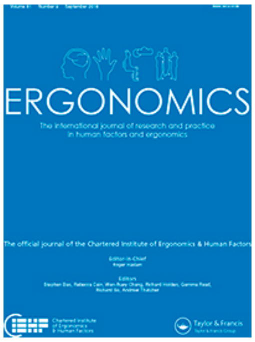

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Reducing back stress to nursing personnel: an ergonomic intervention in a nursing home

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Keywords: Patient transfers; Compressive force; Ratings of perceived exertion; Acceptability rates; Incidence and severity rates.

A prospective epidemiologic study was conducted in two units (140 beds and 57 nursing assistants) of a nursing home to demonstrate the efficacy of an ergonomic intervention strategy to reduce back stress to nursing personnel. The total programme involved the following: determining patient handling tasks perceived to be most stressful by the nursing assistants (NAs); performing an ergonomic evaluation of these tasks; and conducting a laboratory study to select patient transferring devices perceived to produce less physical stress than existing manual patient-handling methods. The intervention phase included training NAs in the use of these devices, modifying toilets and shower rooms, and applying techniques to patient care. Immediately after completing the intervention programme, a post-intervention analysis (which lasted eight months in unit 1 and four months in unit 2) was performed.

A biomechanical evaluation of the physical demands required to perform stressful patient-handling tasks showed that the mean compressive force on the L5/S1 disc, the mean hand force required to make a transfer, and the strength requirements (expressed as percentage female population capable) were 1964 N, 122 N, and 83% after intervention as compared to 4751 N, 312 N, and 41% before intervention. Subjectively, the mean rating of perceived exertion was less than 'very light' after intervention as compared to between 'somewhat hard' and 'hard' before intervention. Overall, the mean acceptability rates for the walking belt and the mechanical hoist were 81% and 87% for patient transfers. The incidence rate for back injuries prior to the intervention, 83 per 200 000 work-hours, decreased to 47 per 200 000 work-hours after the intervention. There were no injuries resulting in lost or restricted work days during the last four months of the post-intervention. It is concluded that an appropriate ergonomic intervention programme offers great promise in reducing physical stress and risk of low-back pain to nursing personnel. However, large-scale studies in different nursing homes are needed to confirm the above findings.

1. Introduction

Occupational back injuries are a major problem in the USA (Kelsey 1982, Klein *et al.* 1984, NIOSH 1986). Nursing personnel have both high prevalence rates of back pain (Biering-Sorensen 1985, Cust *et al.* 1972, Dehlin *et al.* 1976, Harber *et al.* 1985, Stubbs *et al.* 1983a,b, Videman *et al.* 1984) and high incidence rates of workers' compensation claims for back injuries (Jensen 1987, Klein *et al.* 1984, Personick 1990). The low-back pain experienced by nursing personnel is greater than the published statistics indicate, and nurses perceive back pain as an inevitable part of nursing practice (Owen 1987, Garg *et al.* 1991c).

The back injury problem appears to be greater in nursing homes than in hospitals (Jensen 1987, Personick 1990, Valles-Pankratz 1989). Further, the rate of reported back injuries per 100 workers in nursing homes is rising at an alarming rate (Personick 1990, Valles-Pankratz 1989). Nursing assistant is the dominant occupation of the injured nursing home worker (Personick 1990).

Several studies have concluded that frequent manual lifting and/or transferring of patients are the primary, or at least the most recognized, causal factor for low-back pain among nursing personnel (Bell *et al.* 1979, Dehlin *et al.* 1976, Ferguson 1970, Greenwood 1986, Harber *et al.* 1985, Jensen 1985, 1990b, Owen 1985, 1987, Personick 1990). Also, many nurses believe that of all tasks performed by them, patient-handling activities are most likely to result in low-back pain (Harber *et al.* 1989). Owen and Garg (1989) reported significantly higher ratings of perceived exertion for patient transfers than for non-transfers. Indeed, a few quantification studies have found high levels of biomechanical stress induced by patient lifting and transferring tasks (Carlson 1989, Gagnon *et al.* 1986, Garg *et al.* 1991a,b,c, Stubbs *et al.* 1983, Torma-Krajewski 1986). In addition, high levels of postural stress (standing, stooping, etc.) are also cause of concern (Baty and Stubbs 1987, Garg *et al.* 1991c).

The problem of lifting a patient is not simply one of overcoming a heavy weight (Bell 1984, Carlson 1989), as the patient's weight and physical condition, including size, shape, and deformities along with any physical impairments of lower limb function, balance and co-ordination affect the way the transfer can be carried out. Some patients can be combative, contracted, and/or unco-operative (Carlson 1989). Further, patients are unpredictable and may suddenly resist movement and/or grab the nursing personnel and throw them off-balance during the transfer. Often, optimum body postures cannot be assumed due to space limitations, equipment interference, and unadjustable beds, chairs, and commodes, etc. These realities prevent nursing personnel from always using the ideal body mechanics they have been taught.

1.1. *Back injury prevention approaches*

The most obvious programmes for back injury prevention among nursing personnel tend to focus on proper lifting techniques, body mechanics, and back care (Fletcher 1981, Greenwood, 1986, Hollis and Waddington 1975, Iveson-Iveson 1979, Jensen 1990b, McMillan 1979, Owen 1980, Raistrick 1981, Scholey 1984, Takala and Kukkonen 1987). A commonly-held belief among nurses is that the primary way to avoid back injuries from patient-handling activities is to always apply proper body mechanics (Harber *et al.* 1989). The facts are that some patient-handling tasks are so stressful that back injuries result even when all the proper techniques are used (Garg *et al.* 1990a,b,c, Gagnon *et al.* 1986, Stubbs *et al.* 1983b, Torma-Krajewski 1986) and some patient handling tasks are not amenable to the use of proper body mechanics. Further, there is a lack of consensus on proper lifting techniques (Garg 1990) and experts are not in complete agreement concerning which procedures are best for specific patient transfers (Venning 1988). Often methods acceptable in one health institution are not considered appropriate in others (Standard Association of Australia 1982).

Although, instruction on manual lifting and transferring patients is widely believed to have prophylactic value, there is no scientific evidence that it alone is effective in reducing the frequency or severity of back pain, especially in nursing practice (Brown 1972, Buckle 1982, Dehlin *et al.* 1976, Snook *et al.* 1978, Stubbs *et al.* 1983b, Wood 1987). Consequently, some experts believe that training in proper body mechanics and patient handling procedures should not be relied upon as the only component of a back injury prevention programme (Buckle 1982, Dehlin *et al.* 1976, Lloyd *et al.* 1987, Owen 1985, Stubbs *et al.* 1983b, Venning 1988, Wood 1987).

An approach to back injury prevention that goes beyond the traditional employee training approach is known as the ergonomics approach. Instead of focusing on the behaviour of people, ergonomics approach seeks to design work so the physical and mental demands of the tasks are within the capabilities of the workers.

Many researchers have recommended an ergonomic approach for reducing stress on the spine in jobs requiring manual lifting (Bell 1984, Brown 1972, Buckle 1982, Dehlin *et al.* 1976, Garg *et al.* 1991a,b,c, Harber *et al.* 1985, Jensen 1990b, Lloyd *et al.* 1987, Owen 1987, Snook *et al.* 1978, Stubbs *et al.* 1983b, 1986, Videman *et al.* 1984). It has been suggested that application of an ergonomics approach to patient-care jobs could lead to safer and more efficient methods of handling patients which will reduce the present level of low-back stress for nursing personnel (Lloyd *et al.* 1987, Stubbs *et al.* 1983b). This investigation was undertaken to determine if an ergonomics approach applied to a nursing home would be effective.

2. Measuring effectiveness of ergonomic intervention

2.1. *Incidence of low-back pain*

The most obvious and traditional measures of safety performance are the frequency and severity rates of lost time injuries. For measuring the effectiveness of the ergonomic intervention programme, these measures are less than ideal because numerous factors can affect the reporting of injuries and the duration of disability.

2.2. *Intervention acceptability*

When a group of workers are asked to change their established routines, a reluctance to change is often encountered. Their refusal to adopt a work procedure could reflect an unanticipated problem with the recommendation. Thus, in intervention trials it is useful to measure the extent to which workers accept the recommendation.

2.3. *Biomechanical stresses*

The biomechanics of lifting and handling loads provides one basis as to why certain musculoskeletal injuries and, in particular low-back injuries, develop. Two different biomechanical considerations must be met to achieve 'safe levels' for manual materials handling: stress to the low-back should be within the 'safe limit' and the job physical requirements should not exceed workers' strength. Regarding stress to the low back, compressive force is the most widely accepted response measure.

2.4. *Ratings of perceived exertion*

Another measure of the effectiveness of an ergonomic intervention programme is feedback from the workers. Assessing postural discomfort and levels of perceived exertion have been shown as effective methods for identifying and prioritizing musculoskeletal stresses (Corlett and Bishop 1976, Garg and Banaag 1988). In this regard by far the most frequently used scale for determining perceived stresses during physical work is the Rating of Perceived Exertion Scale (RPE Scale) developed by Borg (1962).

In the current study, in addition to objective measures (reportable injuries, acceptability rates, and biomechanical measures of task demands), it was considered highly desirable to obtain feedback from the nursing assistants to determine if they felt a change in task demands. It is believed that since nursing assistants perform the majority of patient transfers, they are the ones who are being subjected to various kinds of physical stresses and can thus integrate these stresses into a single meaningful response variable.

3. Method

3.1. *Setting*

The study took place in a nursing care facility located in Southeastern Wisconsin; it is owned and managed by county government. Two floors (units) of the facility were selected for the study because many of the 140 patients on these two units required frequent help with patient care activities. They were, in general, mentally incompetent (Alzheimer's disease) and unpredictable; had major health problems (strokes, diabetes or Parkinson's disease); were unable to follow directions; were physically dependent; were spastic and rigid (with contracted joints); and were resistive or combative (grabbing, pinching, hitting, and biting). Their body weight ranged from 38 to 120 kg ($\bar{X}=62$ kg). The above characteristics were more prevalent in unit 1 than in unit 2, except major health problems were more prevalent in unit 2. On unit 1, 20% of the patients were independent, 40% required use of a walking belt, and 40% needed a hoist for transfer; on unit 2, 40% were independent, 30% needed a belt, and 30% required a hoist for transfer.

There were four wings on each unit with about 18 patients on each of the wings. Two to three nursing assistants were assigned to each wing during the day and evening shifts.

3.2. *Subjects*

When the pre-intervention observation phase was initiated, 38 of the 57 nursing assistants (NAs) employed at least half-time had volunteered as subjects. All 57 NAs employed on the two units participated during the intervention and post-intervention phases of the study. Ninety-five per cent were females and 5% were males. The mean age, body weight, and length of employment were 33 years (range = 19–61 years), 64 kg (range = 45–106 kg), and five years (range = 0·5–20 years), respectively. When asked about lifetime experience, 75% had suffered from low-back pain and 51% had visited a health care provider for this pain. Sixty-five per cent stated that they lost no work time within the last three years due to back pain perceived to be related to work; 10% lost one to seven days; and 25% lost eight days or more.

3.3. *Procedure*

The study took about four years and was divided into the following phases:

(1) the determination of patient-handling tasks perceived to be most stressful by the NAs (Owen and Garg 1989);
(2) an ergonomic evaluation of the work performed by NA: prior to the introduction of change (Carlson 1989);
(3) a pilot study to identify and locate assistive devices, to establish criteria for their selection, and to perform preliminary trials of these devices (Owen and Garg 1990);

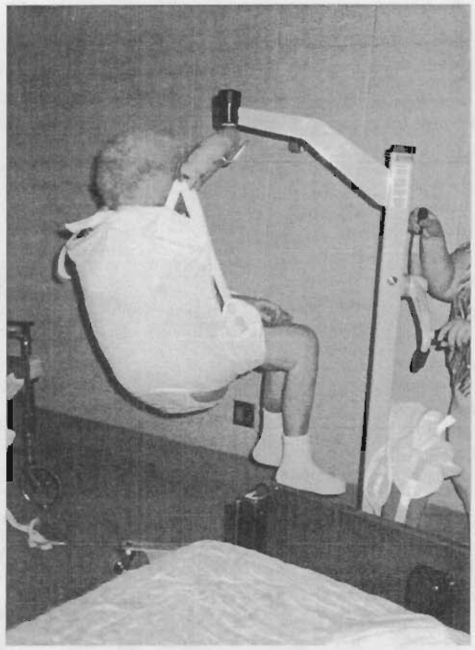

Figure 1. Mechanical hoist used in the study.

(4) a laboratory study to select patient-handling devices that were less stressful than existing methods in the nursing home (Garg *et al.* 1990a,b);
(5) the introduction of selected devices in the nursing home and training of NAs in their use with patients (intervention);
(6) post-intervention measurement of back injury incidence and severity rates, acceptability rates, biomechanical task demands, and perceived level of physical stress.

Details of the pre-intervention phase are given in various references as indicated above. The following is a brief description of the pre-intervention phase to provide continuity with this report on the intervention and post-intervention phases.

Patient-handling tasks perceived as most stressful by the NAs were ranked according to stressfulness and then rated for perceived exertion for shoulder, upper back, lower back, and whole body. Based on these rankings and ratings, the following tasks were selected for intervention: transferring patients from bed to wheelchair and wheelchair to bed, from wheelchair to toilet and toilet to wheelchair, from wheelchair to chairlift and chairlift to wheelchair, into and out of the bathtub, and weighing patients. An ergonomic evaluation was performed to determine such data as patient and NA characteristics; details of each task; method used for transfer; frequency of occurrence for each task; number and degree of trunk flexion, lateral flexion, and axial rotation per transfer; workplace layout, etc. The most frequently used technique for transferring patients was a two-person manual lifting method. The NAs grasped the patient under the axillae and then lifted and carried the patient to the destination.

Patient transfer were simulated in a laboratory using the existing manual lifting method, four different manual pulling methods using slings and belts, and three different mechanical hoists. Eight criteria were used to select devices for intervention

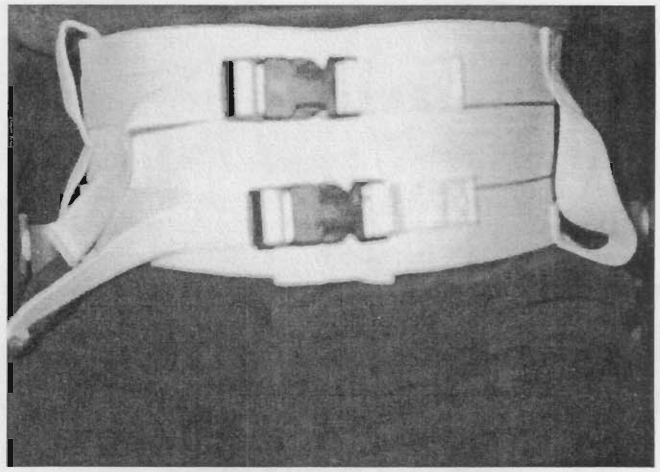

Figure 2. Walking belt with handles used in the study.

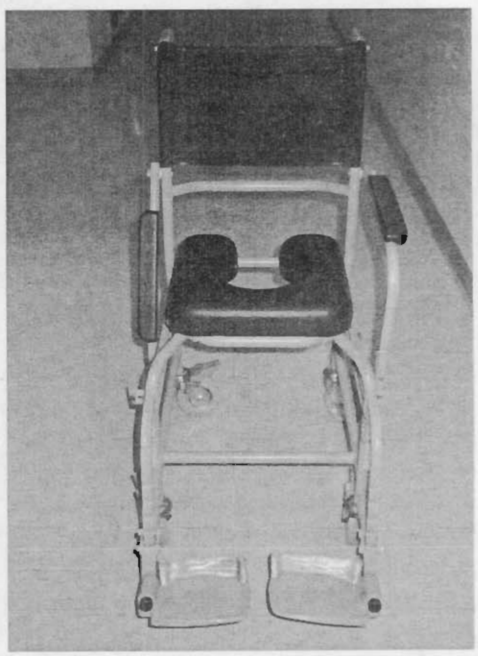

Figure 3. Shower chair with removable foot pedals and arm supports used in the study.

(Owen and Garg 1990). These were compressive force on the L5/S1 disc; strength requirements (% capable females); perceived stress ratings; patient comfort ratings; patient security ratings; applicability of a method to different types of patients; overall method preferences of nurses; and transfer time. Based on these criteria, a hoist (figure 1), a walking belt with handles (figure 2), and a shower chair (figure 3) with removable foot pedals and arm supports were selected for inclusion in the intervention programme. The walking belt utilized gentle rocking and pulling action rather than lifting the patient.

3.4. *Intervention*

Patients were classified into three categories based on their physical ability: dependent, weight-bearing; dependent, non-weight-bearing; and independent. A two-person walking belt (modified by the manufacturer for easy fastening per suggestions of authors) was recommended for transferring dependent, weight-bearing patients with body weights of less than 70 kg. A hoist was recommended for dependent, non-weight-bearing, or heavy patients. Each dependent patient's bed was marked with a blue or red dot to indicate whether a belt or hoist should be used for that patient. Each dependent, weight-bearing patient was provided with an appropriate sized walking belt (small, medium, or large) with the patient's name written on it. Each wing of the two units of the nursing home involved in the study was provided with a hoist (and slings of various sizes) and a shower chair. One hoist had a weighing scale attached to it. In addition, one unit was provided with a ramp-type weighing scale. A separate frame and a sling (modified by the manufacturer per suggestions of authors) were provided for lifting patients from floor level. Commodes in patients' bathrooms were raised to about wheelchair height. Toilet hand rails were adjusted so that the shower chair could fit over the toilet. Adaptive clothing (trousers and dresses) were provided for those patients who were to be toileted using the hoist. Showers in the two units were repaired for water temperature control and were modified to allow easy pushing and pulling of the shower chair into and out of the shower. The head nurses in both units made determinations as to which patients were to be given a bath and which patients were to use the shower.

Hoists, walking belts and shower chairs were first introduced in unit 1. Five months later, after the research team and the nursing home management were satisfied with the devices chosen and after no major problems were encountered with their use, the devices were introduced in unit 2.

The supervisors, the head nurses, the nurses and the NAs were trained by the authors in the use of the hoist, walking belt, and shower chair in groups of four to eight in an empty patient room or in the nursing home (in-service) laboratory with the participants serving both as nursing assistants and passive patients. Fifty-four of the 57 NAs (95%) attended at least two training sessions of 2 h each. First they were trained in the use of the walking belt, followed by the hoist and the shower chair. A given patient transfer task was explained to them, a videotape of the transfer was shown, and then the NAs practised each patient transfer until they felt comfortable with it, and were competent with the task as observed by the authors before moving to the next transfer task. The participants were encouraged to ask questions and give feedback during the training sessions. They were corrected when using the method incorrectly. These training sessions lasted for two to three weeks per unit due to scheduling problems.

Training of NAs on units 1 and 2 differed in relation to room location, the time lapse between training and application, and the addition of a third trainer. On unit 1, training occurred in an in-service education room in an adjacent building and there was a two-week delay between end of training and the application on the patient unit because the custom-made walking belts were late in arriving. On unit 2, the supervisor (trained by the authors) worked with the authors in the training programme. In addition, on unit 2 the training took place in an empty patient room within the patient case area (rather than in the in-service room) and there was no delay between the time when the NA was judged as competent to apply the techniques to the time when he/she actually applied them to the patients. The strategies used in the actual teaching, the time involved, the written take-home materials, the teaching plans, and methods of evaluation were the same for each unit. The two authors were involved in each step of the training on each unit.

When using the walking belt, the NAs stood facing the patient (as close as possible) with feet apart, one foot placed facing the patient and the other foot in the direction of movement to avoid twisting of the spine while transferring. They were instructed to flex their knees and keep their backs straight (if possible) and to grasp the handle of the walking belt with one hand. In synchronization, using a gentle rocking motion to utilize momentum, the NAs *pulled* the patient toward themselves, shifted their weight to the foot facing the direction of the move, pivoted to avoid twisting, and transferred the patient. The NAs were instructed, 'Pull with your hands and not your back. Do not lift.' When using the hoist, special emphasis was placed on properly applying the sling under the thighs of the patient while keeping the front hook away from the patient and also on being aware of patient safety.

After the NAs felt comfortable with these transfer devices, and were judged to be competent by the authors, they were allowed to use them to transfer patients in their units. For about four weeks, both authors and one of the nursing supervisors frequently worked with the NAs to train them further on proper use of these devices, to answer questions, and to solve unforeseen problems. The head nurses in the two units had the responsibility for training new NAs (5% of total number), for coding new patients, and for equipment maintenance.

3.5. *Post-intervention*

Two independent nurse observers (research assistants) randomly observed the NAs performing routine patient transfers to determine acceptability rates for the walking belt and the hoist. Data collection forms were used to record the unit number, the nature of the transfer task (for example, bed to wheelchair), device used if any, patient code (independent, weight-bearing, non-weight-bearing), number of NAs involved in the transfer, and occasionally to record the amount of time it took for the transfer. Ratings of perceived exertion data were collected after completion of a transfer by asking the NAs to enter the level of exertion felt in four areas of the body (shoulder, upper back, lower back, and whole body). The Borg RPE scale (Borg 1962) was attached to the form as well as a body model depicting the four areas of the body. These data were collected over a period of eight months in unit 1 and four months in unit 2.

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 programme: 1986 to 1988 plus the first six months of 1989 for unit 1 and 1986 to 1989 (with the exception of two training months in 1989, July and December) for unit 2. Data were also collected for periods of eight months and four months following intervention in units 1 and 2, respectively.

Task demands before and after intervention were determined from laboratory simulation of the old and the new methods of patient transfer. A three-dimensional, static biomechanical model (Garg and Chaffin 1975) was used to estimate the task demand variables, compressive forces on the L5/S1 disc and strength requirements.

Table 1. Acceptability rates for walking belt for handling dependent, weight-bearing patients.

Task	Acceptability rate (%) Unit 1	Unit 2	Combined
1. Bed to wheelchair (89*,51)	90	82	87
2. Wheelchair to bed (77,45)	94	96	95
3. Wheelchair to toilet (67,36)	78	61	72
4. Toilet to wheelchair (69,48)	81	56	71
5. Wheelchair to chairlift (18,2)	83	50	80
6. Chairlift to wheelchair (15,5)	93	40	80
7. Wheelchair to shower chair (6,4)	100	50	80
8. Shower chair to wheelchair (7,3)	100	67	90
9. Changing attends (25,8)	64	62	64
10. Repositioning in chair (78,28)	41	46	42
11. Repositioning on toilet (18,2)	87	50	80
12. Walk patients (14,0)	86	—	86

*Number of observations in units 1 and 2, respectively.

Task performance times were measured by the nurse observers both before and after the intervention.

4. Results

4.1. *Acceptability rate*

Acceptability rates for the walking belt for different patient handling tasks are summarized in table 1. The task-specific acceptability rates listed in table 1 were computed as follows:

$$\text{Acceptability rate for task belt} = \frac{\text{Number of dependent, weight-bearing patient handlings performed with walking belt for the task}}{\text{Total number of dependent, weight-bearing patient handlings performed for the task}} \times 100$$

Similarly, task-specific acceptability rates were determined for the hoist for handling dependent, non-weight-bearing patients. These are listed in table 2. In general, the acceptability rates for the walking belt were somewhat higher in unit 1 than in unit 2 (table 1). On the other hand, acceptability rates for the hoist were somewhat higher in unit 2 than in unit 1 (table 2). Acceptability rates for both the devices were higher for patient transfers than for non-transfers (such as repositioning in chair, in bed and on toilet, and changing attends [adult absorbent pads]) (tables 1 and 2). For patient-transferring tasks, the combined acceptability rate from the two units ranged from 71% to 95% for the walking belt (table 1), and 50% to 100% for the hoist (table 2). For non-transfers, the combined acceptability rate from the two units ranged from 42% to 86% for the walking belt, and 33% to 72% for the hoist (tables 1 and 2).

It was observed that some dependent, non-weight-bearing patients were transferred using a walking belt instead of the hoist due to a change in physical and mental abilities of these patients from day to day and from morning to evening.

Table 2. Acceptability rates for the hoist for handling dependent, non-weight-bearing patients.

Task	Acceptability rate (%) Unit 1	Unit 2	Combined
1. Bed to wheelchair (52*,67)	79	92	87
2. Wheelchair to bed (70,53)	89	94	91
3. Wheelchair to toilet (16,24)	56	92	77
4. Toilet to wheelchair (19,24)	47	96	74
5. Wheelchair to chairlift (2,6)	50	67	62
6. Chairlift to wheelchair (12,2)	50	50	50
7. Wheelchair to shower chair (2,8)	50	100	90
8. Shower chair to wheelchair (2,12)	100	100	100
9. Bed to shower chair (0,10)	—	100	100
10. Shower chair to bed (0,4)	—	100	100
11. Bed to toilet (0,18)	—	100	100
12. Toilet to bed (0.6)	—	100	100
13. Bed or wheelchair to bathtub (0,6)	—	100	100
14. Bathtub to bed or wheelchair (0,5)	—	100	100
15. Floor to bed (1,0)	100	—	100
16. Weighing patients (7,0)	100	—	100
17. Changing attends (15,3)	80	33	72
18. Repositioning in wheelchair (24,14)	25	29	26
19. Repositioning on toilet (2,1)	50	0	33
20. Repositioning in bed (6,2)	50	100	62

* Number of observations in units 1 and 2, respectively.

Table 3. Acceptability rates from two units for combined the hoist and walking belt for handling dependent, non-weight-bearing patients.

Task	Acceptability rate (%)
1. Bed to wheelchair (119*)	94
2. Wheelchair to bed (123)	96
3. Wheelchair to toilet (40)	87
4. Toilet to wheelchair (43)	98
5. Wheelchair to chairlift (8)	87
6. Chairlift to wheelchair (14)	86
7. Wheelchair to shower chair (10)	100
8. Shower chair to wheelchair (14)	100
9. Bed to shower chair (10)	100
10. Shower chair to bed (4)	100
11. Bed to toilet (18)	100
12. Toilet to bed (6)	100
13. Bed or wheelchair to bathtub (6)	100
14. Bathtub to bed or wheelchair (5)	100
15. Floor to bed (1)	100
16. Weighing patients (7)	100
17. Changing attends (18)	72
18. Repositioning in wheelchair (38)	31
19. Repositioning on toilet (3)	33
20. Repositioning in bed (8)	62

* Total number of observations from two units.

Table 4. Overall acceptability rates.

1. Belt for dependent, weight-bearing patients		
	Transfers	(n=522)=81·2%
	Non-transfers	(n=163)=52.8%
2. Hoist for dependent, non-weight-bearing		
	Transfers	(n=413)=86.9%
	Non-transfers	(n=69) =42·0%
3. Hoist or belt for dependent, non-weight-bearing patients		
	Transfers	(n=413)=95·9%
	Non-transfers	(n=69) =47.8%

Table 3 gives acceptability rates from the two units for combined hoist and walking belt for handling dependent, non-weight-bearing patients, i.e., a patient handling task performed using either the hoist or a walking belt is included in the numerator for determining acceptability rates. As expected these acceptability rates were somewhat higher than those given in table 2, in particular for the first seven patient transfers. The acceptability rates for combined hoist and walking belt for handling dependent, non-weight-bearing patients ranged from 86% to 100% for transfers (tasks 1 to 16) and 31% to 72% for non-transfers (tasks 17 to 20, table 3).

The mean acceptability rates for walking belt and hoist computed by averaging over various patient handling tasks are summarized in table 4. The mean acceptability rate for these devices ranged from 81·2% to 95·9% for patient transfers, and from 42·0% to 52·8% for non-transfers (table 4).

4.2. *RPEs*

An analysis of variance showed that RPE scores were significantly affected by the unit, the 18 patient-handling tasks, the two devices and the four body parts ($p \leq 0 \cdot 01$) (table 5). In general, the RPEs were somewhat higher for unit 2 than for unit 1 (table 6). However, the differences between the two units were of no practical significance. Overall, lower back was the body part most stressed both for the walking belt and the hoist (table 6). Ratings of perceived exertion for the whole body were a little higher than those for shoulder and upper back (table 6). Neither device was perceived to produce significant stresses on any of the four body parts. The mean lower-backs RPEs of 9·0 and 8·0 for the walking belt and the hoist corresponded to 'very light' and between 'very, very light' and 'very light' on the Borg scale.

Table 5. Analysis of variance of ratings of perceived exertion.

Source	S.S.	df	M.S.	F-ratio
Unit	163·6	1	163·6	22·1**
Task	993·6	17	58·4	7·9**
Device	842·6	1	842·6	113·9**
Bodypart	140·5	3	46·8	6·3**
Within	24082	3261	7·4	

**Significant at $p \leq 0 \cdot 01$.

Table 6. Overall ratings of perceived exertion for transferring patients with walking belt and hoist.

Unit	Device	Number of observations	Ratings of perceived exertion: Shoulder	Lower back	Upper back	Whole body
1	Walking belt	313	8·4 ± 3·0 (6–20)	8·8 ± 3·5 (6–20)	8·3 ± 3·1 (6–20)	8·6 ± 3·2 (6–20)
	Hoist	99	7·2 ± 1·8 (6–15)	7·6 ± 2·3 (6–15)	7·2 ± 1·8 (6–14)	7·3 ± 1·8 (6–15)
2	Walking belt	129	8·8 ± 2·8 (6–19)	9·6 ± 3·2 (6–20)	8·8 ± 2·8 (6–19)	9·2 ± 2·8 (6–19)
	Hoist	280	7·7 ± 2·3 (6–18)	8·1 ± 2·7 (6–19)	7·6 ± 2·1 (6–15)	7·0 ± 2·4 (6–18)
Combined units	Walking belt	442	8·5 ± 2·9 (6–20)	9·0 ± 3·4 (6–20)	8·5 ± 3·0 (6–20)	8·8 ± 3·1 (6–20)
	Hoist	379	7·6 ± 2·2 (6–18)	8·0 ± 2·6 (6–19)	7·5 ± 2·1 (6–15)	7·7 ± 2·6 (6–18)

Table 7. Combined ratings of perceived exertion from two units for transferring dependent, weight-bearing patients using walking belt.

Task	Number of observations	Ratings of perceived exertion: Shoulder	Lower back	Upper back	Whole body
1. Bed to wheelchair	129	7·9 ± 2·4 (6–20)	8·6 ± 3·2 (6–20)	8·0 ± 2·8 (6–20)	8·2 ± 2·6 (6–20)
2. Wheelchair to bed	66	8·4 ± 2·3 (6–13)	9·3 ± 3·5 (6–20)	8·7 ± 2·5 (6–15)	9·1 ± 2·9 (6–15)
3. Wheelchair to toilet	93	9·2 ± 3·5 (6–20)	9·5 ± 3·8 (6–20)	8·8 ± 3·5 (6–20)	9·3 ± 3·7 (6–20)
4. Toilet to wheelchair	106	8·3 ± 2·7 (6–17)	8·8 ± 3·2 (6–20)	8·1 ± 2·7 (6–17)	8·6 ± 2·8 (6–17)
5. Wheelchair to chairlift	10	9·4 ± 2·8 (6–15)	9·7 ± 2·9 (6–15)	9·0 ± 2·3 (6–12)	9·9 ± 2·9 (6–15)
6. Chairlift to wheelchair	16	9·4 ± 3·6 (6–19)	9·5 ± 2·7 (6–15)	9·2 ± 3·3 (6–15)	9·1 ± 2·1 (6–13)
7. Wheelchair to shower chair	3	6·0 ± 0 (6–6)	6·0 ± 0 (6–6)	7·0 ± 1·7 (6–9)	6·0 ± 0 (6–6)
8. Shower chair to wheelchair	4	8·5 ± 2·6 (6–12)	8·7 ± 3·1 (6–13)	9·2 ± 4·0 (6–15)	9·2 ± 2·9 (6–13)
9. Changing attends	15	10·7 ± 4·7 (6–17)	10·7 ± 5·0 (6–18)	11·0 ± 5·1 (6–18)	11·2 ± 5·5 (6–20)

Ratings of perceived exertion for different patient handling tasks performed using walking belt and the hoist are summarized in tables 7 and 8, respectively. An examination of table 7 shows that none of the patient handling tasks performed using walking belt was perceived to produce RPE scores over 12 on any of the four body parts. Surprisingly, the highest RPEs were for changing attends, a non-transfer task, probably due to the amount of static effort involved for this task. Even the highest RPEs of about 11 for this task correspond to 'fairly light' effort on the Borg scale. Similarly, none of the patient handling tasks performed using the hoist produced

Table 8. Combined ratings of perceived exertion from two units for transferring dependent, non-weight-bearing patients using the hoist.

Task	Number of observations	Ratings of perceived exertion: Shoulder	Lower back	Upper back	Whole body
1. Bed to wheelchair	102	7·7±2·0 (6–15)	8·2±2·5 (6–18)	7·5±1·8 (6–13)	7·8±2·0 (6–11)
2. Wheelchair to bed	94	7·2±1·9 (6–15)	7·6±2·3 (6–15)	7·2±1·8 (6–14)	7·5±2·0 (6–15)
3. Wheelchair to toilet	29	7·1±1·4 (6–10)	7·2±1·9 (6–14)	7·2±2·1 (6–15)	7·2±1·7 (6–13)
4. Toilet to wheelchair	35	8·3±2·8 (6–17)	8·6±3·2 (6–19)	8·3±2·9 (6–15)	8·5±3·0 (6–16)
5. Wheelchair to chairlift	5	7·0±1·7 (6–10)	6·0±0 (6–6)	7·0±1·7 (6–10)	7·0±1·7 (6–10)
6. Chairlift to wheelchair	2	8·5±3·5 (6–11)	6·0±0 (6–6)	6·0±0 (6–6)	6·5±0·7 (6–7)
7. Wheelchair to shower chair	6	7·7±2·0 (6–10)	7·7±2·0 (6–10)	7·0±1·7 (6–10)	7·2±1·2 (6–10)
8. Shower chair to wheelchair	20	7·5±2·3 (6–16)	7·6±2·4 (6–16)	7·1±1·4 (6–11)	7·7±2·3 (6–15)
9. Bed to shower chair	17	7·2±1·3 (6–10)	6·9±1·2 (6–10)	7·2±1·3 (6–10)	7·2±1·2 (6–10)
10. Shower chair to bed	3	12·0±5·2 (6–15)	12·7±5·9 (6–17)	12·0±5·2 (6–15)	12·7±5·9 (6–17)
11. Bed to toilet	22	8·3±2·4 (6–13)	9·1±3·1 (6–16)	8·8±2·7 (6–15)	8·9±3·0 (6–18)
12. Toilet to bed	6	6·3±0·8 (6–8)	6·3±0·8 (6–8)	7·3±2·4 (6–12)	6·3±0·8 (6–8)
13. Wheelchair to bathtub	5	11·4±3·6 (7–15)	14·0±2·0 (11–16)	8·4±1·9 (7–11)	9·6±3·8 (6–15)
14. Bathtub to wheelchair	5	7·0±1·7 (6–10)	10·0±4·1 (6–15)	6·2±0·4 (6–7)	7·0±1·7 (6–10)
15. Floor to bed	3	12·7±4·6 (10–18)	10·0±0 (10–10)	10·0±0 (10–10)	10·0±0 (10–10)
16. Weighing patients	7	6·1±0·4 (6–7)	6·3±0·5 (6–7)	6·1±0·4 (6–7)	6·3±0·5 (6–7)
17. Changing attends	14	7·0±1·4 (6–10)	7·1±1·7 (6–11)	7·0±1·4 (6–10)	7·3±2·0 (6–7)
18. Repositioning in chair	4	6·7±1·0 (6–8)	6·5±1·0 (6–8)	7·0±1·4 (6–9)	6·7±1·0 (6–8)

significant stresses except wheelchair to bathtub and shower chair to bed transfers (table 8). The wheelchair to bathtub transfer resulted in a mean rating of 14 (between 'somewhat hard' and 'hard') for the lower back. The nursing assistants had to manually lift the patient in the hoist to raise patient's buttocks to clear the top of the bathtub. Later, this problem was solved by using the short loop of the sling in place of the long loop. There is no clear explanation for the higher RPEs given for shower chair to bed transfers. However, a sample size of 3 for this transfer is relatively small.

Table 9 compares the RPEs for the lower back from the pre- and post-intervention phases of this study for those tasks common during the two phases of the study. The two-sample *t*-tests with unknown population variances (Miller and Freund 1977) was used to test whether the post-intervention RPEs for the walking

Table 9. Comparison of ratings of perceived exertion for lower back from pre- and post-intervention phases for selected tasks.

Task	Ratings of perceived exertion Pre-intervention (Manual lifting)	Post-intervention Walking belt	Hoist
Bed to wheelchair	14·1	8·6**	8·2**
Wheelchair to bed	14·2	9·3**	7·6**
Wheelchair to toilet	14·1	9·5**	7·2**
Toilet to wheelchair	14·3	8·8**	8·6**
Chairlift to wheelchair	13·4	9·5**	6·0**
Weighing patients	13·8	—	6·3**
Bathtub to wheelchair	13·3	—	10·1*
Repositioning in wheelchair	12·0	—	6·5**
Changing attends in wheelchair	11·3	10·7	7·1**

*significant at $p \leq 0{\cdot}05$.
**significant at $p \leq 0{\cdot}01$.

Table 10. Summary of biomechanical evaluation of transferring patients using manual lifting and walking belt techniques.

Variable	Pre-intervention (Manual lifting)	Post-intervention (Walking belt)
Hand force (N)	312 ± 54 (263–392)	122 ± 16 (98–156)
Percent capable population (%)	41 ± 8 (14–61)	83 ± 9 (69–98)
Compressive force on L5/S1 disc (N)	4751 ± 106 (3693–5414)	1964 ± 71 (1517–2413)

belt and the hoist were significantly lower ($p \leq 0{\cdot}01$) than the pre-intervention RPEs. All post-intervention RPEs were significantly lower except for the task of changing attends in a wheelchair using a walking belt. In general, the mean RPEs were about 14 (between 'somewhat hard' and 'hard') before intervention and 9 ('very light' for walking belt) and 8 (between 'very, very light' and 'very light' for the hoist) after intervention (table 9). Similar trends were found for other body parts.

4.3. *Biomechanical evaluation*

Task demand data for the before and after intervention phases are summarized in table 10. Separate analyses of variance showed that hand force and compressive force were significantly lower and percentage females capable significantly higher ($p \leq 0{\cdot}01$) after intervention as compared to before intervention (Garg *et al.* 1990b). The mean force required to pull the patient after intervention was 39% of the force required to lift the patient before intervention. Based on static strength simulations (Garg and Chaffin 1975), it is estimated that on the average 83% of female workers were capable of pulling patients with the walking belt as compared to 41% with the manual lifting technique used before intervention. The estimated mean compressive force on the L5/S1 disc after intervention (walking belt) was 41% of that before intervention (manual lifting method).

Table 11. Incidence and severity rates for injuries from two units of the nursing home.

Incidence and severity rates	Pre- or post-intervention	Unit 1 Back	Unit 1 Total	Unit 2 Back	Unit 2 Total	Combined Back	Combined Total
Number of injuries per 200 000 work-hours	Pre-intervention in both units	81	108	85	120	83	114
	Post-intervention in unit 1	62	103	139	193	—	—
	Post-intervention in both units	31	83	64	86	47	84
Number of lost and restricted work-days per 200 000 work-hours	Pre-intervention in both units	765	895	498	674	634	786
	Post-intervention in unit 1	952	952	1596	1596	—	—
	Post-intervention in both units	0	0	0	0	0	0

4.4. *Injury statistics*

Incidence and severity rates per 200 000 work-hours for back injuries and total injuries are summarized in table 11. These rates were calculated for each unit and the three comparable periods: pre-intervention phase (1 January 1986 to 30 June 1989); post-intervention in unit 1 and pre-intervention in unit 2 phase (1 August 1989 to 30 November 1989); and post-intervention phase in both units (1 January 1990 to 30 April 1990). In the subsequent discussion, these are referred to as pre-intervention phase, post-intervention phase I and post-intervention phase II. The two months, July and December 1989, were omitted because these were the months when training was being given in units 1 and 2, respectively. In the respective units these months were not clearly pre-intervention or post-intervention.

In unit 1, the incidence rate for back injuries decreased during each of the two post-intervention phases (table 11). The incidence rate for back injuries decreased by 23% and 62% during post-intervention phases I and II, respectively. In unit 2, the highest incidence rate for back injuries occurred during phase I of the post-intervention (table 11). After intervention, the incidence rate for back injuries decreased by 25% from the pre-intervention phase. Based on combined data from the two units, the incidence rate for back injuries was 43% lower during the post-intervention phase II as compared to pre-intervention phase. The incidence rates for total injuries (including all injuries such as those to lower limbs, upper limbs, trunk, back, hernia, etc.) followed the similar patterns as those for back injuries (table 11). In unit 1, the incidence rate for total injuries decreased by 5% and 23% during the post-intervention phases I and II, respectively. In unit 2, the incidence rate for total injuries increased by 61% during the post-intervention phase I and then decreased by 28% during the post-intervention phase II as compared to pre-intervention phase.

Regarding severity of injury, the number of days lost plus restricted per 200 000 work-hours (severity rates) increased during post-intervention phase I in both units and for both back as well as total injuries (table 11). This increase was much higher in unit 2 than in unit 1. In unit 1, the increase was 24% and 6% for back injuries and total injuries, respectively. In unit 2, the severity rates for back injuries and total injuries increased by 220% and 137%. During post-intervention phase II, the severity

Table 12. Summary of task performance times after intervention.

Task	Performance time(s) Walking belt	Hoist
1. Bed to wheelchair (32,36)	20 ± 16 (4–60)	69 ± 33 (30–185)
2. Wheelchair to bed (16,31)	19 ± 23 (4–90)	76 ± 38 (10–205)
3. Wheelchair to toilet (24,16)	22 ± 16 (5–58)	92 ± 44 (10–180)
4. Toilet to wheelchair (29,11)	39 ± 30 (4–125)	48 ± 16 (35–70)
5. Wheelchair to shower chair (0,5)	—	71 ± 18 (45–95)
6. Shower chair to wheelchair (0,9)	—	62 ± 26 (45–120)
7. Bed to shower chair (0,9)	—	80 ± 24 (55–116)
8. Shower chair to bed (0,3)	—	58 ± 7 (50–65)
9. Bed to toilet (0,12)	—	90 ± 37 (50–185)
10. Toilet to bed (0,3)	—	73 ± 23 (60–100)

rates in both the units were zero for both back injuries and total injuries, i.e., there was not a single day lost or restricted either due to a back injury or any other injury in either of the two units. The overall back injury severity rate for post-intervention (based on lost plus restricted work days during post-intervention phases I and II from unit 1 and during post-intervention phase II from unit 2) was 317 as compared to 634 before intervention.

There were a total of 15 back injuries and 26 total injuries after intervention (post-intervention phases I and II for unit 1 and post-intervention phase II for unit 2). None of the 26 injuries occurred when the hoist was used. Five injuries (19%) occurred when the walking belt was used for patient transfer. The remaining 21 injuries (81%) occurred during the performance of such tasks as pushing tables together, manually transferring a patient from a wheelchair to examination table in a physician's office or to a cart, grabbing a falling patient, manually lifting a patient from floor level, transferring a patient from a geriatric chair to wheelchair using a gait belt (not the walking belt), and turning a patient in the bed.

A year by year analysis of pre-intervention back injury data showed no consistent pattern in the two units. The pre-intervention incidence rates for back injuries for 1986, 1987, 1988 and 1989 were 93, 89, 59, and 83, respectively, in unit 1 and 89, 86, 100, and 43 in unit 2. Similarly, the pre-intervention severity rates for back injuries for 1986, 1987, 1988, and 1989 were 728, 314, 683, and 1903 in unit 1 and 379, 754, 575, and 71 in unit 2.

4.5. *Task performance time*

Mean performance times for different patient transfers performed using the walking belt and hoist are summarized in table 12. The two-sample t-test with unknown population variances (Miller and Freund 1977) showed that there were significant

Table 13. Number of nursing assistants used for patient transfers after intervention.

Device	Number of observations	% of time 1, 2 and, 3 NAs used NAs=1	NAs=2	NAs=3
Walking belt	792	28	70	2
Hoist	530	19	77	4

differences between the walking belt and hoist ($p \leq 0 \cdot 01$). Patient transfer times with hoist were longer than those with walking belt (table 12). On the average, it took 25·8 s to make a transfer with the walking belt and 73·7 s with the hoist. These patient transfer times were substantially longer than the values of about 8 to 18 s for the two-person manual lifting method before intervention (Garg *et al.* 1991a,b,c).

4.6. *Number of NAs*

Most of the patient transfers with the walking belt and hoist were made using two NAs (table 13). About one out of five transfers with hoist were made using one NA. Also, these devices rarely required more than two NAs to transfer patients (table 13). The usual practice in the nursing home before intervention was to use two nursing assistants for patient transfers (Carlson 1989).

5. Discussion

This study showed that with systematic and appropriate ergonomic intervention physical stresses to NAs can be significantly reduced, hence reducing the future risk of musculoskeletal injuries and, in particular, low-back injuries. Four different measures of evaluating the effectiveness of an ergonomic intervention showed highly favourable results.

The approach taken in the present study differed significantly from those used in the past studies. The main focus of this study was on reducing physical stresses to nursing personnel, primarily by providing ergonomically evaluated mechanical hoists and shower chairs and by replacing manual lifting with a pulling technique using a walking belt with handles. Reducing physical stresses to nursing personnel appears to be the most desirable and widely recommended approach, as it reduces the exposure to the hazard. This is especially desirable since lifting of patients is by far the most commonly reported source of injuries (Ferguson 1970, Personick 1990) and there is no relationship between different kinds of lifting techniques and incidence of low-back symptoms (Buckle 1982, Dehlin *et al.* 1976). The ergonomic approach led to new task procedures which eliminated the need for many manual patient lifts. Lastly, with reduced physical stresses, it is possible that some workers may be able to continue performing their job without absenteeism even when suffering from low-back pain (Dehlin *et al.* 1976, Rowe 1983).

5.1. *Acceptability rates*

The overall acceptability rates of 81% to 96% for patient transferring devices observed in this study were very high. The acceptability rates for non-transfer tasks were fairly low (42% to 53%). However, these tasks were not a part of ergonomic intervention. NAs were neither educated nor trained for using walking belt and the hoist for non-transfer tasks. Apparently, some of the NAs started using these devices on their own for patient non-transfer tasks.

The longer transfer time required by the patient-handling devices has been reported as one of the primary reasons for non-compliance with these devices (Bell 1984, Owen 1988, Takala and Kukkonen 1987). The longer transfer times associated with walking belt and hoist, as compared to manual lifting method, did not appear to be a major issue in this study as the acceptability rates were fairly high. Adequate staffing, ability to perform some patient transfers with one nursing assistant, and a reduction in the number of patient transfers (discussed later) may have compensated for longer transfer times associated with these devices.

To the authors' knowledge, there were no major cases of bruises, skin tearing, patient complaints, or patient injury from transferring patients using the hoist. No patients or NAs withdrew their consent even though the option was available to them.

5.2. *Biomechanical stresses*

The ergonomic intervention significantly reduced the biomechanical stresses to the nursing assistants. The mean estimated compressive force of 1964 N after intervention is considerably lower than the 3430 N value for compressive force criteria used to define the action limit recommended by the US Department of Health and Human Services (1981). An exposure to a compressive force of 1964 N appears reasonably safe and represents nominal risk to most workers. The mean pulling force of 122 N required when using the walking belt is substantially lower than the female pulling strength of 179 N to 310 N reported in the literature (Chaffin *et al.* 1983, Snook 1978, Ayoub and McDaniel 1974). Thus, the mean pulling force required with the walking belt is well within female pulling strength.

5.3. *Perceived stresses*

The mean ratings of 8 (between 'very, very light' and 'very light') and 9 ('very light') for hoist and the walking belt suggest that the perceived physical stresses to the nursing assistants after intervention were very low. These ratings of perceived exertion also give credence to the fairly low estimated biomechanical stresses discussed above. On the other hand, RPEs of more than 13 observed for all patient transfers before intervention were comparable to perceived physical stresses associated with lifting very heavy weights (Garg and Banaag 1988, Garg 1989).

5.4. *Injury statistics*

The back injury rate prior to intervention was 83 per 200 000 work hours. After the intervention it was 47 per 200 000 work hours. More importantly, there appears to be a profound decrease in lost and restricted work days, which were reduced to zero in the two units during the last four months of the intervention. This decrease in severity rate might have been due to less serious injuries. Another possible explanation is that back injured employees were able to continue to work because the job demands had been reduced.

It is not clear why there was a dramatic increase in both the incidence and severity rates for back injuries in unit 2 during post-intervention phase I. There were no changes made in unit 2 during this phase. An analysis of injury data for the complete year showed that the incidence and severity rates for back injuries for 1989 in unit 2 were comparable to those from previous three years. Similarly, it is not clear why the severity rate for back injuries in unit 1 increased during post-intervention phase I. As mentioned earlier, most of these injuries occurred during non-patient transfers when the recommended devices were not used. In spite of some unanswered questions, it is worth mentioning that, as expected, both the incidence and the severity rates for both back and total injuries were considerably lower for unit 1 than those for unit 2 during the post-intervention phase I.

5.5. *Reduction in number of patient transfers*

The use of a shower chair and the mechanical hoist resulted in an elimination or a reduction in the need to perform certain patient-handling transfers. The hoist had a built-in weighing scale and patients could be weighed during any transfer made using the hoist. Before intervention, the patient was manually lifted and transferred from wheelchair to weighing scale chair and from weighing scale chair to wheelchair. Also, toileting and bathing the patient required six transfers: bed to wheelchair, wheelchair to toilet, toilet to wheelchair, wheelchair to chairlift or bathtub, bathtub or chairlift to wheelchair, and wheelchair to bed. After intervention, the same task involved transferring the same patient from bed to shower chair using the hoist or a walking belt; pushing the shower chair over the toilet and then to the shower room, and then back to the patient's room where a transfer from shower chair to bed was made. Thus, the number of patient transfers for toileting and bathing was reduced from six to two. Similarly, the number of patient transfers for toileting, bathing, or showering the patients were reduced from four to two when the hoist or the shower chair was used.

Reducing the number of patient transfers along with the magnitude of physical stress during transfers has an important implication for reducing back injuries to NAs (Jensen 1990a). It appears that each stressful patient-handling event involves some risk of a back injury and this risk can be minimized by reducing the number of stressful patient handling tasks. Further, use of these devices eliminated some of the transfers in patient lavatories (highly confined workspaces) which had necessitated that the nursing assistants assume awkward body postures while transferring patients, an important factor for producing low-back pain.

5.6. *Walking belt and the mechanical hoist*

The walking belt has a tendency to slide up on some of the patients who tend to be smaller at the chest and waist level than at the hip level. Immediately after completion of this study, an experiment was performed in unit 2 of the nursing home where the top end of the walking belt was wedged. The wedged belt appeared to solve the sliding problem.

There were a few verbal complaints from some NAs that they felt some discomfort in their wrists and/or forearms when pulling patients with the walking belt. The walking belt had thin handles made of canvas material. Since such handles can cause a significant reduction in grip strength, cylindrical handles made of 1·9 cm diameter dowel and 10 cm long were securely taped to canvas handles and tried on an experimental basis in unit 2 after the completion of this study. The modified handles were very well received by the NAs.

Because NAs are accustomed to lifting patients, it was observed that their natural reaction is to lift the patient when using the walking belt rather than to make use of momentum and pulling the patient to make the transfer. In general, this lifting action was responsible for most of the injuries associated with the walking belt. To modify this ingrained behaviour would, it is believed, require extensive education and training of nursing assistants in new skills with frequent feedback, encouragement, and long-term commitment on the part of administration.

Informal feedback from the NAs indicated that the hoist was well liked and there were no major problems regarding accessibility, patient comfort and safety, or physical effort required to operate, push, or pull it. However, a word of caution is indicated in that the hoist has small wheels and therefore is very difficult to push/pull and manoeuvre on carpeted floors.

6. Conclusions

An ergonomic intervention was performed in two units of a large nursing home to modify the demands of patient transferring tasks perceived to be most stressful. Among other changes, nursing assistants were provided with mechanical hoists with patient weighing capability, walking belts for each dependent, weight-bearing patient, shower chairs, and additional frames and slings for lifting patients from floor level. In addition, showers and toilets were modified for easy access. The nursing assistants were trained in the use of these devices.

The most physically demanding tasks were changed so that compressive force on the L5/S1 disc was 1964 N after intervention as compared with 4751 N before intervention. The percentage of the female workforce with sufficient strength for performing the most demanding patient transfer tasks improved from 41% to 83% after the changes. On the average, it took 26 s to make a transfer with the walking belt and 74 s with the hoist, and these transfer times were substantially longer than those required with the manual lifting method before intervention. Subjectively, patient transfers were perceived to be 'very light' or less stressful after intervention as compared to between 'somewhat hard' and 'hard' before intervention. The mean acceptability rates for the walking belt and hoist were 81% and 87%, respectively for patient transferring tasks and 53% and 42% for non-transfers. The back injury rate after the intervention was 47 per 200000 work-hours as compared to 83 before intervention. The severity rate for back injuries was 317 per 200000 work-hours as compared to 634 before intervention. There were zero lost or restricted work days during the last four months of the post-intervention phase. The statistics for total injuries followed similar patterns as those for back injuries.

In spite of very favourable findings, caution should be used in generalizing these results to other nursing homes. Staffing level, training, workload, and administrative support need to be considered in using the proposed techniques. Large-scale studies in different nursing homes are needed to confirm the above findings.

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