arm supports were down. The safety belt also became tangled, slowing down the use of device.

Lift #4 - This was popular because it was fast and easy to use. The sling was easy to put on the resident because it could be removed from the unit. The sling was soft and comfortable while still holding the residents well. The support arm bars on this lift were a little bit long so residents needed to adjust their hands on the hand holds as they were being raised to a near standing position. The relative long support arms also made them go up and down a little bit too rapidly.

Lift #5 - The nursing assistants found it easier to hook a sling to this lift's stationary frame. The frame seemed very safe because it did not swing. It was easy to steer due to the design, and number, of wheels. The sling was too stiff and hard to get under a resident, even with the resident's help. The sling was so stiff that it got off center and it was very hard to use the handle to pull the resident back into the chair. When lowering a resident into the chair and pulling on the handle, one's hand had a tendency to poke into the residents' backs. A softer and more pliable sling is recommended. Some residents complained their legs were rubbed by the edge of the sling no matter what size was used. The nursing assistants observed that the residents slid down into the sling, almost like they were sliding out of the sling.

Lift #6 - Some assistants felt that it was probably the best piece of equipment for a nursing home because of its size and maneuverability. The lift provided better control while moving the resident with the machine because the resident was not swinging around. A key factor in its maneuverability was that nursing assistants did not have to worry about the resident swinging into anything as the unit moved. Nursing assistants liked the way the sling hooked on the lift because the snap fasteners were easy to reach and connect. The sling held the resident very well. The tilting stick made it fairly easy to get the resident seated properly; however, the tilting bar was hard for some nursing assistants to push down because of their shoulder strength. The leg pieces of the sling were somewhat difficult to maneuver in attaching them under a patient.

Lift #7 - This lift was easy to operate. The pad around the hydraulic shaft kept the resident's legs from getting bruised. The sling design made it easy to attach. The lift was small and one of the easiest to move. The handle on the back of the sling was not difficult to use in pulling residents into good sitting positions. The magnet on the power switch was very convenient. The assistants did not like the swinging bars which made hooking up difficult and allowed the resident to swing freely. If a resident moved around a lot, either the assistant or the resident could get hit in the head or face. Sometimes, it was hard to control the resident in a sling while turning and pushing the machine due to the swing of the suspender bars. The swinging bars came too close to the residents' faces when they were being lowered into the chair. The boom was a little bit short and the assistants had to watch the residents' feet to prevent their legs from hitting the lift column. The spreader bars and suspenders need to be reevaluated. Some residents found the lift base adjustment handle hard to move.

Lift #8 - This lift was slow to use, hard to maneuver, and generally disliked. The lifting and lowering speed was too slow. The sling was too long and could cause shearing on a patient's buttocks when applied or removed. There was nothing sturdy for residents to hold for security, so they would reach for something stable (like the nursing assistant). The power unit was too close to a resident's face while connecting the loops to it. The sling was too restrictive in the groin area and some assistants felt that the sling was confusing with all its various loops. Seating a resident in an upright position back in the chair was somewhat hard to achieve because there was no handle.

Lift #9 - The sling was easy to put on a resident because of the material and design. Seating in the proper position was not difficult because there was a handle on the back of the sling. The lift column, however, was too close to the residents' legs and may cause contact bruises. The bars for attaching the sling to the lift contacted the lift boom as the resident was rotated. This lift was hard to maneuver with weight on it because the legs of the lift base were too long and the suspender bars were swinging too much. The wheels were also difficult to turn, and residents swayed too much during the transfer. The spreader bar may hit the resident's face, due to its length. Some assistants felt that this lifting device was adequate but for some nursing facilities it was too big and bulky to be used effectively. The strap on the back was a little too far down to easily pull the resident back in a chair.

Residents' Comments.

Baseline and Walking Belt Methods - Residents sometimes felt slight pressure under their arms, but were not excessively uncomfortable. They felt very uncomfortable when the two nursing assistants were of different heights. There was no underarm force when the walking belt was used on the residents; the walking belt was more comfortable than the baseline transfer method. The residents felt the belt also supported the back.

Sliding Board - The sliding board had a very hard surface. It was difficult to place the residents in a chair properly with the board because it hit the wheelchair legs. This method of being moved could be frightening to many elderly people and could not be used unless a resident could and would cooperate. It was difficult to remove the board from under a resident in the chair and it hurt the resident's buttocks. The residents twisted their backs during a transfer and they felt as though they might fall off. Unless the board was positioned just exactly right, it was uncomfortable; the board pinched the residents' buttocks if not placed correctly and their legs hit the board.

Lift #1 - The sling of lift #1 was uncomfortable under the arms and pressed too much on the small of the back because it was too narrow. The belt occasionally slipped a little and the support arms were too close to the resident's face. The hand grips were hard and awkward to hold on due to their locations and orientations. The lift went up and down too slowly. Residents preferred a waist security belt to the one on this lift, which hooked behind the knees. When the arms were moved further apart, the belt was more comfortable and the arm support was not right in the face of the patient. The sling tended to ride up on the resident's back due to its design.

Lift #2 - Residents liked this sling because it did not put pressure on their backs or under their arms, and was comfortable and secure because of the material, width, shape, and size of the sling. The knee pad was comfortable because the materials are soft and the pad accommodates the knees well. The handles were well situated for the residents to grasp. Residents stated that the sling did not ride up under their arms. The width of the support arms was very good. The raised metal piece at the back of the foot rest is hard and could injure a resident's heels. Sometimes, the lift lowered the residents too quickly. If the assistant did not explain why it was moving so rapidly, this could be frightening.

Lift #3 - The lift speed was good; quick but not jerky. Hand grips were well positioned and easy to hold but they should be padded. The lift lowered residents far back into the chair. The sling hurt the residents under their arms because it was too bulky. The support arms were too close to a resident's face. Residents complained that the sling was uncomfortable because it put all the weight on the small of the back. For some fragile arthritic elderly people this could be a problem.

Lift #4 - The sling was fairly comfortable. The support arms were well positioned, not too close to the resident's face, the arms were at proper level, and the lift raised smoothly. The sling did not ride up under the arms, however, it did tend to rub in that area. The hand grips were not comfortable to hold, as they changed orientation and residents needed to adjust their hands accordingly. When the nursing assistant started to lower a resident into the chair, she felt as though the resident was going to fall. The sling was rough under the arms and needs redesign. The nursing assistants warned the residents before starting to lower them that the machine lowered at a rapid pace. This helped in giving them a feeling of security. The footrest was not long enough in front; the toes hit the metal end and could be smashed or bruised.

Lift #5 - The residents gave this lift the worst comfort rating of all methods. The residents liked the stable frame to which the sling was attached, as opposed to the movable (swinging) metal bars on other lifts. The sling was too rigid to be comfortable. The residents tended to slide in the sling as though they were going to fall out. Residents' backs hurt when nursing assistants grasped the hand hold to lower them into a chair. The head piece was too hard. The sling was very uncomfortable to the back of the thighs, and it cut circulation to the residents' legs behind the knees. It was difficult for an assistant to seat residents in the chair, and residents were not back in the chair far enough to be comfortable. The sling also bound/cut the residents' hips and hurt the underneath part of the legs. The hips slid through too far, creating pressure on the back and top of the legs.

Lift #6 - The lifting arm of lift #6 was very stable which made the residents feel secure. The sling on the lift held the head and neck firmly and was comfortable except for the stays on the head support which were uncomfortable if not positioned correctly. The arm was stable and was not directly in the resident's face as it was being hooked up. The leg pieces pressed into the thighs and were uncomfortable. When the lift was tilted, the leg pieces pressed into the resident's legs. Residents did not like the fact that the metal frame came so close to the body when hooking the sling to it. It is recommended that the stays be padded. The metal bar sometimes descended, touching the body. The buckles on the sling hurt the back when the resident was rolled into it.

Lift #7 - The padded bar on this lift made bumping into it less dangerous. The sling was comfortable and was easily adjusted in all respects. The sling did not seem to cut or bind any area of the body. Residents did not like metal bars coming so close to their faces and there was a possibility of hitting one's feet on the machine when being turned around. Residents did not like the swinging metal bars; they found them frightening. The sling did not rise high enough to easily clear the bed. The head piece needed careful adjustment or it pressed on the head. The residents felt that the sling swung too much during a transfer and they did not feel secure.

Lift #8 - The sling of lift #8 was comfortable when adjusted properly. During lowering, the device frame came too close to the resident's face. The sling was long so it was difficult to remove after the resident was seated. The machine was relatively noisy. The sling swung too freely leading to a sense of insecurity and a risk of resident injury. The sling material felt rough on the skin.

Lift #9 - The residents found the sling fairly comfortable. The sling swung too freely and did not provide adequate neck support. The metal bars were frightening as it was perceived they could hit an assistant or resident in the face. The sling was too close to the lift column which could be struck be some part of a resident's body. The stays on the head support were too close together, and the suspender bars were too close to the face and upper body during sling attachment and resident lowering. The lifting arms were too flexible and as the machine went one way, the resident swung the other way. When the lift was moved away, the assistant needed to be careful to avoid hitting a resident in the face.

LIFTING RESIDENTS UP IN BED

Biomechanical Analyses - Lifting a person up in bed has been implicated in the literature (Jensen et al., 1989) as a primary cause of back injuries in health care personnel. This part of the project involved analyzing two methods of performing the task (using a drawsheet and the Magic Sheet©).

Nursing assistant specific anthropometric data were used as input to the biomechanical model to obtain results. The biomechanical measures are summarized by method in Table 33. The mean, standard deviation, and range for trunk flexion angle, trunk lateral bending, trunk rotation angle, percentages of the population capable of performing the task, and back compressive force are presented in the table.

While using the drawsheet, the mean trunk flexion angle was 59°, the mean trunk rotation angle was 7°, and the mean trunk lateral bending angle was 8°. The mean hand force was 256 N and the mean back compressive force was 3231 N. The mean back compressive force was slightly below the action limit (3,400 N) established by NIOSH (1981, 1991), but 30 percent of the data exceeded the NIOSH limit. The mean percentages of the population capable of performing the task were 73, 59, and 43 percent based on torso strength, hip strength, and the minimum of all body joints, respectively.

Psychophysical Assessment. The ratings of psychophysical exertion are summarized in Table 34 for both resident-repositioning methods. The mean, standard deviation, and range of ratings of perceived exertion at the shoulders, upper back, lower back, and whole body are presented in the table.

Table 33 Summary of Biomechanical Measures for Lifting Residents up in Bed (Both Residents) (N=40)

	Drawsheet Technique		
Variable	Mean	Standard deviation	Range
Trunk flexion angle (°)	59	9	40-78
Trunk lateral bending (°)	8	5	0-22
Trunk rotation angle (°)	7	5	0-20
Hand force (N)	256	40	89-328
% Capable[1] (Torso)	73	20	18-95
% Capable[1] (Hip)	59	24	7-88
% Capable[1] (Minimum)	43	26	6-87
Compressive force (N)[1]	3231	544	2236-4515
% Capable[2] (Torso)	79	11	49-95
% Capable[2] (Hip)	63	18	30-89
% Capable[2] (Minimum)	47	23	7-87
Compressive force (N)[2]	3071	418	2289-4110

1 Using the specific height, body weight and gender of the nursing assistants.

2 Using the height and body weight of 50% male and 50% female but gender of the nursing assistants.

Table 34 Ratings of Perceived Exertion for Lifting Residents up in Bed

		Ratings of perceived exertion			
Method group	N	Shoulder	Upper back	Lower back	Whole body
Drawsheet (2)[2]	20	11.1±2.1[1] (7-15)[3]	11.1±1.7 (8-15)	11.7±2.0 (7-15)	11.5±2.1 (8-16)
Magic Sheet (1)	18	9.4±2.1 (6-13)	8.9±1.9 (6-12)	8.8±1.8 (6-12)	8.9±1.8 (7-12)
Significant difference[4]		Yes	Yes	Yes	Yes

[1] Mean and standard deviation of nine nursing assistants and two residents.
[2] Number of nursing assistants required by the transfer method.
[3] Range of the ratings.
[4] Mean ratings for the drawsheet and the Magic Sheet are significantly different ($p < 0.01$).

For the drawsheet technique, the mean RPE values for the shoulders, upper back, lower back, and whole body were 11.1, 11.1, 11.7, and 11.5, respectively. In contrast, the Magic Sheet received RPE values of 9.4, 8.9, 8.8, and 8.9, respectively. The Magic Sheet is clearly perceived as less stressful.

Ease of Use Ratings. The nursing assistants used a five-point Likert scale for their ratings. The mean ratings for the drawsheet technique were 2.6 and 1.8 for the Magic Sheet. Table 35 shows that the minimum rating was 1 for both techniques, while the maximum was 5 for the drawsheet and 4 for the Magic Sheet techniques. There was a significant difference in the mean ease of use ratings between the two methods.

Table 35 Ease of Use Ratings for Lifting Residents up in Bed

Method	N	Mean rating[1]	Standard deviation	Range
Drawsheet	20	2.6[A]	1.1	1-5
Magic Sheet	18	1.8[B]	0.9	1-4

[1] The nursing assistants rated from 1 for extremely easy to 5 for extremely difficult; and mean ratings with the same group label (A or B) are not significantly different ($p > 0.05$).

Method Preference. The nursing assistants' preference ranking is summarized in Table 36. The table shows that both techniques received ratings of 1 and 2; indicating that each method was preferred by some nursing assistants. The difference in rankings was not significant.

Table 36 Method Preference for Lifting Residents up in Bed

Method	N	Mean ranking[1]	Standard deviation	Range
Drawsheet	9	1.6[A]	0.5	1-2
Magic Sheet	9	1.4[A]	0.5	1-2

[1] The nursing assistants ranked from 1 for the most preferred method to 2 for the least preferred method; and mean rankings with the same group label (A or B) are not significantly different ($p > 0.05$).

Task Performance Time and Nursing Assistant Work Time. Task performance and nursing assistant work times for lifting the residents up in bed are summarized in Table 37. The mean task performance time was 35 seconds (range = 24 - 57 seconds) using the drawsheet method and 28 seconds (range = 13 - 41 seconds) using the Magic Sheet method. The difference was significant.

The drawsheet method required two nursing assistants, so work time was double the task performance time, or 70 seconds. This is also significantly longer than the nursing assistant work time of 28 seconds for the Magic Sheet. There was no significant difference in the task performance and nursing assistant work times between the heavier and lighter residents. The time required to make the bed with either sheet is not considered, nor is the time required to install the Magic Sheet mechanism.

Table 37 Time to Lift Residents up in Bed

Method	N	Mean time[1]	Standard deviation	Range
Task Performance Time (seconds				
Drawsheet	10	35[A]	12	24-57
Magic Sheet	18	28[B]	9	13-41

[1] Mean task performance times or mean nursing assistant work times with the same group label (A or B) are not significantly different p > 0.05).

Bed Height Preference. Correlation analysis was performed to correlate the bed height preferred by the nursing assistants and the biomechanical and psychophysical measures for lifting residents up in bed. No significant correlation was found. Correlation analysis was also performed to see whether the bed height preferred by the nursing assistants correlated with the height, shoulder height, elbow height, hip height, and knee height of the nursing assistants. Although no significant correlations were found, the subjects generally preferred the bed lower for the manual transfers and higher for the mechanized transfers.

Resident Comfort and Security Ratings. These ratings by the residents are summarized by resident-repositioning method in Table 38. The mean comfort rating was 2.1 (range = 1 - 3) on a five-point Likert scale using the drawsheet technique and 1.1 (range = 1 - 2) using the Magic Sheet.

Table 38 Comfort and Security Ratings for Lifting Residents up in Bed

Method	N	Mean rating[a]	Standard deviation	Range
Comfort Rating				
Drawsheet	10	2.1[A]	0.6	1-3
Magic Sheet	18	1.1[B]	0.2	1-2
Security Rating				
Drawsheet	10	1.9[A]	0.6	1-3
Magic Sheet	18	1.1[B]	0.2	1-2

[a] The nursing assistants rated from 1 for extremely comfortable or secure to 5 for extremely uncomfortable or insure; and mean comfort or security ratings with the same group label (A or B) are not significantly different ($p > 0.05$).

The mean security rating was 1.9 (range = 1 - 3) using the drawsheet technique and 1.1 (range = 1 - 2) using the Magic Sheet. Both differences were statistically significant. The residents felt much better when repositioned with the Magic Sheet.

NURSING ASSISTANTS' COMMENTS

The nursing assistants felt the drawsheet technique was simple to perform under any condition. They also felt that the drawsheet could be used easily at home. The Magic Sheet was the easier to use because it relied primarily on arm strength.

Nursing assistants felt that the Magic Sheet was an excellent device for people who slid down in bed. It was also extremely easy to move a person up in bed. While it seemed easy to use, under some conditions it could be more difficult to use than manual lifting. This difficulty could arise from tangled sheets and keeping a resident in the center of the bed. The assistants had some strain on their shoulders and lower backs; and there was extra bending and straightening after it was used.

One nursing assistant felt that the Magic Sheet worked like a breeze, and would bear up well in long term care. If the Magic Sheet had a crease in it, it could cause pressure folds against the skin of a resident. If a person perspires a lot, then the sheet at the top will be wet and should be completely removed as soon as possible. The absorbent sheet also needs to be removed. Another big problem in use of the Magic Sheet is with a person who is incontinent. A sheet could not be placed at the bottom of the bed and rolled. In addition, there are times that pads will not absorb all dampness and the bed would be wet. When this sheet is used, it would need to be cleaned as well as the mattress. In these cases, this sheet would cause more bending, stretching, and lifting than it was worth. All of these conditions take additional time.

Thus, while it has a high utility in some situations, its potential use must be carefully evaluated as described above before a decision is made to install it.

Residents' Comments. The drawsheet technique sometimes jerks the residents' backs, and they occasionally felt that the nursing assistants' knuckles were pressing against them as they were lifted up. This technique was jarring and residents felt some apprehension before being lifted because they were not sure of the outcome.

The Magic Sheet was very simple and comfortable and residents had no feeling of insecurity with its use.

STRENGTH TESTING

A correlation analysis was performed to correlate the strength of the nursing assistants and the biomechanical and psychophysical measures for transferring residents from bed to chair and lifting residents up in bed. No significant correlations between the strength of the nursing assistants and the biomechanical and psychophysical measures were found. However, the weaker subjects consistently rated the tasks as being more stressful while the stronger subjects consistently rated the tasks as less stressful.

PILOT STUDY RESULTS - FIELD USE OF LIFTING DEVICES IN A NURSING HOME

This study was designed as a laboratory evaluation of patient handling devices, and it included a comfort and safety evaluation by the patient subjects. While this evaluation is helpful, it is not the same as having actual nursing home residents perform the safety and comfort evaluation. A field evaluation of this type was **NOT** a part of this project or contract, but as the study progressed, it became clear that a small field/pilot study might be helpful in understanding the true functionality of the devices.

A number of local nursing homes were contacted and one was identified which was willing to participate. The participation consisted of allowing the manufacturers of the four brands of lifting devices to come into the nursing home and train the nursing personnel designated by the home as participants. Ten personnel received training, although not all ten participated on a day-to-day basis. Since this was a volunteer effort by the nursing home, all nurse and resident activity was "at the convenience of the nursing home".

Once the personnel were trained, they began using the devices on selected nursing home residents. The nursing personnel were interviewed periodically to determine their response to the use of the devices - physically easier or harder? functional? possible improvements? resident response? time required to use? other comments. In addition, where it was feasible, the residents were interviewed as well. The data gathered were descriptive in nature, and it does not cover all personnel or devices. As indicated it was a "sample of nursing home convenience".

The balance of this section summarizes the results of the pilot study. The summary is presented as a series of short statements or discussions about topics that were raised by the nursing personnel and residents.

One interesting outcome of the pilot study was a change in the back injury rate. Historically, this nursing home had a number of lost time back injuries each month. During the period of the pilot study - about four months - there were zero resident handling related back injuries in the home. This serves to further support the study's conclusion that the use of handling devices will cause a drastic decrease in the resident handling related back injury frequency among nursing personnel in nursing homes.

The most notable comment made by the nursing personnel was that using the lifting devices resulted in a significant reduction in physical fatigue over the workday. This comment is particularly important because basic ergonomics has taught us that as people fatigue they become more vulnerable to sudden movement injuries and workplace behavior changes. These behavior changes include taking short cuts, leaving work incompletely done, and trying to force things by jerking on them. In addition, as people fatigue, they change the manner in which they interact with others - in a nursing home, the residents in particular. Comments more specific to the lifting devices follow. The ratings are on a five point scale with five being the best score.

STANDUP LIFT #1. Resident. Security rating, 4.9, comfort rating, 4.2. Comments included: I prefer this to device #2; this is less scary than device #2; it hurts my back just like the others; and, I like it best. The only staff comment was it needs a leg restraint strap to keep the resident's feet on the hoist.

STANDUP LIFT #3. Resident. Security rating 4.2 and comfort rating 3.6. Comments include: it feels more stable than #2; its worse than #2; the sling really pinches me under the arms; the sling is too hard; it hurts my back but not as much as the others; I like it best; I like it better than #2; and, there was one resident who just screamed the whole time she was in it. There were no staff comments.

STANDUP LIFT #2. Resident. Security 4.0 Comfort 3.7. It hurts under my arms; it feels like I'm hanging here; it doesn't provide enough support; and, its ok. Staff. Lift belts are wider than most and are more comfortable; lift belts have a safety strap to prevent the belts from sliding up if residents raise their arms; and the base leg adjustment is fairly easy.

STANDUP LIFT #4. Resident. Security 4.0 Comfort 4.0. It really pinches under my arms; and the lift arms are low enough for me to reach - this helps me feel more stable. Staff. The lift strap was too narrow and residents complained of back pain, if resident raises their arms, the strap will slide up their back and they will fall out of strap; the base legs were hard to adjust.

BASKET LIFT #1 . Resident. Security 3.4 comfort 3.6. It jerks me every which way; it sways too much; I like #3 &4 better; it hurts when they position the sling; and, the sling hurts my legs. Staff. The slings sometimes slide up the resident's back making it easier for them to fall out; combative residents may escape from the sling by thrashing around; it was hard to maneuver when a resident was in it.

BASKET LIFT #3. Resident. Security 3.8 Comfort 3.8. I like it; and, it doesn't hurt much. Staff. The unit was hard to position around some beds.

BASKET LIFT #2. Resident. Security 4.0 Comfort 4.0. It was very comfortable; one person went to sleep; it makes the move real easy; and, once I got control, I wasn't scared any more. Staff. Base legs are easy to adjust; sling design is very secure and combative residents will not fall out; is easy to maneuver with a resident in the sling; manufacturer support was readily available; sling attachments provide for different ways of attaching - this allows any type of resident to be comfortably handled.

BASKET LIFT #4. Resident. Security 3.4 Comfort 3.0. It hurts behind my knees; very uncomfortable - get me out of the sling; one resident slapped repeatedly at the sling expressing discomfort. Staff. It is hard to position the person in the chair correctly with this one; the sling design makes it very unlikely a resident will fall out; it seemed very easy to push with a resident in the sling; the single sling attachment method is simple to use, but not flexible enough to comfortably handle all types to residents; and, the sling tends to squeeze hips very uncomfortably.

Overall, nursing staff preferred manufacturer number two's devices because they were easiest to use and the residents seemed to react most favorably to them.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to evaluate resident-handling procedures to determine which procedures result in reduced biomechanical and/or psychophysical stresses to nursing personnel performing these tasks. This section of the report divides the conclusions and recommendations into task specific areas.

Resident Transfer. There are a number of factors that need to be examined when evaluating resident transfer method. These include physical stresses to nursing personnel (biomechanical and psychophysical), resident characteristics, resident comfort, resident security, and the time required to make a transfer.

Physical Stress - Biomechanical Evaluation. Gagnon, et al. (1986) studied three lifting techniques and estimated that the compressive force on the L5/S1 disc ranged from 5744 N to 7951 N while one person assisted a 72.6 kg manikin from a wheelchair. Garg et al. (1991a, 1991b) evaluated five manual techniques and three hoists for transferring patients from bed to chair, and reported that the back compressive force was over 4,300 N when the resident was lifted from the bed to the chair. In this study, the average back compressive force for the nursing assistant lifting the resident's torso when two nursing assistants rotated the resident to a sitting position on the edge of the bed was 3,487 N (range = 2391 - 4999 N). This force slightly exceeds the NIOSH action limit (3400 N). Clearly, nursing personnel are exposed to excessive biomechanical stress when performing resident transfers without an assistive device.

Baseline Method and the Walking Belt. Garg et al. reported that back compressive forces were about 2000 N in the case of the two-person patient transfer with the previous model of the walking belt. This force is less than the 4300 N compressive force associated with two-person manual lifting (Garg et al., 1991a, 1991b). In drawing the above conclusion, Garg et al. assumed that the residents had achieved a sitting position on the edge of the bed, which ignores the stressful activity of sitting them up in bed.

In this study, the task was to transfer a resident from a supine position on the bed to an upright position in the chair. The baseline transfer and the walking belt methods both required rotating the resident to a sitting position on the edge of the bed. The associated back compressive force exceeded the NIOSH action limit. The back compressive forces while standing the resident up were 2703 N for the baseline method and 2660 N with the walking belt - an insignificant difference. Even though the difference is small, the walking belt still gives the health care personnel much better control of residents - particularly those who are unstable. This extra control greatly reduces the risk of a sudden movement injury.

Basket-sling and Overhead Lifts. Resident movement with the basket-sling and overhead lifts has two phases: resident preparation and resident transfer. To prepare a resident, a nursing assistant rolled a resident onto their side to place the sling underneath the resident. This activity was biomechanically evaluated in this study. To lift a resident the nursing assistant used the handset to operate the lift devices to lift a resident out of the bed and lower her/him into the chair. The basket-sling and overhead lifts can be used for almost any residents.

This study found that the average back compressive force, during resident preparation was 2,951 N when the resident was rolled toward, and 2,698 N when the resident was rolled away from, the assistants. These forces are about 15% and 23%, respectively, smaller than the force (3487 N) associated with the baseline transfer. It is clear that the basket-sling and overhead lifts significantly reduce the biomechanical loading on the nursing assistants residents during residents transfer.

The manufacturers of the basket-sling and overhead lifts recommend that nursing personnel either roll the resident away from (push) or toward them (pull) before placing the sling under the resident. Based on the biomechanical results, nursing assistants should roll the resident away from them by pushing. On beds without siderails, nursing personnel could have better control of the residents if they roll the residents toward them.

Stand-up Lift and Sliding Board. Resident movement with the stand-up lift and sliding board is also divided into two phases: resident preparation and resident transfer. Resident preparation required a single nursing assistant to rotate a resident to a sitting position. Resident transfer required the nursing assistant to use the handset to lift the resident out of the bed and lower her into the chair, for a sliding board transfer, placing a walking belt around the lower abdomen/hips of the resident and placing the seat of the board under her. The nursing assistant then glided the resident slowly across the board to the chair. No biomechanical evaluation was performed for this phase. The stand-up lift can only be used for weight-bearing or partially dependent residents.

Even when the sliding board is used for a transfer, the lifting during the second phase of the manual lifting technique (activity #2) is eliminated along with its biomechanical loading.

Other Activities. Setting the resident in the chair required the nursing assistants to pull the resident back into the chair using a handle on the sling. There were significant differences in the pulling forces among the different basket-sling and overhead lift devices.

The study also found that the maximum pushing force required to move the lift devices was 59 N and the maximum turning force was 52 N. These forces are well within the peak pushing strength of 186 N reported by Snook, 1991.

In summary, the use of all assistive devices resulted in a reduction of biomechanical stress to nursing personnel performing bed to chair transfers of residents. The reduction will be more or less depending on the particular type of device used, the resident characteristics and behavior, and the lifting situation.
In addition, the use of the devices virtually eliminates the risk of one of the most common causes of nursing assistants' injuries - the sudden movement injury which can occur if the resident loses their balance. Finally, the use of devices eliminates the lifting (standing up) of the resident which eliminates at least one half of the back injury exposure due to resident handling.

Physical Stress - Psychophysical Evaluation. The lift devices require relatively small forces for operation. Their use for resident transfer will reduce physical stresses to nursing personnel. However, Garg et al. reported (1991a, 1991b) that the physical stress RPE ratings for two out of three hoists were as high as the stress ratings for manual transfers. In his study, one hoist required a jerky pumping action to raise and lower the hoist, and some subjects found it too hard to pump and steer the hoist. The subjects also had difficulty in applying the sling and hooking the sling to the hoist due to its short leg straps and hooks. It was concluded that some hoists may result in greater perceived stress (hassle) to nurses as compared to some manual techniques.

This study had similar results with respect to perceived stress. Some devices received psychophysical stress ratings as high as the baseline transfer method. The high stress ratings for some devices may have been caused by the postural stresses which result from sub-tasks such as placing and removing the slings from underneath the patient, attaching slings to the lift, maneuvering and steering the lift to the chair, etc. It could also be the result of the greater complexity of the activity; i.e., there are only a few steps in the manual transfer method, while the device transfers require the nursing assistants to remember and do a number of things. This could result in a perception of "hassle" which, could translate into a higher stress rating. The better psychophysical evaluations found in this study are due to the technical improvements in device design and operation that have occurred since this study. For example the hydraulic pump in Garg's study has been replaced by an electric motor, and the slings have been redesigned to make them easier to use.

Resident Comfort and Security. In Garg's study, the two-person walking belt technique received high patient comfort and security ratings, while two of three hoists received fairly low ratings (Garg et al., 1991a, 1991b). In this study, the residents' subjective evaluation of assistive devices comfort and security was favorable. The walking belt was statistically more comfortable than the baseline transfer method. The security ratings indicated that the sliding board and basket-sling and overhead lifts were statistically less secure than the baseline method, stand-up lift, and walking belt.

The residents were concerned about the swinging of the sling during transfers with the basket-sling and overhead lifts. As a result, their subjective security ratings for these lift devices were reduced.

Potential users of these devices should experiment with them in their facility to determine resident reaction. If residents are uncomfortable or insecure in the device, they will make device use such a hassle, that it will end of its own accord.

Transfer Time. Previous studies found that one of the reasons for not using patient-handling devices is that they require too much time (Bell, 1984; Owen, 1988; Takala and Kukkonen, 1987). Without adequate staffing, the additional time may interfere with other functions that nursing personnel perform.

Additional time is needed to use the assistive devices as compared to manual lifting. Takala and Kukkonen (1987) reported a transfer time of 120 to 150 seconds with a hoist. Bell (1984) reported 295 seconds and Garg et al. (1991a) reported times of 124 to 193 seconds. The additional time to use a two-person walking belt, as compared to the manual lifting method, was 49 seconds

(Garg et al., 1991a).

In this study, the task performance time for the basket-sling lifts ranged from 257 to 324 seconds and from 207 to 235 seconds for the stand-up lifts. It took 63 and 132 seconds to transfer residents from bed to chair with the baseline and the walking belt methods, respectively. The additional task performance time to use a two-person walking belt, as compared to the baseline method, was 69 seconds.

Carlson (1989) reported that nursing aides working in teams of two made an average of 38 patient transfers per shift using the manual lifting method in a nursing home. These transfers would require a total of 80 minutes assistant work time. The additional nursing assistant work time per transfer or per shift is summarized by the method group in Table 39. The additional total nursing assistant work time would be 87 minutes with the walking belt method, 86 minutes with the basket-sling lift, 125 minutes with the overhead lift, 58 minutes with the stand-up lift, and 32 minutes with the sliding board. These additional nursing assistant work times were calculated based on the work load of a team of two nursing aides working for one shift. These additional times represent a maximum increase in the amount of nursing assistant time. They do not consider the time saved by the use of services - for example, the devices can save time in transit because the residents cannot walk as fast as the devices can move them. It also does not consider the fact that not all of the time spent on use of assistive devices is lost time - for example when a nursing assistant approaches a resident, there is generally a period of time during which the people talk. This talking can occur simultaneous with the application of the devices. In actual fact, the extra work times in Table 39 significantly overstate the actual lost time - probably by a factor of two or more. Furthermore, the whole body fatigue reduction that occurs when the devices are used is not considered. The effects of this fatigue could include skipping some work, working in a less thorough manner, becoming rough with the residents, and working more slowly at the end of the shift.

The 38 transfers require only 80 minutes of total nursing assistant work time, which accounts for only eight percent of the total work time for a team of two nursing assistants. It takes more time to use the lift devices than the baseline method, but the nursing assistants in this study felt it was a worthwhile tradeoff, that it would be safer for them and the residents, and that it would not be a reason not to use the lifting devices.

Table 39 Additional Nursing Assistant Work Time Required by each Method Group

Method group	Nursing assistant work time (seconds)	Additional time per transfer (seconds)[1]	Additional time per shift (minutes)[2]
Baseline method (2)[3]	126	-	-
Walking belt (2)	264	138	87
Basket-sling lift (1)	261	135	86
Overhead lift (1)	324	198	125
Stand-up lift (1)	217	91	58
Sliding board (1)	176	50	32

[1] The additional nursing assistant work time per transfer is calculated by subtracting the nursing assistant work time for the baseline from the nursing assistant work time for a given method group.
[2] The additional nursing assistant work time per shift is calculated by multiplying the additional nursing assistant work time by 38; then divided by 60.
[3] Number of nursing assistants required by the transfer method.

Device Preference. When all methods were considered, the nursing assistants preferred lifts #6 and 7. The baseline transfer, walking belt, sliding board, and lift #8 were the least preferred methods.

The analysis of the nursing assistants' preference of method data by method group indicated that the nursing assistants preferred the basket-sling and stand-up lift groups to the other method groups.

Recommendations Regarding Effective Procedures. Table 40 gives a qualitative summary of eight criteria the authors developed and used to evaluate the 12 methods of transferring residents from bed to chair. The table shows that the walking belt and lifts #2, 4, 6, and 7 are the five methods which satisfy all the criteria except transfer time. Table 40 shows that Lifts #2, 4, 6, and 7 not only reduced biomechanical and psychophysical stress to nursing personnel, but were also preferred by the nursing assistants. Comments of the nursing assistants and residents were also favorable. Lifts #3 and 5 need to be improved with regard to the comfort of residents, while lifts #1, 5, 8, and 9 need to address the issue of ease of use.

Table 40 Qualitative Summary of Different Resident Transfer Methods

Criteria	Walking belt	Sliding board	Lift1	Lift2	Lift3	Lift4	Lift5	Lift6	Lift7	Lift8	Lift9
Biomechanical stress	E	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Perceived stress	Y	E	Y	Y	Y	Y	E	Y	Y	E	E
Resident comfort	Y	E	E	Y	N	Y	N	E	Y	E	E
Resident security	E	N	E	E	E	E	E	E	E	E	E
Ease of use	E	N	N	E	E	E	N	E	E	N	N
Method preference	E	E	E	Y	Y	Y	Y	Y	Y	E	Y
Transfer time	N	N	N	N	N	N	N	N	N	N	N
Favorable comments	Y	N	E	Y	E	Y	E	Y	Y	E	Y

Notes: All techniques used one nursing assistant except baseline method and walking belt.
N = relatively high stress or unfavorable ratings as compared to the baseline transfer
E = no difference between a technique and the baseline transfer
Y = relatively low stress or favorable ratings as compared to the baseline transfer

Lifting Residents up in Bed. A biomechanical evaluation by Lindbeck and Engkvist (1993) evaluated two methods of moving a patient up in the bed: pulling the sheet with both hands and pulling the sheet with one hand while the other hand was held under the patient's shoulder. The estimated hand force in that study was about 150 N for both methods. Low back compressive force was not estimated.

In this study, the mean hand force of 256 N, is considerably larger than that reported by Lindbeck and Engkvist (1993). The difference is probably explained by the lifting and pulling combination. In this study, the residents were lifted up in bed, while in the work by Lindbeck and Engkvist, the patients were pulled up in the bed. This study found that the mean back compressive force was 3231 N when the nursing assistants lifted the residents up in bed with the drawsheet technique. This was slightly below the NIOSH action limit (3,400 N).

For the Magic Sheet, there is no lifting activity involved with the task performance; instead, nursing assistants rotated a handle to roll the residents up in bed. Each rotation cycle of the handle consists of pushing the handle down and pulling the handle up. The force associated with pulling the handle up was measured. On the average, the nursing assistants exerted a force of 55 N to roll the residents up in bed. This was significantly smaller than the drawsheet hand force (256 N).

In summary, the mean back compressive force for lifting residents up in bed was slightly below the NIOSH action limit; however, 30 percent of the data exceeded the NIOSH limit. The use of the Magic Sheet resulted in a much smaller hand force than the drawsheet technique, and virtually eliminates the well known risks of lifting - residents or anything else. In addition, use of the Magic Sheet virtually eliminates the risk of sudden movement injury due to the "jerk lift" commonly used with the drawsheet.

Psychophysical Evaluation. In this study, the mean RPE values for the shoulders, upper back, lower back, and whole body when the drawsheet technique was used were significantly higher than the mean ratings for the Magic Sheet method in each of the corresponding body areas.

Resident Comfort and Security. The residents' subjective responses to the comfort and security of the two methods were generally favorable; however, comfort ratings indicated that the drawsheet technique was less comfortable than the Magic Sheet. The security rating indicated that residents considered the drawsheet technique less secure than the Magic Sheet. Residents were lifted up in bed in a rapid motion with the drawsheet and if nursing personnel did not lift the resident up to a proper position in bed, the resident's head would at times hit the headboard. With the Magic Sheet, the residents were slowly rolled up in bed and did not fear that their heads would be hit.

Task Performance Time. In this study, the mean task performance time using the drawsheet method (35 seconds) was significantly longer than using the Magic Sheet (28 seconds). Since the drawsheet method required two nursing assistants, the nursing assistant work time for the drawsheet was 70 seconds. Once installed, which will take some time, the Magic Sheet was found to be easier and faster.

Method Preference. The mean rankings for the drawsheet technique and the Magic Sheet were not significantly different (1.6 and 1.4 respectively). Those nursing assistants who did not like it felt that its usefulness in a nursing home was questionable for the reasons previously indicated. As indicated, this device appears to have excellent utility in selected circumstances.

EFFECTIVE PROCEDURES - RECOMMENDATIONS TO THE MANUFACTURERS

Resident and nursing assistant assessments of the assistive devices under consideration were generally favorable, however, design problems were identified with all of the devices. The problems described apply to one or more of the assistive devices.

1. The sling is connected to the suspender bars, and on some basket-sling lifts they are too flexible and swing or move around too much during a transfer. This swinging creates feelings of insecurity. In addition, this led the nursing assistants to feel that the devices were hard to maneuver because as they pushed or turned the devices one way, the resident swung in another direction. Under these conditions, combative residents can hurt themselves and/or the nursing personnel. The manufacturers should evaluate their devices to insure that the sling sway is well controlled.
2. On one of the lift devices, if the boom (frame of the lift) is in the high position, the sling supports contact the boom and the resident cannot be rotated. The manufacturer should evaluate the boom to insure that the sling supports can rotate freely.

3. One lift device has a tilting frame which is hard to push, especially when there is a heavy resident in the sling. If it is too loose, the stability of the resident will be affected. If it is too rigid or stable, nursing personnel will be exposed to high biomechanical and perceived stress.
4. The residents did not like the stays in the head support of some slings. If the nursing personnel do not place the sling and head support in exactly the right place, the resident's head will be hurt or be uncomfortable. Manufacturers should evaluate their head supports for head and neck comfort, and insure the stiffeners do not cause pain or irritation.
5. The handle on the back of some slings is not positioned properly. The handles are too low and the nursing assistants cannot easily grasp them when the resident is pulled back into the chair. The handle position causes large pulling forces in an awkward posture. Manufacturers should evaluate their sling designs to insure easy accessibility to sling controls, keep use force low, and to insure they are functional for a variety of chair types.
6. The support arms of some stand-up lifts are too narrow. If the nursing assistants are not careful, the arms may hit the residents in the face. The manufacturers should consider locating the two support arms farther apart.
7. On one lift, the sling is permanently attached to the lift and nursing assistants had difficulty in placing this sling around residents. The safety belt design forces nursing assistants to bend down to fasten the safety belt, removable slings allow the nursing assistants to use good body mechanics to place the slings on the residents, thereby reducing high postural

stress.

8. The space between the arm supports of one stand-up lift is too small, and thus as the resident is lifted, the sling causes undue pressure on the resident's back and two sides of the trunk. The manufacturer should evaluate this situation to improve the safety and comfort of the residents.

9. One stand-up lift does not have a safety belt. This is a dangerous situation. In this lift, if a resident suddenly collapses or lifts their arms, they will fall. A well designed safety belt will prevent them from falling. The manufacturer should evaluate their hoist to determine the best way to add a sling.

10. Some safety belts are very time consuming to fasten or release. The nursing assistants also had difficulty in using those safety belts. A properly guarded quick release button is recommended. The belt must be fast and easy to use.

11. The foot plates of some stand-up lifts are poorly designed. The plate edges are sharp and high, and may injure the resident's toe when the stand-up lifts are brought up to face the resident. A resident's heel may be hurt when the lifts are moved away from the person after being lowered into the chair and having the slings disconnected. All manufacturers should evaluate their devices for sharp edges and protruding points which may injure a resident, nursing assistant, or passerby.

12. The knee pad of one stand-up lift device is too far from the shaft of the lift. The support arms on this lift are relatively short as well. As a result, residents can only be lowered to the edge of the chair, and it is difficult to

situate the resident all the way back in the chair in an upright position. Further manual repositioning may be required, which partially defeats the purpose of the lift.

13. One stand-up lift has a safety belt which wraps around and attaches behind the resident's legs. Nursing assistants felt it was very difficult to fasten or release the belt, and they had to bend forward in an awkward position to use the belt. Assistants also felt the safety belt around the legs may not be necessary; however, they felt that a safety belt around the lower part of the back is imperative to prevent falls.

14. Some stand-up lifts lower the resident into the chair too rapidly. This leads to a feeling of discomfort and insecurity in some residents. The resulting fear may cause frantic random movements by the resident which could cause an injury. The manufacturers should conduct a human factors study to determine the up and down speeds which are acceptable to people in this age group.

15. Some stand-up lifts are too slow or do not pick up the residents correctly. The low lift speed is the combined effect of low motor speed and the long travel distance of the support arms. The residents felt very uncomfortable hanging in the air for a relatively long period of time. See recommendation #14.

16. The overhead lift was also very slow. Although this may not cause excessive discomfort to the resident, the nursing assistants did not like it. See recommendation #14.

17. The manufacturer of one stand-up lift device does not require the nursing assistants to lock the wheels when connecting the sling to the lift. Unlocked wheels may easily be pushed away,

causing a danger of falling. If the straps are hooked to the support arms or boom and residents push the lift away, they may drag themselves away from the bed and fall.

18. In previous studies, the walking belt reportedly had a tendency to slip over the resident's waist and "ride up their back" (Garg et al., 1991a, 1991b). This tendency was not observed with the belt used on the two residents in this study. This new model had redesigned handles and an additional adjustability strap to prevent the belt from riding up a resident's back. It did, however, have some design problems. Plastic or some soft/semi rigid metal could be used to wrap the end of the straps of the belt to make it easier to put the straps through the material closure hooks. The manufacturer of the walking belt should incorporate properly guarded "quick release" latches.

GUIDELINES FOR PATIENT LIFTING DEVICE SELECTION

There is little doubt that the routine use of patient lifting devices in nursing homes will reduce the frequency and severity of back injuries among nursing personnel. While this is true for any of the devices tested, it is also true that there is considerable variability in the devices and some are more functional and cost effective than others. In these days of constantly shrinking budgets, it is important to consider a variety of relevant factors when making a lifting device selection.

This section describes a number of such factors which have been identified by the author as potentially important during the selection process. The list, and its associated discussion are by no means exhaustive. Remember the true cost of these devices is at least the purchase price, plus maintenance, minus the direct and indirect cost of the injuries eliminated, plus the cost of injuries occurring when a unit is down for maintenance.

FACTOR DISCUSSION

Initial price - Given the substantial differences in price between the different devices, it may be possible to purchase six of one device for the price of five of another. Assuming a fixed budget, the extra device may be worth some of the inconvenience associated with the cheaper device.

Features included in initial price - In reviewing the brochures provided by the device manufacturers, it was obvious that the list price included different options or add-ons on different devices. Items like the number of slings, presence of a scale, the number of batteries provided, a battery charger, extent of training provided, etc., can result in major changes in "initial price". Make sure it is "apples to apples" that are being compared.

Options v. standard equipment - Some manufacturers provide options - for example a number of slings in different sizes - with their equipment. A thorough analysis of a facility's needs may reveal that some or all of the options are in fact necessary requirements if the devices are to be truly functional in the facility. Again, compare "apples to apples".

Maintenance requirements - Evaluate the potential maintenance costs - check the manufacturer's requirements, and then check with others that have purchased the devices to see what their experience has been. Other user names should be available from the manufacturer - if they aren't, that may suggest there is a problem you should know about.

Maintenance difficulty - how much maintenance can be done by your staff and how much will require a factory person? At $100/hour, externally supplied maintenance can be expensive, and it may also mean your device is out of service for an extended time period.

Parts integrity - Look over the device closely; the use of plastic in lieu of metal is sometimes appropriate - and sometimes it is just cheap construction. Consider where the parts are used, what wear they are subject to, and whether abuse may cause failure. Again, check with other users of the device to find out its maintenance history.

Price of spare parts - Over a few years, the cost of spare parts may be greater than the cost of the unit itself. Obtain a spare parts list and a likely in-service interval for key parts; then compare across manufacturers. Other users may be helpful in obtaining these data.

Availability of spare parts - When equipment is down for maintenance, your personnel are at an increased risk of injury - that injury will cost more than a few of these devices. You need to know the availability of spare parts - how long it will take to obtain them, how reliable is the spare parts system, will the company provide a replacement while your device is out of service, will this be provided for free, how long will it take to get the replacement, where will the replacement come from or who will supply it (salesperson, warehouse, etc.) - it is easier to obtain assistance from a person than from a place?

Manufacturer's training - The correct and efficient use of these devices is important if their full benefit is to be obtained. The quality, availability, and follow-up of the manufacturer's training was observed to vary considerably. Make sure you have a clear agreement on what will be provided, by whom, when, and at what cost (especially for follow-up training after the initial in-service). In addition arrange for the trainer to return periodically to be sure your personnel are using the devices correctly.

Type of residents in facility - Consider the special needs of the residents in your facility (combative, heavy, recent surgery, frail, etc.), and consider whether the device being considered will meet these special needs.

Resident comfort - This is a prime consideration since devices (usually the slings) which are uncomfortable, insecure, or painful for the residents will not be accepted by them. Carefully evaluate the device design (especially the sling) and its relation to your residents condition.

Ease of sling use - As was noted in this report, the ease of sling use (positioning and removing) varies between devices. Evaluate carefully in the context of your facility and the beds and chairs that you use.

Ease of sling cleaning - Slings come in a variety of materials and costs. They will get soiled and need cleaning. How easy is it to clean a given sling, and how many additional slings will be needed to make sure slings of the right size are available. When a sling is repeatedly cleaned, what will its service life be?

Facility design - The selected device must be usable in your facility. Tight corners, small doorways, rough floors, travel on and off carpets, small bathrooms, etc., all play a role in determining the size and maneuverability criteria for your facility.

Sales representative availability - How long will it take them to respond when you have a device problem; how capable are they of solving problems, and how willing and committed are they to solving your problems. Check this out with other users to verify.

Maneuverability - Is the device flexible enough for your facility; how much force is required to push/pull/turn the device? Is it likely that the device will stick and require impact loading to overcome (exposes personnel to sudden movement injuries)?

Leg spread adjustability - How easily does the leg spread adjust? Difficulty adjusting leg spread (especially when the device was loaded) was a common complaint in the nursing home and in the research study? This also exposes personnel to sudden movement injury.

Ease of control use - The design and placement of the device controls (electronics, brakes, leg adjust, speed of up/down, smoothness, battery location and change requirements, etc.) all contribute to the device's utility. Make sure your personnel have evaluated the device and that they are comfortable with it.

Accidental misuse of controls - evaluate the likelihood of accidental misuse and its possible effects. These events happen infrequently, but they are usually very severe events - like a dropped resident for example.

Security of slings - In the nursing home evaluation, concern was expressed that some slings made it too easy for residents to wriggle or thrash out of the sling. Since these designs change periodically, carefully evaluate the devices for this possibility - the result, a dropped resident would be a serious problem.

Strap design - Numerous complaints were made about the strap design on the stand-up devices. Evaluate them to insure they are wide enough to distribute the load on the resident's back and they do not allow the resident to slip out of the strap; does the main strap have a backup safety strap to keep the main strap on the resident?

Manual v. electric power - Electric is easier and less hazardous, but manual is more reliable and cheaper.

Time to use correctly - The time to correctly use the device is important in determining its utility. Evaluate it carefully during the on-site demonstration. Have your personnel use the device to determine the time.

Number of devices needed - How many devices are needed to make sure the wait time for a device is kept to a level at which personnel will not revert to the quicker but more hazardous manual handling methods?

Lifting devices are evolving - models change quickly - be sure you know what you are buying.

Protrusions in the resident hang area or operator areas - these could cause injuries, and will be regarded as "hassles" which translate into non-use of the device. In evaluating the devices, consider all of the movements required for the operator (moving device, getting resident in device, using controls, changing the battery, doing maintenance, etc.) and those of the swinging resident.

Unit stability under various loading conditions including legs at different widths - There are industry standards for stability. Make sure that the device being considered meets these minimum standards. If you have very heavy or combative residents, consider the added need for stability associated with these residents.

Up/down speed control - The speed should be adjustable to accommodate the needs of operator and resident. Moving too fast may panic a resident and that could result in an accident.

Place for residents to hang on if they feel insecure - Residents consistently requested this because it made them feel more secure. It also keeps them from grabbing the operator.

Does device meet industry design standards - Do not accept the salesperson's word; check with the standards organization.

Test all devices with your staff - Remember, if it is PERCEIVED as hard or slow or unsafe to use, it will end up in the closet.

Battery life and recharge options - These units must be available at all times, and battery life, recharge time, and battery switching ease are all considerations in device selection - no battery means no use.

As indicated, this list is based on the author's observations and experience with the devices. It is for the consideration of potential device purchasers, and is not intended to be an all inclusive list. Potential users are encouraged to develop their own list and to shop wisely. These devices will reduce a facility's worker's compensation costs, but to do so, there must be a match between the facility's needs and the devices abilities.

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