

## Prevention of back injuries in healthcare workers

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Received December 15, 1993; accepted in revised form May 16, 1994

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### Abstract

A laboratory study was conducted to evaluate five different manual techniques (two-person lifting; rocking and pulling the patient using a gait belt with two persons; walking belt with handles with one and two persons; and a patient handling sling with cutouts with one person) for transferring patients from wheelchair to toilet and toilet to wheelchair. In addition, three different mechanical hoists (H, T and A) were studied for transferring patients from toilet to wheelchair. Six female nursing students with prior patient transfer experience served both as nurses and passive patients.

The mean trunk flexion moments, erector spinae muscle forces and compressive forces for the four manual pulling methods ranged from 93 to 133 Nm, 1861 to 2653 N and 1974 to 2745 N, respectively, as compared to about 200 Nm, 4100 N and 4800 N for two-person manual lifting. Manual lifting was perceived to be the most stressful by the nurses and the least comfortable and secure by the patients. Hoist A was perceived to be the least stressful and the most comfortable and secure. Hoists H and T were perceived to be more stressful, less comfortable and less secure than the walking belt.

An intervention study was conducted in two units of a nursing home (140 beds and 57 NAs) to determine the effectiveness of ergonomic changes. Nursing assistants (NAs) in the two units of the nursing home were trained in the use of selected devices and shower rooms and toilets were modified. The mean acceptability rates for walking belt and hoist A were 81% and 87%, respectively. The reported incidence and severity rates for back injuries over 13 months decreased from 83 to 43 and from 634 to 0, respectively, after the intervention. Nursing assistants perceived their job as “very light” after the intervention as compared to between “somewhat hard” and “hard” before intervention.

### Relevance to industry

Results of this study show that an appropriate ergonomic intervention program offers great promise in reducing physical stress and risk of low-back injury to nursing personnel. In particular, the study shows that the severity of injury (lost and restricted workdays) can be substantially reduced with ergonomic intervention.

**Keywords:** Patient transferring devices; Compressive force; Ratings of perceived exertion; Acceptability; Back injuries; Incidence and severity rates

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## 1. Introduction

It is generally believed that the high prevalence of low-back pain among nursing personnel is the result of, or is precipitated by, frequent patient lifting tasks (Raistrick, 1981; Lloyd et al.,

1987; Stubbs et al., 1983; Videman et al., 1984; Harber et al., 1985; Jensen, 1985, 1990; Owen, 1985, 1987; Gagnon et al., 1986; Torma-Krajewski, 1986; Venning et al., 1987; Garg et al., 1991a, b; Garg and Owen, 1992). Lifting of patients was considered to be the heaviest task by about 73%



Fig. 1. Manual patient-transferring methods studied in the laboratory. Two-person manual lifting (top left), gait belt (top right), walking belt (bottom right), and sling (bottom left). Gait belt, walking belt and sling used gently rocking and pulling technique.

of the nursing aides and bed-making in a stooping posture by 21% (Dehlin et al., 1976). Owen and Garg (1989) and Garg et al. (1992) reported that those tasks that involved bending and stooping were ranked and rated lower by the nursing aides in terms of perceived physical stresses than the lifting and transferring tasks.

Bell et al. (1979) concluded that priority should be given to a detailed investigation of the problems of five different patient transfer tasks. Lifting patients on and off toilets was ranked third by these authors. The study also reported that manual lifting was used 96% of the time for toileting patients. Garg et al. (1992) reported that the toileting process was ranked as the most stressful task out of 16 different tasks by the nursing aides. The task of transferring the patient from toilet to wheelchair was ranked first with a mean rating of 14.3 on the Borg scale and wheelchair to toilet was ranked second with a mean rating of 14.1 (Garg et al., 1992). The static muscular work, confined workplace in the bathroom and unevenness in the heights of the toilet and the wheelchair seats have been given as some of the reasons for this high ranking (Garg et al., 1992; Garg and Owen, 1993). Torma-Krajewski (1986) showed that transferring a 50 kg patient from commode to wheelchair exceeded the maximum permissible limit (MPL) of the U.S. Department of Health and Human Services (1981).

The objectives of this study were (1) to compare different methods for transferring patients from wheelchair to toilet and toilet to wheelchair in a laboratory setting, and (2) to determine if laboratory results applied to a nursing home would be effective in preventing back injuries.

## 2. Method (laboratory study)

### 2.1. Subjects

Six female paid volunteers participated as subjects. They were all nursing students with at least one year of experience in patient transferring tasks. Their mean age, body weight and height were 22.5 years (range = 21 to 23 years), 63.3 kg (range = 53 to 79 kg) and 165.3 cm (range = 157

to 168 cm). While serving as a patient they were instructed to act as a passive patient model and not to assist in supporting their own body weight.

### 2.2. Manual methods and mechanical hoists

The five manual methods studied were: lifting by two persons, gently rocking and pulling the patient with a gait belt and walking belt by two persons, and rocking and pulling the patient with a walking belt and using a sling by one person. The three mechanical hoists used for patient transfers were H, T and A. The walking belt, sling, and hoists A and T were selected based on a preliminary laboratory study. Two-person manual lifting, gait belt, and hoist H were studied because they were the most commonly used methods found through observation in a large nursing home (Carlson, 1989) and through questionnaire (Owen, 1988).

For manual lifting, two nursing assistants stood facing the patient, each grasped the patient under an axilla with the lower arm near the elbow, lifted the patient up and carried the patient to the toilet (Fig. 1). The walking belt was 12.5 cm wide, had handles on each side, had a velcro closure and two quick-release buckles. The belt was placed snugly around the patient's lower abdomen/hips. The nursing assistants stood facing the patient with feet apart, one foot facing the patient and the other foot in the direction of the move (toilet), and grasped the handle of the walking belt with one hand. In synchronization, using a gentle rocking motion to utilize momentum, the nursing assistants *pulled* the patient toward themselves, shifted their weight to avoid twisting, and moved the patient to the toilet (Fig. 1). The procedures used with the gait belt and the sling were similar to the above. The gait belt was 5 cm wide, had an adjustable belt-like loop closure, and had no handles (Fig. 1). The sling was made of flexible polymer, was 20.5 cm wide and 51 cm long, and had cutouts at both ends for gripping. It could not be fastened to the patient (Fig. 1).

The three hoists differed in terms of stability, types of sling used, patient posture while being transferred, and the hand motion and body pos-

ture required of the nursing assistant to raise or lower the patient. The hoist H had an adjustable base, a handle requiring a manual pumping action for raising and lowering the patient, and a transfer sling that attached through hooks, chains, and metal bars (Fig. 2). The hoist T had no adjustable base, the crank for raising and lowering the resident was in the horizontal plane at about chest height, and the sling attached by hooks and chains (Fig. 2). The hoist A had a semi-adjustable base, a crank located in the vertical plane, and the lift-up sling attached by loops and hooks (Fig. 2).

### 2.3. Criteria for selecting patient-transferring devices

Eight different criteria were used to evaluate the devices in the laboratory and to recommend

the selected devices to the nursing home. These included: biomechanical stresses (compressive force on low back and strength required to make the transfer), physical stresses perceived by the nursing personnel, safety and comfort rated by the patients, applicability of a device to different types of patients (patient characteristics), method preferred by the nursing personnel on the whole, transfer time, and comments from nurses and patients.

### 2.4. Procedure

Each patient transfer was explained and demonstrated to subjects. The subjects were also shown a videotape of the transfer. The subjects were required to try the transfer procedure several times until they felt comfortable with it. For

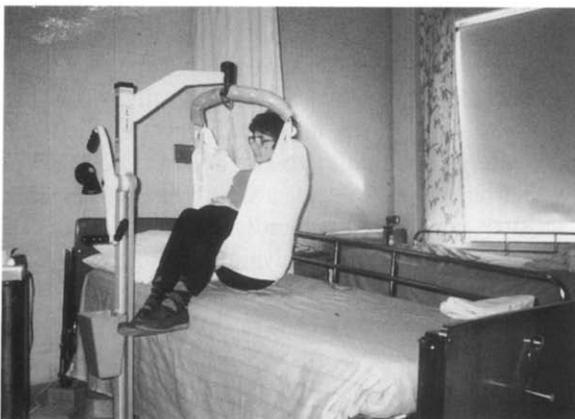


Fig. 2. The three mechanical hoists studied in the laboratory. Hoist H (top left), hoist T (top right) and hoist A (bottom left).

two-person transfers, nurses were selected at random. The subjects did not work in the same team and the teams were not matched for height or body weight to simulate real-life conditions in nursing homes. A given transfer technique was selected at random and all six subjects completed that technique (for details see Garg et al., 1991a, b).

Manual transfers from wheelchair to toilet were studied first, followed by toilet to wheelchair transfers using manual methods and mechanical hoists. A given transfer method was selected and all six subjects performed that task. After each patient transfer the nurses were asked to rate the physical stresses for shoulder, upper back, lower back and whole body on a nine-point scale (Webb, 1983; Blache et al., 1987). They were also required to make a check mark under what conditions (patient characteristics) they felt the method would not work. The patients were asked to rate how comfortable they felt and how secure they felt on a seven-point Likert scale (0 = extremely comfortable and 7 = extremely uncomfortable; 0 = extremely secure and 7 = extremely insecure). Both nurses and patients were encouraged to write down their comments. Each transfer was videotaped and timed using a stopwatch. Then, the nurses were asked to assume the initial body position for the transfer and body angles were determined using a goniometer for biomechanical analysis (Garg and Chaffin, 1975). The pulling forces were determined by attaching a force dynamometer to the gait belt, walking belt and the sling. For manual lifting, the magnitude of hand force per subject was assumed to be 50% of the patient's weight. After completing all five manual methods, the nurses were asked to rank these methods in order of their overall preference (1 = most preferred and 5 = least preferred). For the mechanical hoists, the study site was moved to a hallway as the nurses found it very hard to push and maneuver these hoists on a carpeted floor.

The toilet height was 44 cm and the wheelchair seat height was 47.5 cm. A 1.7 m × 1.35 m lavatory with a sink (57.5 cm × 31 cm) was created by placing artificial barriers. These dimensions correspond to the lavatory dimensions given by Carlson (1989) and result in a confined workspace.

A three-dimensional static biomechanical model (Garg and Chaffin, 1975) was used for manual methods to determine trunk moments; erector spinae, compressive and shear forces at L<sub>5</sub>/S<sub>1</sub> disc; and percentage of female population capable of performing the transfer based on static strength simulation. Data on manual methods and mechanical hoists were analyzed separately. All data (both biomechanical measures and ratings of perceived exertion) were subjected to an analysis of variance (for example, 2 tasks × 5 methods × 6 subjects × 4 body parts for stress ratings on manual methods). Similarly, various ratings for the three hoists were analyzed separately (2 tasks × 3 hoists × 4 body parts × 6 subjects).

### 3. Method (field study)

#### 3.1. Pre-intervention

Two units of a nursing home were selected for participation in the study. There were 140 patients and 57 nursing assistants on these two units. Data was collected on nursing assistant and patient characteristics (Garg et al., 1992; Carlson, 1989). The NAs were asked to list the patient-handling tasks perceived as most stressful, and the tasks were grouped into 16 task categories in order of frequency of response (Garg et al., 1992). The NAs were asked to rank these tasks and to rate perceived exertion for the lower back from these tasks using the Borg scale (1962). An NA was selected at random and observed and videotaped for four hours continuously to determine task performed, frequency of occurrence, method used, number of NAs used, etc. (Garg et al., 1992). A total of 79 four-hour shifts were observed. Details of per-intervention observations are described in Garg et al. (1992).

#### 3.2. Intervention

Patients were classified into three groups based on their physical ability: independent; dependent, weight-bearing; and dependent, non-weight-bearing. Based on laboratory study, a two-person



Fig. 3. Shower chair with removable foot pedals and arm supports and modified shower room.

walking belt was recommended for transferring dependent, weight-bearing patients with body weights less than 70 kg. Each of these patients was provided with an appropriately sized walking belt (small, medium or large) with patient's name written on it. Hoist A was recommended for transferring dependent, non-weight-bearing, or heavy patients (body weight > 70 kg). Each wing (about 20 patients) of the two units of the nursing home was provided with Hoist A, slings of various sizes and a shower chair with removable foot pedals and arm supports (Fig. 3). One of the hoists on each unit had a built-in weighing scale attached to it. In addition, each unit was provided with a ramp-type weighing scale. A separate frame and a sling were provided for hoist A for lifting patients from the floor. Adaptive clothing (trousers and dresses) was provided for those patients who were to be toileted using the hoist. Toilets and showers were modified to allow easy pushing and pulling of shower chair over the toilet and into and out of the showers. Hoists, walking belts and shower chairs were first introduced in unit 1. Five months later, when no

major problems were encountered with their use, the devices were introduced in unit 2.

The supervisors, head nurse and nursing staff were trained by the authors in the use of recommended devices in groups of four to eight in an empty patient room. They attended at least two training sessions of two hours each. Training consisted of explaining the patient transfer, showing the videotape and then the NAs practiced each patient transfer until they felt comfortable with it.

### 3.3. Post-intervention

Two independent nurse observers (research assistants) randomly observed the NAs performing their routine patient transfers to determine acceptability of the recommended devices over a 13-month period (9 months in unit 1 and 4 months in unit 2). Ratings of perceived exertion data were collected after completion of a transfer using the Borg RPE scale (Borg, 1962).

At the end of each transfer, the NAs were asked to fill out the RPE form. Transfer times were measured by the two independent nurse observers using stopwatches. The transfer time included obtaining the device, preparing the patient, applying the sling, transferring the patient and removing the sling. The NAs were selected at random by the nurse observers for observation. The independent nurse observers visited the nursing home twice per week for four hours each time over the 13-month period.

At the end of the study, the nursing home's Accident Investigative Report forms and OSHA 200 forms were reviewed to collect injury data for a period of approximately four years prior to the intervention and four months after the intervention (when both units were provided with the patient transferring devices). Details on intervention and post-intervention procedures are described in Garg and Owen (1992).

## 4. Results (laboratory study)

Biomechanical evaluations, ratings of perceived stresses from nurses, comfort and security ratings from patients, nurses' assessments of

transfer methods for different patient characteristics, overall method preference, and transfer times are summarized in Tables 1 to 7.

#### 4.1. Biomechanical evaluations

Trunk flexion, lateral bending and axial rotation angles for the five manual transfer methods were approximately 60°, 10° and 9°, respectively (Tables 1 and 2). Neither task nor transfer method had a significant effect on these angles ( $p > 0.05$ ). As expected, pulling the patients required significantly lower forces than lifting the patients ( $p \leq 0.01$ ). Based on a static strength simulation, about 77% of female workers would be capable of transferring patients from wheelchair to toilet and toilet to wheelchair using the two-person gait belt and walking belt, as compared to about 40%

using the two-person manual lifting method. The task had no significant effect on the percentage of capable females ( $p > 0.05$ ). Two-person manual lifting produced significantly larger trunk flexion, lateral bending and axial rotation moments than any of the four pulling techniques ( $p \leq 0.01$ ). Trunk lateral bending and axial rotation moments were relatively very small as compared to trunk flexion moments (Tables 1 and 2).

The two-person manual lifting method resulted in a significantly larger erector spinae muscle force, compressive force and shear force at the L<sub>5</sub>/S<sub>1</sub> disc than any of the four pulling methods ( $p \leq 0.01$ ). There were no significant differences in these variables between wheelchair to toilet and toilet to wheelchair transfers. On the average, compressive forces at the L<sub>5</sub>/S<sub>1</sub> disc were the lowest for two-person pulling transfers

Table 1  
Summary of biomechanical analysis of five different manual methods for transferring patients from wheelchair to toilet ( $n = 6$ )

Variable	Manual lifting (2 person)	Gait belt (2 person)	Walking belt (2 person)	Walking belt (1 person)	Sling (1 person)
Trunk flexion angle (°)	58 ± 6 50–65	62 ± 10 45–75	59 ± 9 45–70	58 ± 4 55–65	58 ± 4 50–60
Trunk lateral bending (°)	13 ± 3 10–15	9 ± 4 5–15	10 ± 3 10–15	9 ± 2 5–10	10 ± 0 10–10
Trunk rotation angle (°)	13 ± 3 10–15	7 ± 3 5–10	12 ± 3 10–15	8 ± 3 5–10	8 ± 3 0–10
Hand force (N)	312 ± 54 263–392	133 ± 11 116–147	129 ± 16 98–138	250 ± 33 196–277	239 ± 31 214–277
% Capable females	38 ± 7 32–50	71 ± 6 65–82	82 ± 9 70–93	42 ± 6 35–70	41 ± 9 30–52
Trunk flexion moment (Nm)	202 ± 23 165–223	102 ± 11 85–117	102 ± 12 83–114	133 ± 13 110–148	117 ± 17 102–147
Lateral bending moment (Nm)	95 ± 16 76–110	16 ± 11 5–33	18 ± 13 2–37	28 ± 6 18–35	27 ± 5 22–35
Trunk rotation moment (Nm)	61 ± 7 54–74	29 ± 9 20–42	33 ± 10 13–44	3 ± 3 1–8	2 ± 1 0–4
Erector spinae force (N)	4073 ± 455 3309–4460	2119 ± 348 1699–2752	2034 ± 232 1668–2962	2653 ± 270 2190–2962	2338 ± 345 2038–2935
Compressive force (N)	4878 ± 337 4291–5178	2258 ± 381 1792–2886	2196 ± 226 1815–2457	2745 ± 328 2163–3068	2397 ± 386 2020–2984
Shear force (N)	879 ± 62 812–972	506 ± 49 455–580	533 ± 85 384–624	474 ± 29 437–508	441 ± 35 410–500

and were the highest for the two-person manual lifting ( $p \leq 0.01$ ) (Tables 1 and 2). The shear forces at the L<sub>5</sub>/S<sub>1</sub> disc were about 900 N for two-person manual lifting, 540 N for two-person pulling transfers and 440 N for one-person pulling transfers.

#### 4.2. Stress ratings

Separate analyses of variance showed that there were significant differences between the five manual techniques and between the three mechanical hoists ( $p \leq 0.01$ ). In general, the shoulder was the body part perceived to be most stressed ( $p \leq 0.01$ ). The differences in perceived stress between the four body parts are very small as compared to the differences in perceived stress between the transfer techniques (Table 3). The

task had no significant effect on stress ratings ( $p > 0.05$ ).

Among the five manual techniques, lifting was perceived to be the most stressful (approximately "very stressed") and the walking belt the least stressful (approximately "noticeable stress") (Table 3). The two-person gait belt was perceived as being "definitely stressed," and one-person sling between "noticeable stress" and "definitely stressed". Among the three mechanical hoists, hoist A was perceived to be the least stressful and hoist H the most stressful.

#### 4.3. Patient comfort and security ratings

There were significant differences between the five manual techniques and between the three mechanical hoists in patient comfort and security

Table 2  
Summary of biomechanical analysis of five different manual methods for transferring patients from toilet to wheelchair ( $n = 6$ )

Variable	Manual lifting (2 person)	Gait belt (2 person)	Walking belt (2 person)	Walking belt (1 person)	Sling (1 person)
Trunk flexion angle (°)	68 ± 7 60-75	53 ± 8 45-60	56 ± 10 40-70	63 ± 5 55-70	64 ± 8 50-75
Trunk lateral bending (°)	11 ± 2 10-15	10 ± 3 5-15	8 ± 4 5-15	9 ± 2 5-10	10 ± 0 10-10
Trunk rotation angle (°)	10 ± 3 5-15	9 ± 4 5-15	8 ± 3 5-10	5 ± 0 5-15	6 ± 2 5-10
Hand force (N)	312 ± 54 263-392	108 ± 21 89-147	118 ± 12 89-147	239 ± 50 178-294	230 ± 30 196-277
% Capable females	43 ± 6 38-54	74 ± 10 56-83	81 ± 11 67-97	47 ± 25 14-81	50 ± 15 32-72
Trunk flexion moment (Nm)	206 ± 12 184-218	93 ± 12 80-110	95 ± 8 87-109	99 ± 19 65-116	102 ± 17 84-130
Lateral bending moment (Nm)	75 ± 12 57-90	7 ± 7 1-18	12 ± 8 2-22	18 ± 4 12-24	21 ± 5 17-31
Trunk rotation moment (Nm)	69 ± 6 64-79	39 ± 6 33-50	38 ± 12 16-50	1 ± 1 0-3	1 ± 2 0-5
Erector spinae force (N)	4729 ± 238 3693-4366	1861 ± 233 1606-2190	1896 ± 164 1744-2190	1974 ± 383 1293-2315	2043 ± 338 1673-2605
Compressive force (N)	4795 ± 183 4433-4915	1996 ± 191 1775-2257	2042 ± 167 1896-2337	1974 ± 428 1298-2524	2030 ± 362 1588-2600
Shear force (N)	954 ± 48 905-1030	559 ± 62 482-665	558 ± 91 397-673	424 ± 57 326-486	424 ± 34 379-477

Table 3

Stress ratings for the five manual techniques and the three hoists (on a scale of 0 = no stress to 9 = extremely stressful) ( $n = 6$ )

Task	Body part	Manual lifting (2) <sup>a</sup>	Gait belt (2)	Walking belt (2)	Walking belt (1)	Sling (1)	Hoist H (2)	Hoist T (2)	Hoist A (2)
Wheelchair to toilet	Shoulder	7.1 ± 1.0 5.9-8.8	5.7 ± 1.3 3.2-7.0	3.7 ± 1.1 1.8-5.2	4.2 ± 1.1 3.0-6.0	4.9 ± 1.7 3.2-8.0			
	Upper back	6.5 ± 1.9 2.0-8.8	5.1 ± 1.5 2.9-7.0	2.9 ± 1.2 1.3-5.0	4.4 ± 1.1 3.2-5.8	4.8 ± 1.7 3.2-8.0			
	Lower back	7.6 ± 1.4 4.7-9.0	5.7 ± 1.9 2.8-8.4	3.6 ± 1.6 1.0-5.8	3.5 ± 1.4 1.5-5.2	4.5 ± 1.6 3.0-7.0			
	Whole body	7.2 ± 1.3 5.0-8.8	5.4 ± 1.5 3.0-7.4	3.7 ± 1.4 1.0-5.9	3.7 ± 1.0 3.0-5.2	4.7 ± 1.3 3.0-6.2			
Toilet to wheelchair	Shoulder	7.4 ± 1.2 5.3-9.0	6.3 ± 1.0 4.3-7.7	4.0 ± 0.9 2.4-6.0	3.4 ± 0.8 2.0-4.0	4.2 ± 1.5 2.4-7.0	5.4 ± 1.5 2.5-8.2	4.0 ± 1.3 2.0-6.0	2.6 ± 1.2 1.0-5.0
	Upper back	7.5 ± 0.8 5.8-8.6	6.1 ± 1.0 4.8-7.8	3.4 ± 1.0 2.0-5.3	3.5 ± 0.4 3.0-4.0	3.4 ± 1.0 2.0-5.3	4.8 ± 1.4 2.9-6.6	3.2 ± 1.7 0.9-6.4	1.9 ± 1.2 0.6-5.0
	Lower back	6.9 ± 2.0 2.3-8.4	5.5 ± 2.3 1.6-8.8	3.4 ± 1.8 0.9-6.0	3.5 ± 1.5 1.5-5.8	4.4 ± 1.8 2.2-7.0	4.7 ± 1.8 1.4-7.6	3.1 ± 1.5 1.4-5.8	1.3 ± 0.8 0.3-3.0
	Whole body	7.1 ± 0.9 6.0-8.2	5.8 ± 1.0 4.0-7.2	3.6 ± 1.0 2.0-5.0	3.2 ± 0.3 3.0-3.8	3.9 ± 1.1 2.4-5.1	4.6 ± 1.5 1.7-6.7	3.0 ± 1.4 0.4-5.9	1.5 ± 0.9 0.0-3.1

<sup>a</sup> Indicates number of nurses employed for patient transfer.

ratings ( $p \leq 0.01$ ). Among the five manual techniques, the two-person walking belt was perceived as being most comfortable and secure, followed by the one-person walking belt, sling, gait belt and manual lifting (Table 4). Both manual lifting and the gait belt were rated as being highly uncomfortable and insecure. The sling was rated as being comfortable but insecure. Among the three mechanical hoists, hoist A was perceived to be the most comfortable and secure,

followed by hoists T and H, which were rated as being highly uncomfortable and insecure (Table 4).

#### 4.4. Patient characteristics and overall preference

Practically all nurses felt that all five manual methods would work on weight-bearing patients (Table 5). A significant number of nurses felt that none of the five methods would work if any

Table 4

Summary of comfort and security ratings from the patients ( $n = 6$ )

Task	Variable	Manual lifting (2) <sup>a</sup>	Gait belt (2)	Walking belt (2)	Walking belt (1)	Sling (1)	Hoist H (2)	Hoist T (2)	Hoist A (2)
Wheelchair to toilet	Comfort rating <sup>b</sup>	6.4 ± 0.5 5.6-6.8	5.8 ± 0.8 5.0-7.0	1.2 ± 0.7 0.6-2.6	2.1 ± 0.7 1.4-3.5	3.5 ± 1.7 0.4-5.5			
	Security rating <sup>c</sup>	6.3 ± 0.6 5.8-7.0	4.3 ± 1.4 2.4-6.3	1.0 ± 0.6 0.2-2.0	1.7 ± 0.8 0.8-3.0	3.7 ± 0.9 0.4-6.2			
	Comfort rating <sup>b</sup>	6.7 ± 0.4 5.9-7.0	6.1 ± 0.9 4.7-7.0	1.3 ± 0.8 0.8-2.9	1.2 ± 0.7 0.4-2.0	2.6 ± 1.2 1.0-4.0	6.4 ± 0.7 5.5-7.0	2.7 ± 1.3 0.5-4.5	0.9 ± 1.4 0.0-3.5
Toilet to wheelchair	Security rating <sup>c</sup>	6.8 ± 0.4 6.0-7.0	4.3 ± 1.4 2.3-6.0	1.3 ± 1.0 0.2-2.9	1.0 ± 0.6 0.5-2.0	3.9 ± 1.6 2.0-6.0	6.3 ± 0.8 5.4-7.0	2.8 ± 1.2 1.2-4.0	0.5 ± 0.5 0.0-1.3

<sup>a</sup> Indicates number of nurses employed for patient transfer.<sup>b</sup> On a scale of 0 to 7 with 0 = extremely comfortable and 7 = extremely uncomfortable.<sup>c</sup> On a scale of 0 to 7 with 0 = extremely secure and 7 = extremely insecure.

Table 5

Number of nurses believing manual transfer methods studied will not work for different patient conditions ( $n = 6$ )

Task	Patient condition	Number of nurses believing method will not work				
		Manual lift (2) <sup>a</sup>	Gait belt (2)	Walking belt (2)	Walking belt (1)	Sling (1)
Wheelchair to toilet	Patient can bear weight	0	0	0	0	0
	Patient cannot bear weight	5	0	0	2	6
	Heavy patient	5	0	1	4	5
	Combative patient	3	1	1	5	5
	Contracted patient	4	2	2	4	6
	Patient with equipment	5	3	2	2	5
Toilet to wheelchair	Patient can bear weight	1	0	0	0	0
	Patient cannot bear	3	1	0	4	6
	Heavy patient	5	1	1	4	6
	Combative patient	2	2	1	4	5
	Contracted patient	2	1	0	5	6
	Patient with equipment	4	2	3	6	5

<sup>a</sup> Indicates number of nurses employed for the transfer.

Table 6

Summary of nurses' method preferences for manual transfers (1 = most preferred and 5 = least preferred) ( $n = 6$ )

Technique	Method preference for					
	Wheelchair to toilet			Toilet to wheelchair		
	Mean	<i>s.d.</i>	Range	Mean	<i>s.d.</i>	Range
Manual lifting (2)	5.0	0.0	5–5	5.0	0.0	5–5
Gait belt (2)	4.0	0.0	4–4	4.0	0.0	4–4
Walking belt (2)	1.8	1.0	1–3	1.8	1.0	1–3
Walking belt (1)	1.7	0.5	1–2	1.7	0.8	1–3
Sling (1)	2.5	0.8	1–3	2.5	0.5	2–3

Table 7

Summary of transfer times in seconds ( $n = 6$ )

Technique	Transfer time(s) for					
	Wheelchair to toilet			Toilet to wheelchair		
	Mean	<i>s.d.</i>	Range	Mean	<i>s.d.</i>	Range
Manual lift (2) <sup>a</sup>	8.0	1.8	5.7–11.8	8.2	1.9	5.9–11.2
Gait belt (2)	29.9	2.8	26.3–33.2	28.4	3.9	24.9–36.0
Walking belt (2)	35.8	6.5	27.7–48.9	37.2	4.6	33.1–44.2
Walking belt (1)	46.8	7.8	37.9–57.4	34.1	3.4	29.1–38.8
Sling (1)	9.5	2.3	7.4–14.3	8.3	2.5	5.2–12.5
Hoist H (2)				180.6	23.8	158.9–216.1
Hoist T (2)				203.5	35.4	159.9–261.0
Hoist A (2)				140.1	10.8	130.3–157.8

<sup>a</sup> Indicates number of nurses employed for the transfer.

equipment was attached to the patient (Table 5). The majority of the nurses indicated that the two-person manual lifting method, sling and one-person walking belt would not work on those patients who could not bear weight and those who were heavy, combative or had contracted joints (Table 5).

Overall, the nurses liked the walking belt the most (mean ratings = 1.7 and 1.8 for one- and two-person, Table 6). Two-person manual lifting was the least preferred method (mean rating = 5) both for wheelchair to toilet and toilet to wheelchair transfers (Table 6).

#### 4.5. Transfer time

The two-person manual lifting method and the sling required the least amounts of time and mechanical hoists required the largest amounts of time for transferring patients from toilet to wheelchair (Table 7). It took about 10 s to transfer patients from wheelchair to toilet or toilet to wheelchair with manual lifting and the sling, as compared to about 30 s with gait belt, 40 s with walking belt and 175 s with the mechanical hoists (Table 7). Among the three mechanical hoists, hoist A took the least amount of time, 140 s.

### 5. Results (field study)

#### 5.1. Acceptability rates

Fig. 4 shows the overall acceptability rates for walking belt and hoist A. Acceptability rate was defined as the ratio of total number of patient transfers made with walking belt (hoist) where walking belt was recommended to total number of transfers where walking belt (hoist) should have been used. It was observed that some patient transfers were made using a walking belt in place of hoist A and hoist A in place of walking belt due to a change in physical and mental capabilities of the patients from day to day and from morning to evening. Therefore, a combined acceptability rate was defined as a transfer made using hoist A or walking belt. The overall combined acceptability rate was 96% (Fig. 4).

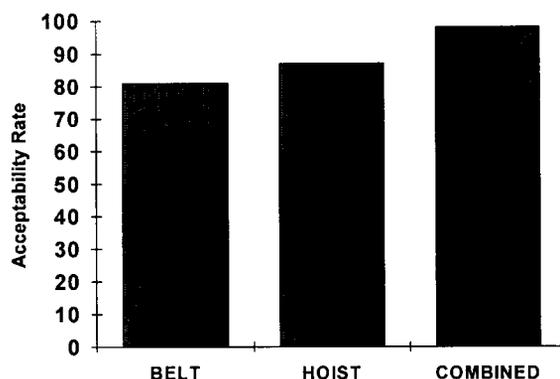


Fig. 4. Acceptability rates for walking belt and hoist A from a nursing home.

#### 5.2. Ratings of perceived exertion

Overall, lower back was the body part perceived to be most stressed both for the walking belt and the hoist A. The lower back was followed by whole body, shoulders and upper back for rating of perceived exertion. An analysis of variance showed that the post-intervention RPEs for the walking belt and hoist A were significantly lower ( $p \leq 0.01$ ) than the pre-intervention RPEs for manual lifting (Fig. 5). The mean RPEs were between “somewhat hard” and “hard” before intervention and “very light” for walking belt and between “very very light” and “very light” for hoist A after intervention (Fig. 5).

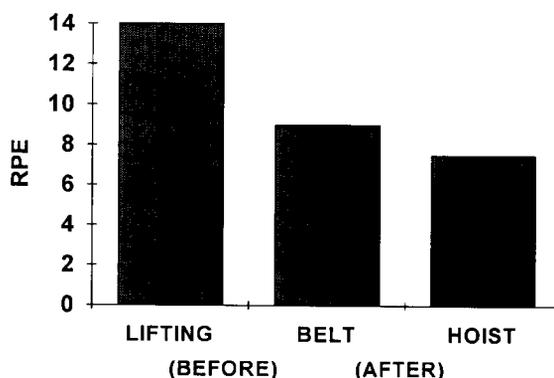


Fig. 5. Comparison of ratings of perceived exertion for lower back from pre- and post-intervention phases in a nursing home.

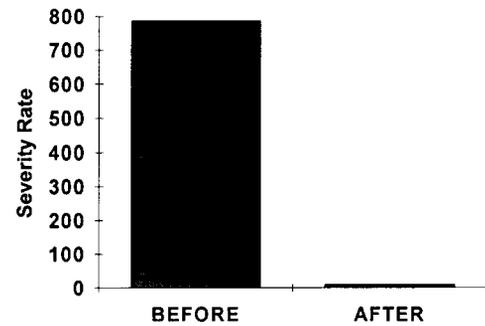
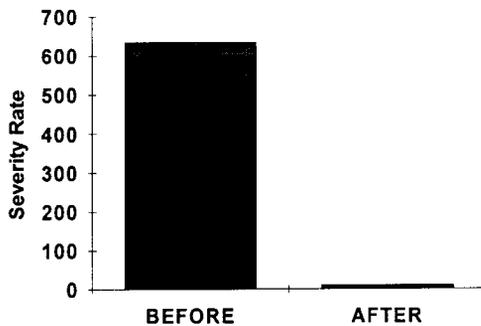
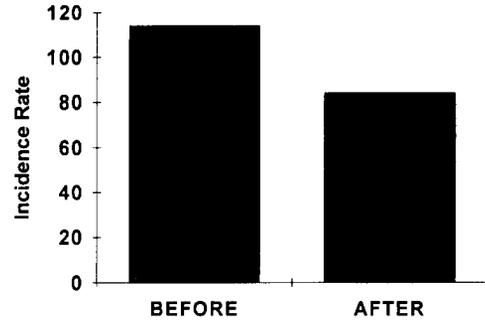
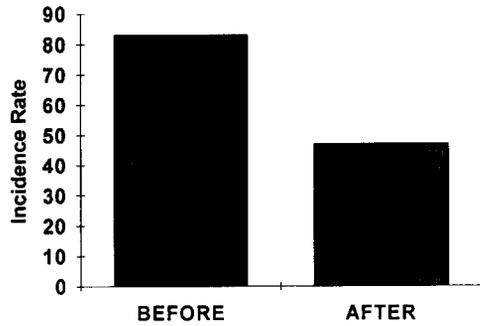


Fig. 6. Effects of ergonomic intervention on incidence and severity rates for back injuries in a nursing home.

Fig. 7. Effects of ergonomic intervention on incidence and severity rates for all injuries in a nursing home.

### 5.3. Injury statistics

Figs. 6 and 7 compare incidence and severity rates for back and all injuries from pre-intervention to those from post-intervention. Incidence and severity rates are based on equivalent expo-

sure to 100 full-time nursing assistants for 1 year. Severity rates are defined as lost or restricted work days. Pre-intervention statistics are based on injury data over 3.5 years. Post-intervention statistics are based on injury data over last four months in both units. The severity rates for both

Table 8  
Qualitative summary of different patient transfer methods

Criteria	Manual lift (2)	Gait belt (2)	Walking belt (2)	Walking belt (1)	Sling (1)	Hoist H (2)	Hoist T (2)	Hoist A (2)
Biomechanical stresses	N	Y	Y	Y	Y	-	-	-
Perceived stresses	N	N	Y	Y	N	N	Y	Y
Patient security	N	N	Y	Y	N	N	Y	Y
Patient comfort	N	N	Y	Y	Y	N	Y	Y
Patient characteristics	N	Y	Y	N	N	-	-	-
Method preference	N	N	Y	Y	Y	-	-	-
Transfer time	Y	N	N	N	Y	N	N	N
Favorable comments	N	N	Y	Y	N	N	N	Y

N: Relatively high stresses, unfavorable ratings or large transfer times.

Y: Relatively low stresses, favorable ratings or small transfer times.

back and all injuries during the post-intervention phase were zero (Figs. 6 and 7), i.e., there was not a single day lost or restricted due to an injury either to back or any other part of the body.

After nursing assistants were provided with walking belts and hoists A, there were 15 back injuries out of a total of 26 injuries reported on OSHA 200 forms. Five injuries (19%) occurred when patients were transferred using walking belts. None of the 26 injuries occurred when hoist A was used for patient transfers.

#### 5.4. *Transfer time and NAs*

On the average, it took 26 s to make a transfer with the walking belt and 74 s with hoist A. The transfer time for the manual lifting method before intervention ranged from 8 to 18 s.

The majority of patient transfers with the walking belt and hoist A was made using two NAs (70% and 77%, respectively). Remaining transfers were made using one NA. These devices rarely required more than 2 NAs.

### 6. Discussion (laboratory study)

Table 8 gives a qualitative summary of the eight different criteria used to evaluate the five different manual techniques and the three different hoists for transferring patients from wheelchair to toilet and toilet to wheelchair. The two-person walking belt and hoist A are the only techniques which satisfy all the criteria, except transfer time (Table 8). Assuming adequate staffing, these two methods are recommended for transferring patients from wheelchair to toilet and toilet to wheelchair. However, if space around the toilet is insufficient, the one-person walking belt using a gentle rocking motion and pulling is recommended for transferring those lightweight patients who can bear weight.

#### 6.1. *Biomechanical stresses*

This research showed that pulling a patient for transferring from wheelchair to toilet and toilet to wheelchair, as compared to manually lifting a

patient, requires significantly lower hand forces and results in significantly lower trunk moments, erector spinae muscle force, compressive force and shear force at the L<sub>5</sub>/S<sub>1</sub> disc. The mean compressive forces of 1974 N to 2653 N estimated for the four pulling methods are considerably lower than the 3430 N action limit recommended by the U.S. Department of Health and Human Services (1981). These compressive forces are believed to represent nominal risk to most industrial workers. The pulling forces of about 130 N required by the two-person pulling techniques are substantially lower than female pulling strength of 179 N at 68 cm height reported by Chaffin et al. (1983); 310 N at 40% of reach height reported by Ayoub and McDaniel (1974); and 294 N (25th percentile small female at 57 cm height and 1 pull every 5 minutes) reported by Snook (1978).

#### 6.2. *Perceived stresses*

The perceived stresses from the four pulling methods were substantially different from each other even though all four pulling methods produced somewhat similar and acceptable levels of biomechanical stresses. This shows the importance of determining both the biomechanical as well as subjective stresses in evaluating a patient transfer technique or device. For example, the gait belt required low pulling forces and produced low compressive, shear and erector spinae forces. Nonetheless, perceived physical stresses were very high, probably due to lack of handholds and the tendency of the belt to slide up on the patient.

Contrary to general belief, two of the three mechanical hoists were perceived to be as stressful or even more stressful than the one- and two-person walking belts. This shows that use of a mechanical hoist in place of a manual device may not necessarily result in reduced physical stresses to nursing personnel, as perceived by the subjects. This does not imply that the hoists actually increased the physical stress.

#### 6.3. *Comfort and security ratings*

If a patient is fearful or very uncomfortable, he/she may refuse the use of a manual device or

mechanical hoist (Owen, 1988). An unsafe patient-transferring device may cause broken ribs, significant skin problems and loss of control of the patient during transfer (Owen, 1988). In this study, one of the three mechanical hoists and three of the five manual techniques were perceived as being insecure by the patients. With the manual lifting technique, the patients were lifted and carried across the bathroom floor and they complained of discomfort in the axilla area. Also, the nurses could not see where they were going. The gait belt hurt the patient in the abdominal and rib areas. The sling was fast and comfortable but was perceived as being insecure because it could not be securely fastened to the patient.

The walking belt was perceived to be more comfortable and secure than two of the three mechanical hoists. These hoist slings did not place the patient in a comfortable sitting position for transfer and the hoists tended to swing so much that some patients were concerned about it tipping over. In addition, some patients could feel the hooks and chains used for attaching the sling to the hoist and, hence, there was potential for bruising or tearing of the skin.

#### 6.4. Patient characteristics

Consideration of patient characteristics is important for patient safety during a transfer (Owen, 1988). Also, the physical stresses to the nurses can be substantially greater when transferring an uncooperative or struggling patient (Lloyd et al., 1981). In this study, the gait belt and the two-person walking belt were the only manual devices that the nurses felt would work with those patients who could not bear weight and those who were heavy, combative or had contracted joints. However, the gait belt could not be recommended based on high perceived physical stresses to the nurses and poor patient comfort and security ratings. Also, the gait belt was the second lowest method in overall preference.

The nurses preferred using a walking belt with one person over a walking belt with two persons because it provided more room for a patient transfer in a highly confined workspace. Therefore, the one-person walking belt is recom-

mended for transferring those patients who can bear weight and are not heavy.

The amount of time required to transfer with the walking belt and hoist A was substantially longer than with the existing manual lifting method used in a nursing home. This longer transfer time and lack of work space in a lavatory could be major problems for non-compliance with the recommended devices. Also, without adequate staffing, nursing personnel are likely to perform patient transfers in the most expeditious manner (Jensen, 1989).

#### 7. Discussion (field study)

This study showed that it is possible to reduce back and other musculoskeletal injuries to nursing assistants with a comprehensive ergonomic intervention. The study also showed that an ergonomic intervention has much greater impact on severity of injuries than on incidence of injuries. It appears that either an ergonomic intervention results in less serious injuries and/or injured employees are able to continue to work because job physical demands have been reduced.

The approach taken in this study was different from that used in past studies. The primary focus of this study was on reducing physical stresses to nursing personnel through ergonomic job design. On the other hand, focus on past studies has been on modifying the worker by emphasizing proper lifting technique, body mechanics, back care and physical fitness. The ergonomic approach should be preferred as it reduces the exposure to the hazard.

The longer transfer time required by mechanical hoists has been reported as one of the primary reasons for non-compliance with these devices (Bell, 1984; Owen, 1988; Takala and Kukkonen, 1987). However, it did not appear to be a major issue in this study as the acceptability rates were fairly high. Also, transfer times for using the walking belt and hoist A were much lower in the nursing home than those observed in the laboratory study, probably because of the learning curve effect.

The mean ratings of 8 and 9 for hoist A and the walking belt suggest that the job physical

demands were perceived by NAs to be fairly low after the intervention. This observation is consistent with the low compressive and pulling forces observed in the laboratory study.

### 7.1. Reduction in number of patient transfers

The use of shower chair and built-in weighing scale in the hoist reduced or eliminated some of

the patient transfers. For example, patients could be weighed during any transfer made using the hoist. This eliminated the transfers required to weigh patients (from wheelchair to weighing scale chair and from weighing scale to wheelchair). The use of shower chair also reduced patient transfers required for toileting, bathing or showering. For example, after intervention, toileting and showering required two transfers: bed to shower chair



Fig. 8. Modified walking belt: wrap-around handles and quick-release buckle, front view (top) and adjustable buckle for wedging the belt, rear view (bottom).

and shower chair to bed. The patient was toileted and given a shower by pushing the shower chair over the toilet, then to the shower room, and then back to the patient's room. These tasks required six transfers before intervention: bed to wheelchair, wheelchair to toilet, toilet to wheelchair, wheelchair to bathtub, bathtub to wheelchair, and wheelchair to bed.

Reducing the number of transfers is important in reducing back injuries to nursing personnel. Jensen (1990) reported that the greater the frequency of patient transfers, the greater is the number of back injuries to the nursing personnel.

### 7.2. *Improved patient transferring devices*

There were a few verbal complaints from NAs that they felt some discomfort in their wrists or forearms when pulling patients with the walking belt because the walking belt had thin handles made of canvas material. Similarly, the walking belt had a tendency to slide up on some of the patients when the NAs would lift up rather than pull the patient. This was because NAs are accustomed to lifting patients and some patients tend to be smaller at the chest and waist level than at the hip level (pear-shaped). Since this study, the walking belt has been modified by the manufacturer based on authors' recommendations. The modified walking belt has cylindrical handles, and is 1.9 cm in diameter and 10 cm long to provide secure wrap-around grasp (Fig. 8). The top end of the walking belt has been wedged by providing an adjustable buckle similar to that used on trousers in the old days (Fig. 8).

It is worth mentioning that since this study, several new hoists have become commercially available. Our preliminary analysis shows that, in general, these hoists are much superior to those employed in this study.

Lastly, in spite of very favorable findings, caution should be used in generalizing these results to other nursing homes. The post-intervention observations are based over a short time period. In this regard, long-term studies are needed. Also, staffing level, training, workload and management commitment need to be considered for an ergonomic approach to be effective.

## 8. Conclusion

Using a gentle rocking motion to utilize momentum and then pulling a patient, as compared to manually lifting the patient, results in significantly lower biomechanical and perceived stresses to the nurses and increased comfort and security of the patients. However, there are significant differences in perceived stresses and patient comfort and security levels between different manual devices used for pulling the patient. The use of a mechanical hoist, in place of a manual technique, may not necessarily reduce perceived physical stresses to the nurses or increase the comfort and security of the patient.

The ergonomic intervention in a nursing home resulted in reduced perceived stresses to nursing personnel and high acceptability rates for the recommended devices. The back injury incidence rate was reduced from 83 to 47. There were no lost or restricted workdays during the last four months of the post-intervention phase.

## Acknowledgements

The authors thank the nurse subjects who participated in the laboratory study and Dr. Roger Jensen for his valuable help and suggestions. This study was supported in part by contract #200-86-2923 from The National Institute for Occupational Safety and Health (NIOSH), Morgantown, West Virginia. Findings, conclusions, and recommendations expressed by the authors are not to be imputed to the funding organization, NIOSH. Mention of product names does not imply endorsement by NIOSH or the University of Wisconsin Board of Regents.

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