EFFECTS OF TRAINING IN MODIFYING WORK METHODS AND BEHAVIORS DURING COMMON PATIENT HANDLING ACTIVITIES

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(ABSTRACT)

In a 1994 survey, on incidence rates of musculoskeletal injuries among private industries within the U.S, nurses ranked first nationally. Patient handling tasks are considered to be a precipitating factor in the development of many musculoskeletal injuries. For many decades personnel training has been an intervention widely used for the nursing back problem. Inconsistency regarding the effectiveness of many personnel training programs, lack of controlled research among existing studies, and a primary focus only on long term reduction of injury rates makes the interpretation of the success of personnel training programs a difficult one. This study is based on the assumption that, if a training program is to be effective as a means of reducing musculoskeletal injuries, it must first modify worker behaviors and biomechanical stresses to a measurable degree.

This research investigated the effects of training (Video and Lecture/Practice) on modifying working behaviors and biomechanical stress. Two tasks were examined (wheelchair to bed and lift up in bed) with two types of assistance (one-person or two-person) and two levels of patient's dependence (semi-dependent or dependent). Changes in behaviors were examined immediately following training (1-2 days delay) and after a short period of time (4-6 weeks) and evaluated using the criteria of subjective ratings of exertion, and postural and biomechanical measures. Results indicated that training led to several significant changes in the knee, hip, elbow and torso angles, whole body, shoulders and low back RPE, shear forces and shoulder moments. No differences were observed in these measures after a short period of time, suggesting retention of the information presented during the training programs. Results as a whole suggest that training can positively affect the working postures and biomechanical stress

during common patient handling tasks. All the postural changes and biomechanical measures were advantageous in terms of reducing musculoskeletal stress. It was also found that after a short period of time (4-6 weeks) still retained the information presented during the training programs. Training using a combination of lecture and practice in some cases achieved better results than Video-based training.

To my beloved husband…

for your love and support

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CHAPTER 1. INTRODUCTION

1.1. Background

Work related musculoskeletal disorders (MSDs) include disorders or injuries of the back, trunk, upper extremities, neck, and lower extremities (Frymoyer, 1997). In the U.S. it has been estimated that there are approximately 1.8 million disabling work related injuries per year, 60,000 of which result in permanent impairment (Frymoyer, 1997). The Bureau of Labor Statistics reported that musculoskeletal disorders accounted for the majority of the occupational injuries and illnesses that resulted in work loss with an estimated total cost of $13 billion per year (NIOSH, 1997). Musculoskeletal injuries accounted for 76% of the workplace injuries, of which 47% involved the back, and 25% involved the neck and upper limbs (NIOSH, 1997).

MSDs arise principally from forces and stresses within the human body as it interacts with its immediate physical environment (Ayoub, Dempsey, and Karwowski, 1997). Specific force and stress levels are influenced by both workplace and personal risk factors (key aspects associated with higher MSD incidence). Workplace risk factors include: work shift, heavy physical work, heavy manual material handling, lifting, bending, repetitive work, frequency and duration of a task, and dynamic work load (Ayoub et al., 1997). Overexertion, particularly when associated with workplace risk factors such as heavy material handling, lifting, carrying, pushing, and pulling is the leading cause of injuries during manual material handling (NIOSH, 1997). Personal risk factors include age, gender, anthropometry, musculoskeletal abnormalities, muscle strength, physical fitness, psychosocial factors, smoking, and previous history of musculoskeletal disorders (Ayoub et al., 1997; and Ryden, Molgaard, Bobbitt, and Conway, 1989). Workplace risk factors are considered to be the principal and most important cause for the majority of the MSDs in industry (Ryden et al.,1989). The literature suggests that although both workplace and personal factors are key contributors to higher incidences of MSDs, the former is the most significant source of MSDs.

Nurses are among the occupational groups with the highest incidence rates of musculoskeletal injuries, especially those of the back (Cato, Olson, and Studer, 1989; Garg, Owen, Beller, and Banaag, 1991a; Harber, Billet, Gutwski, SooHoo, Lew, and

Roman, 1985; Klein, Jensen, and Sanderson, 1984; Stubbs, Buckle, Hudson, Rivers, and Worringham, 1983a; Troup, and Rauhala, 1987; Venning, Walter, and Stitt, 1987; Videman, Rauhala, Asp, Lindstrom, Cedercreutz, Kamppi, Tola, and Troup, 1984; and Winckelmolen, Landewwerd, and Drost, 1994). Nurses ranked first nationally (for the year 1994) based on incidence rates among private industries within the U.S. (NIOSH, 1997). Patient handling tasks, which are considered here as a form of manual material handling (MMH), involve many of the workplace factors associated with injury risk. Since patients, as loads to be handled, may be characterized as being unpredictable (may resist movement), having an undefined shape, and being dynamic loads, patient handling tasks are considered a precipitating factor in the development of severe low back pain (Corlett, Lloyd, Tarling, Troup, and Wright, 1994).

As an attempt to control high costs of MSDs, several intervention approaches have been used in industry to reduce overexertion injuries. Particular attention, given the high prevalence and cost, has been paid to upper extremity and low back injuries by implementing workplace interventions. Workplace interventions generally follow one of three major ergonomic approaches toward safer and more efficient MMH: personnel selection, personnel training, and ergonomic job design (Kroemer, Kroemer, and Kroemer-Elbert, 1994).

Personnel selection and personnel training are administrative interventions or worker-directed approaches. The goal of personnel selection is to match the capacity of the worker to the demands of the job while personnel training focuses on developing specific material handling skills and informing the worker of the hazards of the job and how to avoid them. Ergonomic job design is a workplace-directed approach that attempts to fit the job to the worker.

For many decades personnel training has been an intervention widely used for the nursing back problem. Some previous studies (Troup and Rauhala, 1987; Videman, et al., 1989; and Wood, 1987) have supported that reduction of muskuloskeletal symptoms among nurses may be achieved through the education and training of nursing personnel. These studies have primarily examined ‘skills’, though this term has not been clearly defined. Troup and Rauhala (1987), while analyzing patient handling tasks, observed significant differences in the working postures of a trained and an untrained group of

nurses. Videman et al. (1989) reported that nurses who received education and training on ergonomics and patient lifting techniques developed better patient handling skills compared to nurses who did not receive the training condition. In addition, decreases in injuries and lost time among nurses after the application of a training program have been reported (Wood, 1987).

In contrast to these limited examples, some experts believe that training in proper body mechanics and patient handling procedures has not been effective in reducing the incidence of low back injuries. In a study of 4,000 workers who participated in a back school training program, no reduction in the rate of low back injuries was reported after a five year period (Daltroy, Iversen, Larson, Lew, Wright, Ryan, Zwerling, Fossel, and Liang, 1997). Similarly, Lagerström and Hagberg (1997) reported no reduction of musculoskeletal disorders in a group of nurses after participating in a training program containing patient lifting techniques, physical fitness, and stress management. The inconsistency of the results of many personnel training programs, and the lack of controlled research among these studies, make very difficult the interpretation of the success and effectiveness of personnel training programs.

A variety of assessment methodologies exist and have been used by researchers to quantitatively or qualitatively evaluate nurses' performance during patient handling activities. The most common methodologies used are psychophysical, postural evaluation and biomechanical models. The psychophysical methodology uses the worker's perception of workload, which is believed to be directly correlated to the degree of physical strain on the human body (Borg, 1982). Evaluation of working postures to identify the most frequent and potentially stressful job postures has also been used with nursing as well as industrial work tasks. Biomechanical models are used to determine musculoskeletal stresses on specific body regions; for instance, spinal forces during manual handling activities (Chaffin and Andersson, 1991; and Garg, 1997).

Most studies related to training effectiveness have focused on long term reduction in existing injury rates. Even though this must be the ultimate goal, the majority of the available literature, rather than quantitatively measuring behavioral and biomechanical changes during patient handling activities, has focused on qualitative measures. Further,

the type of training is often quite varied, failing to examine which methods and media are adequate and optimal (Chaffin, Gallay, Woolley, and Kuciemba, 1986).

This study is based on the assumption that, if training is to be effective as a means of reducing musculoskeletal injuries, it must first be able to modify worker behaviors and biomechanical stresses to a measurable degree. It is the aim of this study to evaluate whether and how instructional methods and media affect or modify task performance. This study was focused on a particular set of relatively stressful tasks commonly performed by nurses.

1.2. Research Objectives

The purpose of this research is to evaluate the potential effectiveness of different types of training as interventions to alleviate musculoskeletal stress (specifically low back and shoulder) associated with moving, lifting, and handling patients. This study determined if training results in the short-term decrease of known injury risk factors through changes in behaviors. The tasks investigated include transfer of a patient from a wheelchair to a bed and lifting a patient up in bed. In addition to the type of training and task, the level of dependence in a patient (dependent and semi-dependent) and lifting assistance (one person and two person) are variables that were manipulated.

Each patient handling task was evaluated using the criteria of subjective rating of exertion, working postures, and biomechanical loading. Ratings of perceived exertion during patient handling tasks was assessed to evaluate the subjective perception of physical stress in the whole body, shoulders, and low back. Working postures were quantitatively evaluated to determine postural stress assumed at the beginning or at the end of each task. The low back (L5/S1) compressive and shear forces, lumbar and shoulder joint moments, and strength capabilities at the shoulders and torso were estimated to evaluate the biomechanical stress during simulated patient handling tasks.

The experiment tested the following null hypotheses relating to data obtained during the simulated patient transfer tasks:

Hypothesis #1: Biomechanical stress during patient-handling activities, specifically the compressive and shear forces at the lumbrosacral disc, the lumbar and shoulder joint moments, and the strength capabilities at the shoulders and torso, will not be affected by the training program(s).

Hypothesis #2: Working postures, specifically the included hip, knee, elbow and torso angles, and horizontal distances during patient handling activities will not be affected by the training program(s).

Hypothesis #3: Whole body, shoulder, and low back ratings of perceived exertion during patient handling activities will not be affected by the training program(s).

CHAPTER 2. REVIEW OF THE LITERATURE

2.1. Musculoskeletal Injuries and Stressful Work

Work related musculoskeletal disorders (MSDs) can be defined as any disease, injury or trauma that affects the body's soft tissues, including damage to the tendons, tendon sheaths, muscles, and nerves of the hands, wrists, elbows, shoulders, neck and back (Saldaña, 1996). In the U.S., work related MSDs are a major component of the cost of work related illnesses and injuries, and results in work loss with an estimated total direct cost of $13 billion annually (NIOSH, 1997).

The Bureau of Labor Statistics reported in their "Annual Survey of Occupational Injuries and Illnesses" (from NIOSH, 1997) that injury and illness cases involving lost days (approximately 705,800 cases or 32% of the total cases), and specifically resulting from overexertion or repetitive motion, were principally caused by manual material handling activities such as lifting, pulling, pushing, carrying and holding. NIOSH (1997) reported that in 1994 lifting activities represented 367 thousand injuries, where 65% affected the back. A total of nearly 100 thousand injuries were due to overexertion in pushing/pulling activities, 52% affecting the back. Holding/carrying activities represented 70 thousand cases, where 58% affected the back. Of the total across these categories nearly 50 thousand injuries affected the shoulders.

Back pain is by far the most prevalent and costly MSD among industries today (NIOSH, 1997). Within the worker's compensation system it has been estimated that the total cost (direct and indirect costs) for low back pain could be as high as $35 billion each year (Frymoyer, 1997). MSDs, especially those of the back and shoulders are a costly and prevalent problem that is commonly induced by work related activities that are stressful and repetitive. Their high incidence has forced the need to identify the risk factors that are associated with them.

2.1.1 Risk Factors.

Due to the prevalence and excessive costs associated with MSDs, many studies of manual material handling (MMH) tasks have been done to identify risk inducing factors (e.g. Marras, Lavender, Leurgans, Fathallah, Ferfuson, Allread, and Rajulu, 1995). Risk factors associated with injuries during MMH are divided into two

main categories: 1) personal risk factors, and 2) workplace risk factors (Ayoub et al., 1997).

Personal risk factors are characteristics of the worker that might contribute to the probability that an injury occurs. These factors include age, gender, anthropometry (height and weight), physical fitness and training, previous medical history, and smoking among others (Chaffin and Andersson, 1991; and Waters and Putz-Andersson, 1997). Some of the more important risk factors and possible reasons for their association with injury risk are as follows.

1) Age: muscle strength appears to be greatest in the late 20's and early 30's and declines thereafter.
2) Gender: women on average are weaker than men. Gender differences reported in population strength data, however, are almost entirely explained by differences in muscle size, as estimated by either the person's fat-free body weight or cross sectional area dimensions.
3) Anthropometry: body weight and height have been correlated with muscle static strength.

Workplace risk factors probably are the most important because they are directly related with the physical hazards to the worker (Waters and Putz-Andersson, 1997). The more important job related risk factors and possible reasons for their association with injury risk associated with manual material handling of loads are (Ayoub et al., 1997; and Garg, 1997):

1) Horizontal and vertical location of the load relative to the worker: with an increase in horizontal distance the external joint loads will increase, and workers will use a larger proportion of their strength capability.
2) Distance load is to be moved: increased travel distance results in reduced strength and higher energy expenditures.
3) Frequency and duration of the task: as the frequency of lifting increases, metabolic demands are higher, and the onset of physical fatigue is more rapid.
4) Weight and size of the load: the weight of the load can affect the required strength, and postural stress and metabolic demands.

These risk factors are also assumed to apply to patient handling tasks performed by nurses since these tasks are similar to industrial material handling tasks. Patient handling, like MMH, involves the acts of lifting, carrying, pushing, pulling, and holding.

2.2. Nursing Personnel

Available literature supports the premise that nursing professionals are at great risk of suffering back injuries (Cato, et al., 1989; Garg, et al., 1991a; Harber, et al., 1985; Klein, et al., 1984; Stubbs, et al., 1983a; Troup, and Rauhala, 1987; Venning, et al., 1987; Videman et al, 1984; and Winckelmolen, et al., 1994). NIOSH (1997) established that the nursing profession, which ranked first nationally (during 1994) in terms of the incidence of musculoskeletal injuries, have rates of overexertion disorders four times higher (40 thousand cases) than the average rate among all private industries. Harber et al. (1985), based on results from a questionnaire administered to 550 nurses in a California hospital, reported that 58% of the nurses had suffered some degree of low back pain due to work related activities sometime during the previous six months. Also, 44% of the nurses reported having developed back pain at work at least once during the two-week study period. Twenty nine percent of the nurses took medication for their back pain, and 9% missed work.

In another study, Cato et al. (1989) reported that 72% of the nurses stated they had experienced low back pain (LBP). Fifty three percent of the respondents experienced LBP within the six months prior to the study; 62% of these cases were associated with the current working environment. Dehlin, Hedenrud, and Horal (1976) reported that 46.8% of the Swedish nursing aides in a geriatric hospital had low back pain symptoms. A recurrence of these symptoms appeared in 82% of the subjects.

A survey developed by Venning et al. (1987) was performed to identify potential factors that may affect the incidence rate of occupational back pain among nursing personnel. Job related factors, rather than personal characteristics, were found to be major predictors of back injuries. Job related factors such as service area, lifting, and job categories were found to be significant predictors of back injury. The major personal factor that contributed to the development of back injuries was previous medical history of back pain or injury. It was also reported that 60% of the injuries (in 204 events) were low

back injuries, 16% neck injuries, and 18% upper back injuries. These injuries were observed during a one-year period in 199 subjects.

2.2.1. Patient Handling as a Risk Factor for Musculoskeletal Disorders. Nurses have attributed the onset of LBP to their patient handling activities (Cato et al., 1989; Harber et al., 1985; Jensen, 1985; Owen and Garg, 1989). About 40% of all back pain episodes and 75% of compensable back injuries appear to be related to lifting, transfer or movement of patients (Fragala, 1997). Out of the literature available, six major studies have been selected and are introduced next. These studies addressed patient handling as a precipitating factor in the development of LBP.

Stubbs et al. (1983a) administered a survey to 3,912 British nurses and reported that 15.9% of all cases and 13% of the new cases of back pain complaints were associated with patient handling tasks. A second study, by Jensen (1985), reported that the prevalence rate of back injuries among nurses who are considered frequent patient handlers was 3.7 times greater than the prevalence rate among infrequent patient handlers.

A questionnaire administered in a large U.S. hospital helped identify which nursing activities were the most common causes of back pain (Harber et al., 1985). Forty eight percent of the nurses rated lifting a patient in bed as an activity causing back pain; helping a patient out of bed (30%) and lifting a patient from bed to bed (22%) were also commonly reported. Another questionnaire study by Cato et al. (1989) reported that lifting a patient in bed was most often (24%) rated by the staff to be the primary reason for LBP. Other causes included turning a patient (12%), one person transfer (19%), and two person transfer (9%). A study by Owen and Garg (1989), in a nursing care facility in Wisconsin, U.S., tried to determine the patient handling tasks perceived as most stressful among 57 nursing assistants. The top 5 patient handling tasks perceived by nurses as most stressful were: transferring patient from wheelchair to toilet and toilet to wheelchair, transferring patient from wheelchair to bed and bed to wheelchair, and lifting a patient up in bed.

It has been suggested that the main reasons why patient handling is a physically demanding activity and may precipitate low back pain involve the fact that patients may be uncooperative, unpredictable (may resist movement), and they might have an uneven

and heavy weight that may move during patient transfers (Corlett et al., 1994). Furthermore, the level of physical dependency of the patients and their need for nursing care constitute additional significant contributors toward patient handling risks (Corlett et al., 1994). Constraints in the working environment such as equipment interference, unadjustable beds, and inadequate space also make the job difficult (Hellsing, Linton, Andershed, Bergam, and Liew, 1993).

Patient handling by manual transferring or lifting, by using assistive devices (such as gait belts, and draw sheets), or by employing hoists are the three methods by which patient handling tasks are typically done (Garg et al., 1991a). The selection and use of these methods are based on nurses' preference, custom, and experience (Winkelmolen et al., 1994). It is important to highlight the difference between a transfer and a lift during patient handling activities. Transfer or transferring refers generally to actions in which the movement is mainly horizontal though there may be a vertical component. Lift or lifting refers to the action of raising vertically or to actions in which vertical displacement is the dominant feature (Corlett et al., 1992).

2.3. Workplace Interventions to Control Musculoskeletal Disorders (MSDs)

2.3.1. Background. Given the magnitude and severity of MSDs, several workplace intervention programs have been used to reduce or prevent musculoskeletal injuries. These usually are classified as engineering and administrative controls (Waters and Putz-Anderson, 1996).

Engineering controls are workplace-directed approaches that rely on changes in the work to eliminate or minimize the physical stresses associated with manual material handling (Waters and Putz-Anderson, 1996). These controls include elimination of manual handling through automation or reduction of the amount of physical exertion required to perform the task by using mechanical aids, or job modification. Automation is recommended when the work requires high physical demands or is highly repetitive, and is best suited for the design of new work processes (Waters and Putz-Anderson, 1996). The main disadvantage of automation is that it may require a large capital investment. In cases where automation is not practical or feasible (such as in patient handling tasks), mechanical aids or assistive devices can be used to reduce the extent of physical stress of

a task. The use of assistive devices and hoists for patient-handling tasks may be helpful in reducing back stress among nurses, yet they are infrequently used due to the excessive time it takes to operate the sometimes sophisticated hoists (Garg and Owen, 1992). In addition, neither assistive devices nor hoists are readily available to all nurses. Finally, the use of mechanical devices to transfer patients has not necessarily been perceived by nurses as less stressful nor more comfortable for patients (Garg and Owen, 1992). However, in situations where none of the two previous engineering controls are appropriate, job modification through ergonomic design is an alternative that attempts to fit the job to the worker by reducing the job's physical demands. Ergonomic design can be accomplished by modifying the job layout or implementing procedures to reduce bending, twisting, heavy lifting and repetitive motions among other stressful activities (Garg, 1997).

Administrative interventions are worker-directed approaches that attempt to maintain a match between the worker's capacity and the demands of the job (Waters and Putz-Anderson, 1996). Job rotation, job enlargement, personnel selection, and personnel training are among the most common work practices used as administrative interventions (Goldenhar and Schutle, 1994). The goal of job rotation is to reduce the constant exposure to physically stressful tasks by, for example, rotating workers through different workstations or tasks. Likewise, the adverse influences of low job content that creates repetition and boredom can be balanced through job enlargement that introduces task variety (Waters and Putz-Anderson, 1996). Personnel selection (or screening of worker) attempts to match individual capabilities with the job demand by way of assessing worker's attributes (e.g. strength). This approach relies on the assessment of one or more physical characteristics of the worker to select specific workers for certain manual material handling jobs (Kroemer, 1992).

Finally, personnel training has been identified as an administrative solution to minimize the exposure of workers to occupational hazards. The purpose of training is to ensure that employees are sufficiently informed about the hazards to which they may be exposed and thus be able to apply correct procedures to avoid them (Nordin, 1997). Training in safe manual material handling is based on the belief that people can safely

handle greater loads when they perform the task correctly (Waters and Putz-Anderson, 1996).

2.3.2. Personnel Training. For many decades, personnel training has been an administrative intervention widely used for the nursing back problem. Several researchers (Takala and Kukkonen, 1987; Lagerström, and Hagberg, 1997; Videman, et al., 1989; and Wood, 1987) have suggested that training in proper patient handling techniques, and education on ergonomics, develops higher handling skills among nurses, and prevents injuries. Several training methods used to reduce and prevent LBP have been categorized in the literature as back injury prevention programs. The most common prevention programs include back schools, fitness training, and education and training in proper lifting techniques.

Even though back schools can be traced to the late 1950s, it was not until the 1980s that they became a popular intervention to rehabilitate back-injured patients (Kroemer, et al, 1994). A typical back school program educates the worker on anatomy, the structure and function of the spine, lifting techniques, ergonomics and biomechanics, pain control, relaxation, nutrition, weight control, and personal responsibilities within work related activities (Kroemer, et al., 1994). It may also provide information on stress management and basic exercises.

Several studies have been performed to assess the impact of back schools. In a recent review, Karas and Conrad (1996) surveyed literature related to back schools programs, two of which are discussed next. Brown (1992) introduced a back school program among 140 municipality workers. The results showed a reduction in back injury rates but there was no change in the total cost for compensable back injuries. Galka (1991) also reported a reduction in back injury rates among the nursing staff of a veteran hospital following a training program. In another back school intervention study of 1,500 employees of eight different industries, a 40% reduction in lost workdays in the year following the training program was observed (Goldenhar and Schulte, 1994). However, an increase in the number of back injuries was reported and attributed to the newly positive attitude of management and among employees to report injuries. The lack of control groups within these studies puts into question the success of these programs

(Goldenhar and Schulte, 1994). The inconsistency of the results and the need of controlled research make the interpretation of the success and effectiveness of back schools very difficult.

Fitness training programs emphasize factors such as musculoskeletal strength, aerobic capacity, endurance and flexibility (Kroemer, 1992). This training approach includes topics on fitness, body mechanics, exercises, ways to prevent backache, weight control, stress management, and nutrition (Appenzeller and Atkinson, 1981). It is widely believed that improved physical fitness among workers would be associated with a reduction in overexertion and thus low back pain (Garg, 1997). Some investigators have reported that physical fitness has a significant effect on musculoskeletal injuries while others have found that physical fitness and training have little or no effect in preventing musculoskeletal injuries.

The work most frequently cited to support the premise that strong workers with a high fitness level are at lower risk of suffering back injuries was provided by Cady, Bischoff, O'Connell, Thomas, and Allan (1979). The study classified a group of firefighters from California as most fit, middle fit, and least fit. In their results, 0.8% of the most fit, 3.2% of the middle fit, and 7.1% of the least fit, experienced LBP. In contrast, Hilyer, Brown, Sirles, and Peoples (1990) reported no significant difference in the injury rate in a fitness training program applied to 469 firefighters. Another study (Feldstein, Valanis, Vollmer, Stevens, and Overton, 1983) found no within group differences between nurses and orderlies based on the results obtained after fitness training was used to decrease back injuries.

Another way to reduce the risk of a back injury is through the training of the workers on proper lifting, and transferring techniques. Training in safe handling is a commonly used approach in the prevention of musculoskeletal injuries among manual material handling activities (Authier, Lortie, and Gagnon, 1996). A training program on lifting techniques is comprised of two major components: training on proper lifting techniques and education on body mechanics. The program typically includes topics such as 1) anatomy and physiology, 2) biomechanics and ergonomics, 3) injury prevention methods, 4) stress and pain management, and 5) lifting techniques specifics to the job (Hellsing et al., 1993; and Troup and Raulaha, 1987).

Researchers (Dehlin et al., 1976; Stubbs et al., 1983b; Wood, 1987; and Venning, 1988) have suggested that the traditional training on proper lifting techniques should not be relied upon as the only component of an intervention program. As noted above, preventing injuries by increasing knowledge of the body, ergonomics, biomechanics and promoting attitude changes has been seen as an essential part of a training program on lifting techniques (Troup and Rauhala, 1987). Training program can help employees become aware of the risk factors for LBP. Finally, it is believed that education increases safe behavior in work practices (King, Fisher, and Garg, 1997).

Available reports in the literature suggest that some existing training programs show little effectiveness in reducing the incidence of injuries while some are successful in reducing the number of back injuries. There is, in addition, a lack of agreement about the best ways to train people to lift using methods that reduce back injuries, and even about whether lifting behavior may be improved by training. St-Vincent, Tellier, and Lortie (1989) speculate whether training is ineffective because the methods are never put into practice or because methods themselves are inadequate. However, in order to properly assess training as an administrative intervention to prevent LBP it is necessary to focus not only on the results but on the media used to provide the training since the overall results will be a function of what is being taught and how it is being taught. The following section describes some of the alternate methods that can be used to introduce both the practical and the educational components of a training program.

2.4. Instructional Media

The differences in learning outcomes are reflected by the type of media used to deliver instruction in a training program. The type of instructional media must be based on the skills to be taught and the availability of personnel and materials (Dick and Carey, 1996).

Special attention must be placed on psychomotor skills since patient handling tasks are classified as such. The main characteristic describing a psychomotor or motor skill is that the learner must execute muscular actions, with or without equipment, to achieve specified results (Dick and Carey, 1996). The most efficient representation of the skill is by visual instruction. Video or films can be used to capture movement, but often photos

or drawings are used. Practice and feedback are the hallmarks of psychomotor skills. Practice of a skill should lead to mastery. Immediate feedback on the correctness of the execution of the skill is important, since incorrect rehearsal will not promote skill improvement (Dick and Carey, 1996). Also, simulators or equipment should be used for teaching such skill to simulate the real physical environment.

The availability of a media can be expressed as its practicality. It is important to consider if a suggested media will be available to the learner and the instructor. For example, if a training program is to be designed for a community center, it is likely that equipment such as projectors, video cassette recorders, etc. will not be available. A related concern is the ability of the teacher to manage the selected media. The final factor is the cost-effectiveness of a media when compared to others. For example, it might be cheaper to videotape a lecture to view again and again as needed, than having an instructor to work with the group as needed. Although the type of skill and the practicality of a media influence the media selection process, it is important to evaluate the advantages and disadvantages of each instructional media considered. Then, a trade-off analysis can be performed to select the most appropriate media.

One of the most frequently used instructional media is the lecture method. Lectures as well as videos are criticized for their one-way communication resulting in passive learners that do not have the opportunity to clarify material (Goldstein, 1993). During demonstrations learners are able to clarify material and practice sessions can be included. Table 1 shows some advantages and disadvantages of these and other media that can be applied to teaching and learning motor skills (i.e., patient handling tasks).

Table 1. Trade-off analysis: advantages and disadvantages of various media sources (Adapted from Goldstein, 1993; and Andre and Schopper, 1997)

Media	Advantages	Disadvantages
Lecture	• Presents facts and ideas rapidly • Emphasis placed where teacher wishes • Excellent for background information • Can be interrupted by requests for more detail • Teacher controls content and sequencing	• One way communication • Difficult to adjust to individual speed of comprehension • Difficult to maintain attention • Effectiveness depends on skill and personality
Demonstration/ Hands-on Practice	• Saves time and talk • Helps assure understanding • Demonstration provides model and standards for learner performance • Gives learner confidence when he or she performs better • Easier to watch a procedure than to listen to verbal description	• Requires preparation for effective demonstration • May require expensive equipment and personnel • Frequent rehearsal needed to maintain demonstration
Video	• Large amount of visual information • Allows motion and more three dimensional processes to be described easily	• Costly to produce • Can look very bad with inadequate equipment
Photos	• Can require little hardware • Shows hard to explain material	• Can be difficult to produce • Photos may look bad • Can be hardware intensive
Text	• Low cost • Can be combined with lecture methods • Large amount of information • Relatively easy and cheap to produce • Easily memorized	• Not visually attractive • Can bore user • Description of procedural information gets complicated

2.5. Personnel Training Programs in the Nursing Profession

This section summarizes seven studies that aimed to evaluate the effectiveness of personnel training programs among nurses performing patient handling activities. Although most of the studies did not specify the type of training used, some of the studies were classified by the investigators as back schools programs and educational training programs.

- Stubbs et al. (1983b) studied eight patient handling tasks to investigate the effectiveness of teaching one and two person lifting techniques. Except for the task of turning a patient on bed, all other tasks observed showed a reduction in intraabdominal pressure (IAP) following training. Although controversial, some hypothesize that IAP may protect the spine during heavy lifting. It is generally agreed, however, that this protection is of small magnitude. Regardless, the study failed to prove a relationship between time spent receiving training in handling techniques and the prevalence of back pain.

- Troup and Rauhala (1987) studied the effects of introducing ergonomics and biomechanical concepts in a nursing school program. As a result, significant differences in working performance were found between handling 'skills' of the trained and control groups of student nurses. The term 'skills' was not clearly defined.

- Wood (1987) used a back school program in an attempt to reduce back injuries. Although there was a decrease in injuries and lost time, the effect was not significant. Unfortunately, the first part of the study (a personnel program) prevented the determination of which program had the greatest effect on the overall reduction of back injuries.

- An observational methodology was used by St-Vincent et al. (1989) to evaluate the methods taught in a 12-hour training program. The observational methodology consisted of analyzing the vertical (i.e. lifting a patient up in bed) and horizontal components (i.e. tasks carried out of bed) of several patient transferring tasks. The results showed that the use of taught principles depended upon the type of patient

handling carried out. Mainly because of physical constraints, the methods suggested during the training could not always be applied.

- Videman et al. (1989) reported that after training on patient handling for 40 hours the trained group had higher patient handling skills than the control group. These results were measured by observing subjects performing the patient handling tasks and assessing their performance (using a 7-point scale). A reduction of incidences of LBP in the trained group, when compared to the control group of nursing' students, was observed. The difference between these two groups was not significant.

- Hellsing et al. (1993) evaluated the effects of incorporating ergonomics as part of a nursing program. Nursing students received an average of two hours of ergonomic lectures per week during the two-year program and an intensive 3-day course on patient handling techniques. Fifty-two nursing students were surveyed about their attitudes and behaviors before, half way, and after receiving the training program. The experimental group had better working postures than the control group (judged by the investigators) and was more pleased with their education.

- In a recent study, Lagerström and Hagberg (1997) evaluated an education and training program comprised of: 1) patient transfer techniques, 2) physical fitness exercise, and 3) stress management. A total of 348 nurses participated in the program during the 3-year study period. Although 90% of the participants felt positive about the training program, and 93% of the nurses actually used the techniques taught a reduction in musculoskeletal disorders was not observed.

All of these studies have focused on reducing back injury rates in a long-term basis, neglecting, however, changes in behavior in either short or long term. Other studies have failed to isolate the effects of the training program when they are used in combination with other intervention approaches. Moreover, the lack of agreement among these studies may compromise the validity of these results (Goldenhar and Schulte, 1994).

2.6. Task Evaluation Methods

A variety of analytic tools are available for the evaluation of manual material handling tasks in response to the need to reduce overexertion injuries. Among these tools, three basic task evaluation methods have been widely used to assess manual lifting tasks such as those performed during nursing activities. These are: psychophysical, postural evaluation methods and biomechanical models.

2.6.1. Psychophysical Methods. Psychophysical methods assess the degree of subjective physical strain on the human body based on the assumption that people perceive relative physical stress levels (Borg, 1982). Several studies have sought to determine lifting capacities based on subjective perception of exertion (e.g. Karwowski, 1991). Perceived effort depends not only on the intensity of physical work performed but also on the duration of the work (Gambergale, 1985). As previously reviewed, there are several physical factors known to be associated with MSD risk. Psychophysical methods allow for the simultaneous evaluation of the combined effects of different physical stressors (Krawczyk, 1996). Psychophysical ratings are believed to result from an integration of various information by the central nervous system, including the many signals elicited from the peripheral working muscles and joints, and from the cardiovascular and respiratory systems (Krawczyk, 1996). All of these signals, perceptions and experience are combined to form a subjective response to workload.

Psychophysical approaches are based on the subjective judgement of physical work, which are typically measured through the use of self reporting techniques such as rating scales. Borg’s Rate of Perceived Exertion Scale (RPE Scale) has been identified by many researchers as an useful tool to evaluate the perceived exertion of workload in patient handling tasks (Garg et al., 1991a; Garg et al., 1991b; Garg and Owen, 1992; Owen and Garg, 1989; and Winkelmolen et al., 1994). Garg et al. (1991b) reported that when comparing pulling and lifting techniques to move patients the perceived stress ratings for the whole body, the shoulder, the upper back, and the lower back were significantly lower for the pulling than for the lifting techniques. The greatest amount of exertion was felt in the lower back. Similarly, in a survey of nursing assistants, the tasks that involved lifting and transferring patients received the highest ratings of perceived

exertion for the shoulder, upper back, lower back, and whole body (Owen and Garg, 1989). Garg and Owen (1992) used Borg's scale to demonstrate how the ratings of perceived exertion were affected by the working units, devices, the patient handling tasks, and the whole body, shoulders, lower back and upper back before and after implementing an ergonomic intervention. The wheelchair to bathtub transfer received the highest rating for the lower back. No significant differences in the rating of perceived exertion between the units and the devices used were found. In general, the ratings of perceived exertion for the patient handling tasks were significantly reduced after the intervention.

2.6.2. Postural Evaluation Methods. Posture has been identified as an occupational risk factor that can cause stress and precipitate or aggravate a MSD (Armstrong, 1996). It has been found that posture is an important factor in determining the maximal forces that subjects can exert in pushing and pulling tasks (Ayoub and McDaniel, 1974). Postural evaluation methods can help identify the most frequent and potentially stressful job postures. This also allows for a more detailed biomechanical analysis, which examines the effects of body postures and loading on workers. Several means have been proposed to collect more specific job data to classify and evaluate manual work (Chaffin and Andersson, 1991).

The Ovako Working Posture Analysis System (OWAS) has been used in two studies as one of the observational methods to assess the nursing activities (Hignett, 1996a; and Ljunberg, Kilbom, and Hägg, 1989). Hignett (1996a) showed that nurses are exposed to physically stressful postures while performing patient handling tasks. Tasks such as hoist transfer, dressing /washing in bed, transfer of patients from bed to bed, and washing patient in the bath were some patient handling tasks that needed some type of corrective measures based on the OWAS procedural approach. Ljungberg et al. (1989) used OWAS to compare patient-handling tasks performed by nurses in a traditional and a modern geriatric ward. As a result, it was found that there was very little difference in the postural strain between the two types of ward.

2.6.3. Biomechanical Models. Biomechanical models are frequently reported as methods to estimate forces exerted on tissues of the musculoskeletal system and how body joints are strained during work. As an example, spinal stress is often quantified in manual material handling activities. These models are based on the analysis of forces and torques acting on the body during a given physical activity (Baker and Atha, 1994). The estimated forces can be compared to predetermined tissue tolerance limits to assess the biomechanical stress associated with specific loading conditions (Ayoub and Karwowski, 1997). Therefore, the goals of a biomechanical model are to help define exertion limits so that excessive stresses on the components of the musculoskeletal system can be avoided and to predict whether someone is likely to suffer an injury during a task (Chaffin, Herrin, Keyserling, and Garg, 1977).

Biomechanical models have been used to determine spinal stress in the nursing profession (Garg et al., 1991a; Garg and Owen, 1992; Ulin, Patellos, Chaffin, Blitz, Emerick, Lundy, and Misher, 1997; and Winckelmolen et al., 1994). The results from these four reports show how static biomechanical models can be used to measure physical stress for specific postures. A biomechanical model was used by Garg et al. (1991a) as one of the methods to evaluate different patient handling tasks requiring lifting and pulling techniques. Compressive and shear forces at the L5/S1 disc were higher for the lifting techniques than for the pulling techniques.

In a similar study performed at a nursing home, Garg and Owen (1992) evaluated the physical demands required to perform patient handling tasks before and after an ergonomic intervention. A biomechanical model (3D SSPP™) was used to compute the mean compressive force on the L5/S1 disc, hand force required, and strength requirement. It was found that the ergonomic intervention was effective in reducing back injuries.

Ulin et al. (1997) analyzed six patient transfer techniques completed by two nurses to transfer dependent patients. The 3D SSPP™ was used to compute the peak compressive forces on the L5/S1 disc and to estimate the percentage of the population able to transfer patients based on their strength capabilities. The results of the biomechanical analysis showed that compressive forces at the L5/S1 disc exceeded the NIOSH recommended limit, except when using a mechanical lift.

Winkelmolen et al. (1994) evaluated five two-person manual lifting techniques to determine the amount of physical exertion required by the nurses as well as spinal stress. The compressive forces at the L5/S1 disc were assessed by means of a static biomechanical program. In almost all situations the compressive force on the nurse's spine exceeded the NIOSH recommended limit.

2.7. Summary of Previous Studies

The following tables (Tables 2-4) summarize all the studies previously discussed. It is a comprehensive review of the literature found to be relevant to handling tasks and training programs associated with the nursing profession. Each study was classified as a biomechanical, epidemiological or observational study based on the type of dependent measure used. Most studies had multiple dependent measures, but the measure given the most emphasis was used to classify the study. The elements examined in each of the studies were: author and year of publication, sample size, population characteristics, study period, dependent variables, independent variables, results, and conclusions.

Sample sizes ranged from six to twelve among the biomechanical studies, epidemiological studies from 38 to 4,000, and observational studies from 26 to 5,649. The mean age of participants among all studies ranged from 18 to 41 years. The study durations ranged from 1 month to 5.5 years; some authors did not specify the exact duration of their studies. Volunteers as well as experienced nurses have being involved.

2.7.1. Biomechanical Studies.

Biomechanical studies (Table 2) have used several biomechanical models to measure the compressive forces acting at the L5/S1 disc. These studies have evaluated how different manual lifting techniques, and mechanical hoists affect the physical stress on the back. The relative stress during patient handling tasks has often been estimated using compressive forces on the L5/S1 disc in conjunction with the perceived exertion. It can be concluded from the different studies that those techniques learned from written instructions only and performed by one person are the ones that generate the highest compressive force on the L5/S1 disc, more so if the patient is heavy. In addition, it was determined that among manual lifting techniques and mechanical hoists, it was the former one that exerted the most physical stress on the back. This was

not the case for all situations, and patients did not always feel secure or comfortable with the hoists.

Table 2. Biomechanical studies of patient handling tasks and training among nurses

Author	Population, Sample size	Dependent variables	Independent variables	Results/ Conclusion
Baker and Atha, 1994	Volunteers Age range: 18-40 yrs. N=12	Spinal compression at L5/S1; Video analysis; RPE.	3 levels of training: written instructions, interactive personal instruction, and no training.	The volunteers that participated in the training using written instructions had higher compressive forces. Training should be performed on an interactive basis.
Garg et al, 1991a	Volunteers Age: ? N=6	Compressive force at the L5/S1 disc; RPE; Comfort and security ratings	5 manual lifting techniques and 3 mechanical aids; 1 or 2 person lifts; Task: bed-wheelchair and wheelchair-bed.	Compressive forces at L5/S1 in one-person techniques were higher but not statistically significant. Hoists had worst biomechanical and subjective effects.
Garg et al, 1991b	Volunteers served as nurses Age: ? N=6	Compressive force on the L5/S1 disc; Comfort ratings; RPE.	5 manual lifting techniques and 3 mechanical aids; 1 or 2 person lifts; Tasks: wheelchair-showerchair, and viceversa.	Manual lifting techniques had higher compressive forces than mechanical hoists. Showerchair to wheelchair was more stressful than wheelchair to showerchair.
Garg and Owen, 1992	Nursing assistants Average age: 33 yrs N=38 Patient: 62 kg	Compressive force on L5/S1; RPE; perform. time, comfort ratings.	Manual techniques; Patients: dependent (weight bearing & non-weight bearing) and independent; Training:2 sessions.	Ergonomic intervention is effective. Gait belt is better for light patients and hoists for heavy patients. The low back was the body part most stressed for walking belt and the use of the hoist.
Ulin et al, 1997	Nurses Age range: 32 –39 yrs N=2	Compressive forces at L5/S1 using 3D-SSPP, and force gauge; Video Analysis, and RPE, (Borg 20)	Heavy and light patients; 6 transfer methods (3 manual, and 3 mechanical); Task: bed-to-wheelchair; Heavy and light weight nurse.	Higher compressive forces when moving heavy patient and when using manual techniques.

Author	Population, Sample size	Dependent variables	Independent variables	Results/ Conclusion
Winkelmolen et al, 1994	Unexperienced volunteers N=10	Compressive force on the L5/S1 disc; Video analysis; RPE.	Patients: heavy (75 kg) and light (55 kg); 5 manual lifting techniques.	Australian lift had the lowest compressive forces. Significant difference between the techniques as to compressive force when lifting the 55 kg patient.

2.7.2. Longitudinal Studies. Longitudinal studies monitor prevalence, incident reporting, and compensation claims of work-related disorders or injuries over a extended period of time (Hignett, 1996b). The predominant methodologies used to measure the dependent variables were questionnaires and incidence reports. Body comfort ratings, ratings of perceived exertion and even compressive forces were used in some of the studies as their dependent variables. Back injury rate/back pain rate was the outcome variable analyzed in most of the epidemiological studies. Many of the longitudinal studies evaluated the effectiveness of training programs on a long-term basis. Among the epidemiological studies relevant to the nursing profession (Table 3), it can be seen that more than half of the patients in each of the studies experienced LBP during the course of the last six to twelve months. The results from the studies discussed do not show a common agreement upon the effectiveness of training. Most of the trained nurses used the techniques taught, and showed good attitudes towards the training.

Table 3. Longitudinal studies of patient handling tasks and training among nurses

Author	Population, sample size, and study period	Dependent variables	Independent variables	Results/ Conclusion
Cato et al, 1989	Nurses N=52 Study period:3 mths.	Questionnaire	Incidence of LBP, availability and use of mechanical aides	72% of the nurses experienced low back pain in the previous six months.
Daltroy et al, 1997	N=4,000 Study period: 5 yrs.	Incidence reports	Back School Training	No reduction in rate of low back injuries.
Harber et al, 1985	Nurses Average age: 32 yrs N=550	Questionnaires	Incidence Reports	58% of the nurses suffered of back pain in the 6 months previous to the study. 29% took medication for back pain and 44% experienced back pain during the study period.

Author	Population, sample size, and study period	Dependent variables	Independent variables	Results/ Conclusion
Lagerström and Hagberg, 1997	Nurses Average age: 41 yrs. N=348 Study period: 1 year	Nordic Questionnaire; RPE; Surveys	Education and exercises 1 day of training. Training on: patient lifting techniques, physical, stress management.	93% of the nurses used the techniques taught. No reduction on musculoskeletal disorders. 90% were positive about expected outcomes of the program.
Stubbs et al, 1983a	Nurses N=3,912	Questionnaire	Incidence and prevalence reports for back pain	43.1% of the nurses suffered back pain in one year. 16% was attributed to patient handling. 53.7% of the cases affected low back.
Stubbs et al, 1983b	Nurses Age range: 19-23 yrs N= ? Study period: 9 months	Intraabdominal pressure (IAP)	8 lifting techniques; 5 treatments; posttest after 15 weeks of applying the training condition	Reduction of IAP in most of the tasks, except in turning a patient in bed. No relationship between time spent in training in handling techniques and prevalence of LBP.
Venning et al, 1987	Nurses Average age:37 yrs. N=5,649 Study period:12mths.	Questionnaires	Reports of incidences.	60% of the total musculoskeletal injuries were LBP. 52% of the injuries required lost time.
Wood, 1987	Nurses N= ? Study period: 9-13 months	Incidents reports	Back School Training Program	Decrease in injuries, and lost time.

2.7.3. Cross-sectional Studies. Cross-sectional epidemiological studies measure health outcomes and exposures at a single point in time and are useful in identifying risk factors (NIOSH, 1997). Questionnaires, OWAS, observational grids, and video analysis are the most frequently used observational methods (Table 4) to evaluate patient handling tasks, especially working postures. Cross sectional studies have also been used to evaluate the effectiveness of training programs through the improvement of patient handling skills. An improvement in patient handling 'skills' was reported in all studies where an educational training program based on ergonomics was administered.

Table 4. Cross-sectional studies of patient handling tasks and training among nurses

Author	Population, Sample size	Dependent variables	Independent variables	Results/ Conclusion
Hellsing et al, 1993	Nursing students Average age: 25 yrs. N=52	Questionnaires; Observations; Attitudes and behaviors	Training: lectures on ergonomics 2 hrs/week, and no training.	Experimental group was more pleased with their education than control group. Expert group had better working postures.
Hignett, 1996a	Nurses Age: ? N=26	OWAS	Nursing tasks (regular tasks vs patient handling tasks)	Significant amount of "harmful" postures adopted when performing patient-handling.
Ljungberg et al, 1989	Nurses Age: ? N=24	RPE, OWAS, and heart rate.	Traditional and modern ward	No significant difference in postural strain between traditional and modern ward.
St-Vincent et al, 1989	Nurses Age: ? N=32	Observational method	Training for 12 hrs. (Theory and Practice)	Because of physical constraints, training could not always be applied. Techniques not often used for tasks carried out of bed.
Takala et al, 1987	Nurses Age: 35.4 yrs. N=143	Questionnaire; Video Analysis; Workplace Analysis	Patients: totally dependent, partially dependent, independent; Training:1-2 hrs	92% of the nurses adopted bending positions. Nurses don't usually use lifting aids.
Troup and Rauhala, 1987	Nursing students N=199	Rating Scales	Observations performing patient handling tasks; Training: 20 hrs of theory and practice in nursing school.	Significant differences between skills of trained and control group.
Videman et al, 1989	Nursing students Age range: 20-24 yrs. N=199	Questionnaires and observational method.	Training (40 hrs) and no training	Education and training program based on ergonomics can improve patient handling skills; nurses with poor handling skills were at risk of back injuries. Trained group had higher skills than control group but, no statistical difference between groups.

CHAPTER 3. EXPERIMENTAL METHOD

3.1. Model of Injury Processes and the Influence of Training

Before presenting the experimental methods, a model of the relationship between work tasks and musculoskeletal injuries is described. This model presents both the underlying assumptions and the rationale to understand how training may have an influence on injury risk. The model (Figure 1) treats injuries as resulting directly from overload of the musculoskeletal system. These overloads are caused by specific working behaviors, which in turn result from the required work tasks.

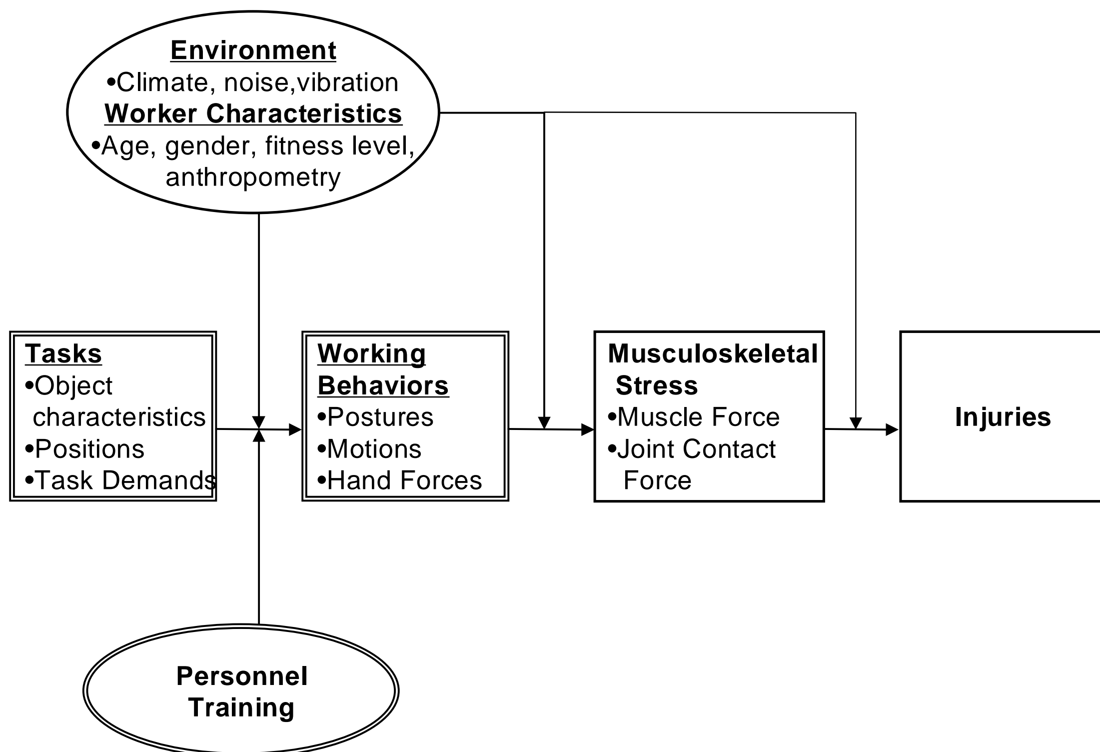


Figure 1. Model of injury processes and the influence of training

Workers are commonly asked to perform tasks that involve the movement of humans or objects. These tasks are characterized by the work procedures involved, by the situation in which it will be performed and by the baseline requirements. These are known altogether as the task's specifications and may be many depending on its nature. Working behaviors depend upon the tasks to be performed. The worker's postures,

motions and forces exerted are a function of the task demands and characterize the working behaviors. The specific behaviors used to accomplish a task, the musculoskeletal stress resulting from these behaviors, and whether an injury occurs, can all be influenced by the workers environment and personal characteristics. Personnel training is considered to specifically influence how and which behaviors are used to complete a work task.

A long-term investigation of training on injury risk is beyond the scope of the proposed work. Instead, it was the intention of this study to focus on the effect of training on behaviors used to perform a specific task. It was assumed that a reduction of musculoskeletal injuries can only be realized if working behaviors are modified or improved through training. Training effects on behaviors will thus be examined in detail for specific nursing tasks.

3.2. Experimental goals

The experimental methodology was designed in order to achieve the research objectives presented in Section 1.2. In review, the focus of this research was to:

1. Determine if the perceived exertion of the whole body, shoulders, and low back while performing simulated patient handling tasks were affected by the training programs.
2. Determine if the posture, specifically the included hip, included knee, included elbow and torso angles, and horizontal distance while performing simulated patient handling tasks were affected by the training programs.
3. Determine if the compressive and shear forces at the lumbrosacral disc, lumbar and shoulder joint moments, and strength capabilities at the shoulders and torso while performing simulated patient handling tasks were affected by the training programs.

3.3. Experimental Design

A 2X2X2X3 mixed factor design was used (Table 5). The experimental design employed a pretest and posttest with a control group. There were four independent variables:

1. Type of Training (between subject factor)
2. Task (within subject factor)
3. Patient Dependence (within subject factor)
4. Assistance Technique (within subject factor),

and five categories of dependent variables, which are:

1. Ratings of Perceived Exertion (whole body, shoulders, low back)
2. Postural angles and distances (included hip, included knee, and included elbow and torso angle, and horizontal distance)
3. Spinal Forces (L5/S1 disc compression and shear forces)
4. Joint Moments (L5/S1 disc and shoulder moments)
5. Joint Strength Capabilities (shoulders and torso)

The statistical model that represents the experimental design is:

$$Y = \mu + \alpha_i + \beta_j + \delta_k + \phi_l + \gamma_{m(l)} + \alpha\gamma_{im(l)} + \beta\gamma_{jm(l)} + \alpha\beta_{ij} + \alpha\delta_{ik} + \alpha\beta\gamma_{ijm(l)} + \alpha\delta\gamma_{ikm(l)} + \alpha\phi_{il} + \beta\phi_{jl} + \delta\phi_{kl} + \beta\delta_{jk} + \beta\delta\gamma_{ikm(l)} + \alpha\beta\delta_{ijk} + \alpha\beta\delta\gamma_{ijkm(l)} + \alpha\beta\phi_{ijl} + \beta\delta\phi_{jkl} + \alpha\delta\phi_{ikl} + \alpha\beta\delta\phi_{ijkl} + \varepsilon_{n(ijklm)}$$

where,

μ = Population mean
α = Task, i = type of task
β = Dependence, j = level of patient dependence
δ = Assistance, k = type of assistance
ϕ = Training, l = type of training
γ = Participant, m = participant number
ε = random error, n = random error index

Table 5. Experimental Treatments

Treatment	Tasks	Patient Dependence	Assistance	Type of training
T1	WB	SD	1P	TT1
T2	WB	D	1P	TT1
T3	WB	SD	2P	TT1
T4	WB	D	2P	TT1
T5	LU	SD	1P	TT1
T6	LU	D	1P	TT1
T7	LU	SD	2P	TT1
T8	LU	D	2P	TT1
T1	WB	SD	1P	TT2
T2	WB	D	1P	TT2
T3	WB	SD	2P	TT2
T4	WB	D	2P	TT2
T5	LU	SD	1P	TT2
T6	LU	D	1P	TT2
T7	LU	SD	2P	TT2
T8	LU	D	2P	TT2
T1	WB	SD	1P	TT3
T2	WB	D	1P	TT3
T3	WB	SD	2P	TT3
T4	WB	D	2P	TT3
T5	LU	SD	1P	TT3
T6	LU	D	1P	TT3
T7	LU	SD	2P	TT3
T8	LU	D	2P	TT3

Legend

Tasks	**Patient Dependence**	**Assistance**	**Type of Training**
WB Wheelchair to bed	SD Semi-dependent patient	1P One person	TT1 Video Training
LU Lift patient up in bed	D Dependent patient	2P Two person	TT2 Lecture/Practice
			TT3 No training

In employing within-subject factors, ordering of treatment conditions can introduce a confounding variable to the analysis. This potential confound was controlled by having the conditions presented in a Balanced Latin Square, one for each phase or session of the study (Table 6). There were eight participants (P1-P8) in each of the training conditions for a total of 24 participants. This presentation scheme balanced the ordering of treatments to allow each condition to proceed and follow every other condition an equal number of times, thus reducing confounding influence of treatment order (e.g. intertask learning).

Table 6. Balanced Latin Square

Order	Participants							
	P1	P2	P3	P4	P5	P6	P7	P8
1	T1	T8	T2	T4	T6	T3	T6	T8
2	T2	T7	T5	T3	T5	T7	T2	T4
3	T6	T4	T1	T7	T2	T4	T1	T7
4	T5	T3	T6	T8	T1	T8	T5	T3
5	T7	T5	T3	T2	T8	T5	T7	T6
6	T4	T2	T8	T6	T3	T1	T8	T1
7	T8	T6	T4	T1	T4	T2	T4	T2
8	T3	T1	T7	T5	T7	T6	T3	T5

P_n = Participant n = 1, 2, 3,…, 8
T_n = Treatment order n = 1, 2, 3,…, 8 (Refer to 8 treatments in Table 5 within each training condition)

3.3.1. Independent Variables. Type of Training, Task, Patient Dependence, and Assistance were the independent variables used in the experiment. The three types of training programs used were a video, a lecture/practice training program, and no training (control group). Training by means of a video is a good alternative whenever money is a constraint, however it only allows minimal interaction and can not provide any practice or feedback. On the contrary, an on-site lecture/practice training allows ongoing interaction and permits hands-on practice with immediate feedback. The video is readily available and can be bought and seen numerous times. A lecture/practice training program however, in order to be effective, must be focused on specific work tasks and be well organized. As a result the lecture/practice training program can sometimes be time consuming and expensive. These two training options media are considered the extremes of available training programs. It is the intention of this experiment to analyze both of them as an attempt to find the advantages and disadvantages of such divergent techniques.

The video, "Save Your Back" from Educational Opportunities (Saunders, 1989), included basic information on ergonomics and incorrect lifting techniques. It presented and demonstrated how to perform the patient handling tasks evaluated in the experiment in a 25 minutes video presentation (See Appendix A). The lecture/practice training program was divided into two 1-hour sessions. The first session consisted of a lecture on anatomy, body mechanics, ergonomics, and injury prevention methods presented by Karl

Kroemer, Dr. Ing. (Professor at Virginia Polytechnic Institute, Industrial and Systems Engineering Department and Director of the Industrial Ergonomics Laboratory) (See Appendix A). The second session was held in the Industrial Ergonomics Laboratory for participants to practice in the same setting as the experiment was going to take place. A certified physical therapist, Michael Tatman (Director of the Physical Therapy Department at Radford Hospital) taught and practiced with the participants about how to perform the patient handling tasks and techniques that were used on the experiment. The control group was not exposed to any training program.

Each participant completed two types of patient-handling tasks. These were: 1) wheelchair to bed transfer and 2) lift patient up in bed. As stated in the review of the literature, nurses identified these patient handling activities as physically stressful activities (Harber et al., 1985; Owen and Garg, 1989; and Jensen, 1985).

The level of dependence in a patient as well as the weight and physical condition (size, shape, deformities, consciousness, and coordination) will determine how a patient can be moved. Two levels of the Patient's Dependence (dependent and semi-dependent) were analyzed. A dependent patient was defined as one who can't assist the nurse in the transfer or movement, and may cause additional difficulties because of limited muscle control (Corlett et al., 1992). In contrast, a semi-dependent patient may assist the nurse in the transfer or movement, and may be able to sit up when lifted onto a wheelchair. The principal investigator simulated the passive semi-dependent and dependent patient using the following criteria:

<u>Dependent patient</u>

- Unable to assist or cooperate in the transfer
- Unable to flex knees to push body up in bed
- Unable to stand up
- Unable to sit without assistance

<u>Semi-dependent patient</u>

- Able to assist in the transfer
- Able to flex knees to push body up
- Able to stand up with assistance
- Able to sit and help with rotation of the body

Two assistance levels were studied in the experiment: one person and two person assistant lift. A one-person assistant lift is best suited for semi-dependent patients who are able to assist in the movement, and whose weight is less than 50 kg (Corlett et al, 1992). A two person assistant lift is typically used for dependent patients or patients with

neurological diseases or disabled and patients weighing more than 50 kg. In the two-person assistance, one nurse acts in the leading position and the other one in the assisting position. A detailed description of the steps participants followed when using the two types of assistance for the three tasks are presented in Appendix B. The task descriptions were adapted from Corlett et al. (1992), and Warner (1994).

3.3.2. Dependent Variables. Dependent variables were obtained using a biomechanical model, and a psychophysical evaluation method. The 3D Static Strength Prediction Program ™ (3D SSPP™) software was used as the biomechanical modeling tool to estimate forces, moments, strength capabilities, as well as postural angles, and horizontal distance used for postural evaluation. Borg's Rating of Perceived Exertion assessed the psychophysical aspects (Borg, 1970).

Five categories of dependent variables were obtained for each experimental treatment:

1. Whole body, shoulders, and low back rating of perceived exertion.
2. Postural angles (included hip, included knee, included elbow and torso angles) and horizontal distance (location of patient's center of mass, or hand grip center, measured horizontally from a point on the floor midway between the ankles).
3. Peak low back compressive and shear force on the L5/S1 disc.
4. Peak joint moments at the L5/S1 disc and shoulders.
5. Strength Capabilities at the shoulders and torso.

Static and dynamic biomechanical models are available to simulate physical requirements and estimate forces of the L5/S1 disc. Many of the biomechanical models are static revealing stress due to gravitational forces. Static models neglect the effects of acceleration and inertia on the body, leading to an underestimation of the forces and moments generated on the body (Baker and Atha, 1994). However, static models can be applied to relatively static postures assumed at the beginning and at the end of a task, offering a simple and valid means for analyzing relatively static jobs. It is assumed that

the experimental patient transfer tasks are relatively slow and controlled motions, then a static analysis will be appropriate.

In this study, low back compressive and shear forces on the L5/S1 disc, joint moments and strength capability were assessed through of one of the most widely applied and validated biomechanical models, the Three-Dimensional Static Strength Prediction Program ™ (3D SSPP™) developed by the Center for Ergonomics at the University of Michigan (1997). The biomechanical computations derived from the 3D SSPP™ assume that the effects of acceleration and momentum are negligible and are typically used in the analysis of manual material handling tasks involving slow movements.

Three major inputs were required to use the 3D SSPP™: worker anthropometry, hand force, and posture. The hand force components were measured by using a force platform system (Section 3.5). An example of the 3D SSPP™ task input summary is given in Figure 2. L5/S1 compressive and shear forces, joint moments, and percent of the population with sufficient strength capabilities are among the outputs given by the 3D SSPP™. Figure 3 shows an example of the 3D SSPP™ output. Posture was modeled by entering fifteen joint angles of the body. Anthropometry was determined by measuring the height and weight of the subjects involved in the task to be modeled.

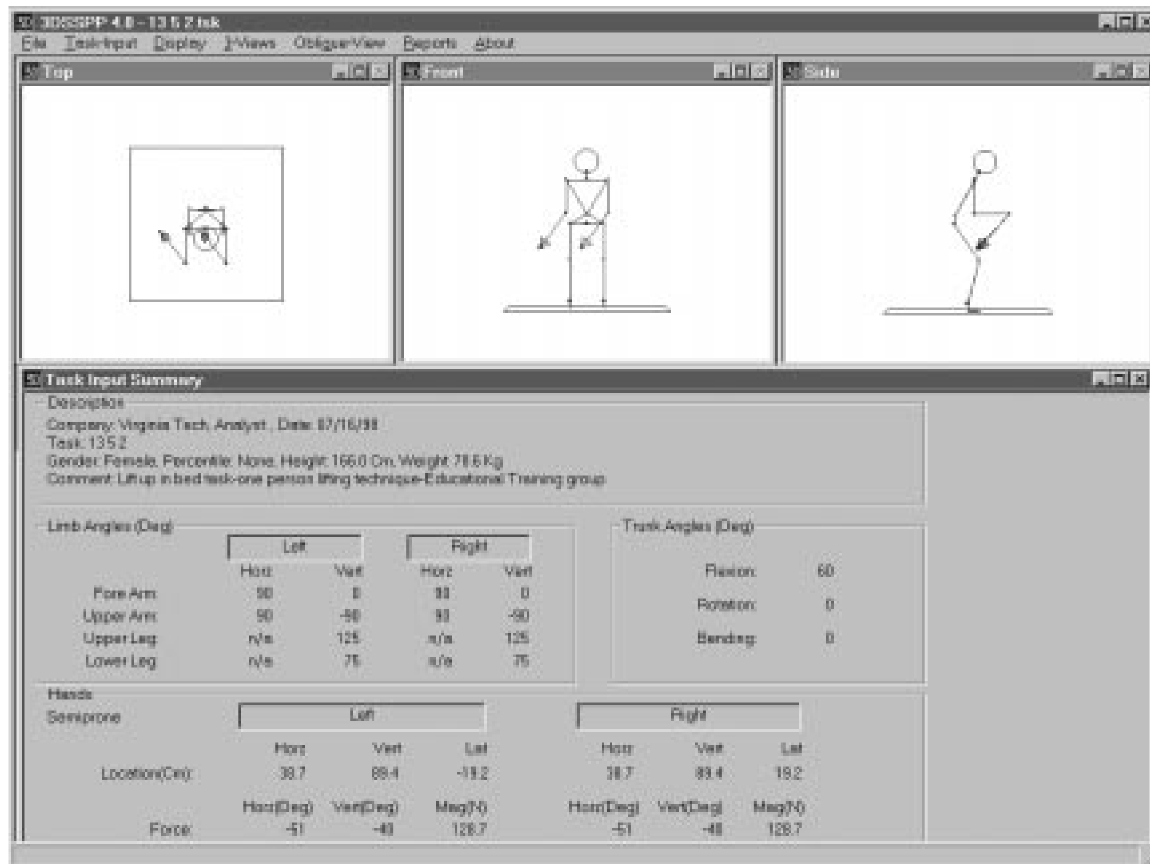


Figure 2. Example of the 3D SSPP™ Task Input Summary report for one experimental task (lift up in bed task with one person).

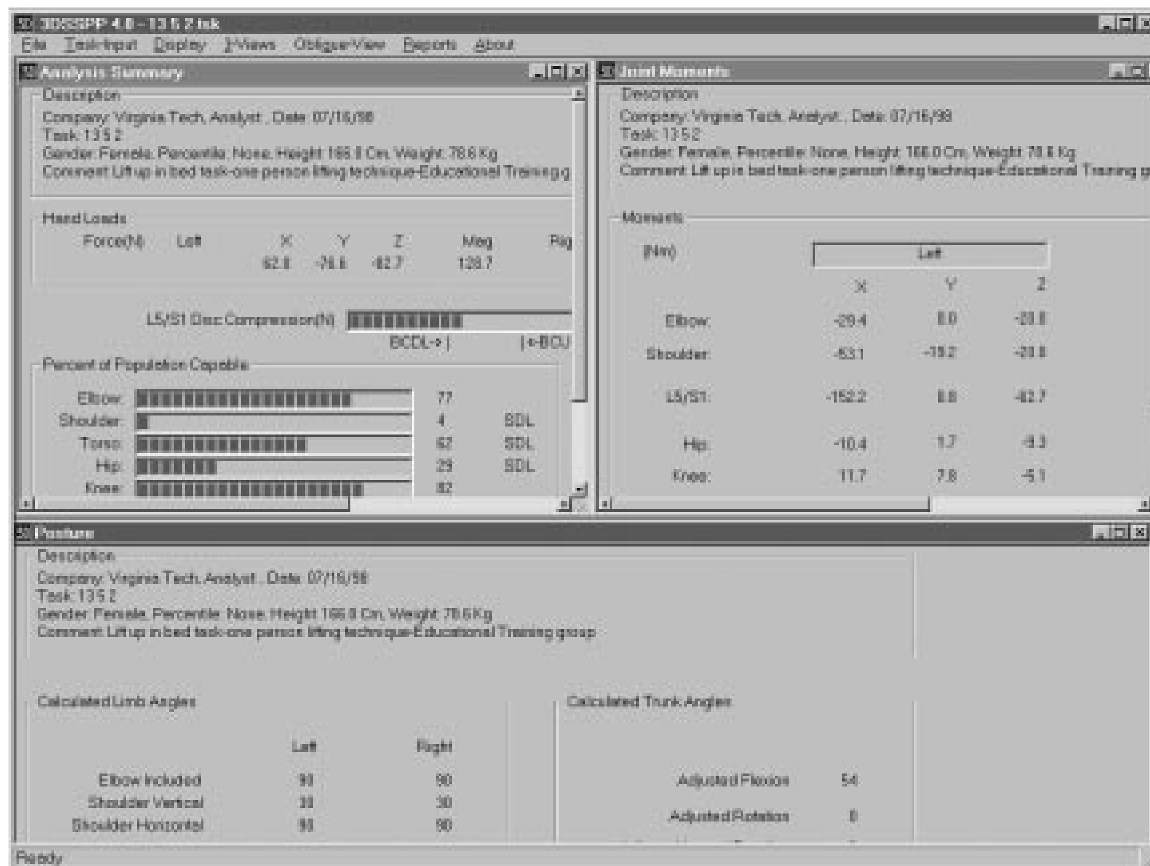


Figure 3. Example of the 3D SSPP™ Analysis Summary, Joint Moments and Posture output reports for one experimental task (lift up in bed task with one person).

Psychophysical methods are used to estimate physical stress based on the worker's subjective perception. One of the most widely used psychophysical methods is the Borg Rating of Perceived Exertion Scale (RPE Scale, Borg, 1970). This scale is considered to be a ratio scale with values ranging from 6 to 20 (Figure 4). The scale has been validated by studies showing correspondence between the heart rate and the RPE (heart rate is approximately 10 times rate of perceived exertion value). RPE ratings can be given for whole body exertions or for specific body segments.

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Figure 4. Borg's RPE Scale (Borg, 1970)

Borg's original RPE Scale did not account for the benefits of a category rating scale since it did not include ratio properties or numbers anchored by verbal expressions that were simple and understandable to most people (Borg, 1982). Therefore, a new scale with ratio properties was developed (Figure 5). The scale values range from 0 nothing at all for to 10 for very, very strong. Since a person may imagine an intensity that is even stronger than a "10", another ratio property was provided ("maximal"). When using the scale, people are permitted to use decimals and also go beyond 10. This scale can also be used for whole body exertions or for specific body segments. Both scales are used with the same procedures. Before the work, the subject is instructed on how to rate the degree of exertion as accurately as possible. The subject has to answer verbally by saying a number or to point with their finger at the scale value (Borg, 1970).

0	Nothing at all	
0.5	Extremely weak	(just noticeable)
1	Very weak	
2	Weak	(light)
3	Moderate	
4	Somewhat strong	
5	Strong	(heavy)
6		
7	Very strong	
8		
9		
10	Extremely strong	(almost max.)
•	Maximal	

Figure 5. Borg's CR-10 RPE Scale (Borg, 1982).

There may not be a scale suitable for all kinds of subjective ratings and situations, and the use of a specific scale likely depends upon the purpose of the study (Borg, 1982). Borg (1982) recommended the use of the original RPE scale for exercise testing and for clinical use in sports and rehabilitation medicine. The new category scale is especially suitable for other subjective symptoms, such as pain and workload. Since this study measured workload, and based on Borg's recommendations, the CR-10 RPE scale was used to evaluate the workers' perceived exertion.

OWAS, the Ovako Working Posture Analysis System, was developed in Finland for examining workers postures in the steel industry (Karhu, Kansi, and Kuorinka, 1997; Karhu, Härkönen, Sorvali, and Vepsäläinen, 1981). It is considered a practical method for identifying and evaluating working postures. The OWAS procedure consists of two parts: an observational technique to classify body postures, and a set of criteria for the redesign of working methods and workplaces. From observations, four back, three arm (upper limb), and seven leg (lower limb) posture categories can be defined in which each category is classified with a digit code (Long, 1992). Given a posture code, an action category can be determined and is used as the criteria to evaluate if the working method or workplace needs to be redesigned.

The original aim of the analyst was to use the OWAS method as the tool to evaluate posture. Once the method was applied to the experimental tasks, however, no observable differences were found on the posture categories across all the eight experimental conditions. The categories were found to be very broad and did not

differentiate for example, how much the back was bent (the back categories were divided in straight or bent back and for most of the cases the participants bent their backs to some degree). Although the method was easy to use it was not beneficial to evaluate the studied postures. Instead, the following angles were used to evaluate posture: included hip, knee and elbow, and torso angles and the horizontal distance obtained from the 3D SSPP™ model (See Figure 6).

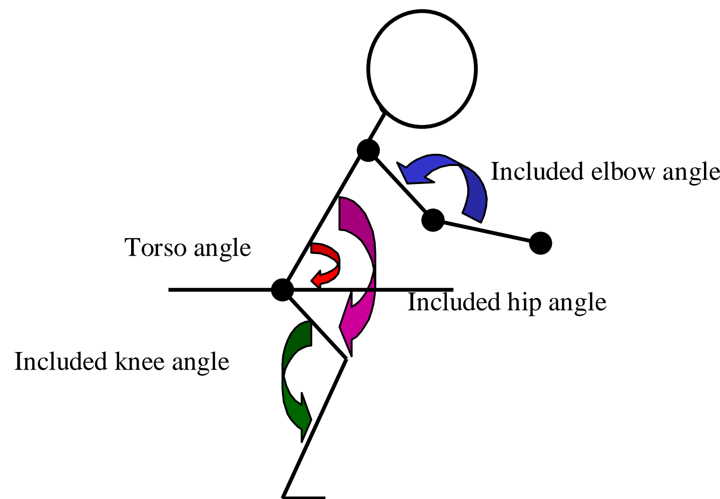


Figure 6. Postural angles measured with the 3DSSPP™ software.

<u>3.3.3. Control Variables.</u> In order to control possible confounding effects, questionnaires were used to identify participants with ongoing (less than a month) or previous back and/or shoulder injuries (less than a year). The questionnaire assessed participants' knowledge about biomechanics, ergonomics and lifting techniques (Appendix C). Knowledge of biomechanics, ergonomics or lifting techniques could introduce confounding in the experiment because the purpose of the study is to measure workers behaviors and biomechanical stress after receiving a lecture/practice training program that will include information on these topics.

Age and gender were also used as control variables. Students with ages ranging from 19-25 years were used in the experiment, since surveys among nursing aides found that the maximum frequency of back pain occurred at this age (Videman et al., 1984).

Only female volunteers were employed in an attempt to match the nursing population (approximately 96% of nurses are females; Harber et al., 1985)

3.4. Participants

Twenty-four female volunteers, ages of 19 to 25 years, were selected according to the control variables from among a pool of college students to serve as participants. The descriptive statistics that characterize the participants are presented in Table 7.

Table 7. Descriptive Statistics for the Study Participants

	Height (cm)	Weight (kg)	Age (yrs)
Mean	165.2	61.9	21.0
Standard Deviation	5.8	7.2	1.9
Range	156, 178	52, 78.6	19, 25

The investigator served as the passive patient to avoid confounding influences in the Patient Dependence factor (semi-dependent and dependent) following the criteria discussed in Section 3.3.1. The participants received monetary compensation for their participation. None of the participants withdrew from the study. Each participant was informed of the purpose, methods, and experimental procedures used in the study. An informed consent, which was approved by the Virginia Polytechnic Institute IRB Committee, was read and signed by each participant (Appendix C). A coding scheme was employed to identify the data by participant's number only (e.g., Participant #1) to maintain anonymity. All video recordings were confidential and will be erased upon completion of the study.

3.5. Apparatus and materials

An automatic hospital bed, All Electric Hospital Bed-Model 820, and a wheelchair were used in the experiment. The hospital bed and the wheelchair were arranged in the laboratory as shown in Figure 7.

Figure 7. Experimental Setting

Two video cameras were used to record the participant's postures while performing the different tasks. The cameras were oriented at 90º from the subject to enable the characterization of postures in the sagittal and frontal planes. The two video cameras were synchronized to record and display both images in one screen using a video mixer (Videonics™ MX-1). This video data was transmitted to a computer using video editing equipment (Adaptec™ 2940UW SCSI controller and micro Video DC30 Video Capture Card) and a digital video editing software, Adobe™ Premiere 4.2, was used to record the postures at which the peak forces were expected for each task. This technology allowed the analyst to obtain printouts of the postures to be analyzed, thus providing an easy and effective way to determine the spatial locations and angular orientations of body segments. This information was input to the 3D SSPP™ software.

In order to acquire data on the exerted hand forces a force platform system, Kistler-Bertec™ 4550-08, was used (See Figure 7). This system permitted the measurement of orthogonal forces and moments exerted in the x, y and z directions. The

force platform output was sampled at a frequency of 100 Hz. The participants stood on the force platform while performing the patient handling activities. The peak force of each task was used as input to the 3D SSPP™ model (See Section 3.8.1). The platform was used to estimate the total dynamic hand forces (total for both hands) occurring during the experimental trials. This analysis was based on the assumption that any additional dynamic contributions (e.g. body segment accelerations) were minimal. The use of a force platform is necessitated by the difficulty of directly measuring hand forces during patient handling. The platform system does not have a display to present the numerical values of the forces and moments. Instead, the platform interfaces with the computer where a numerical manipulation and interpretation software, Lab View™, presents the readings as form of graphs and the actual numerical values stored for later analysis.

3.6 Pilot Testing

The experiment was simulated during a pilot session according to the experimental guidelines previously described. The purpose of the pilot test was to assure that the equipment worked as expected and was placed properly, that the data collection forms were complete and well understood, and to determine the total experimental time. Six participants volunteered to perform the eight patient handling tasks, while their actions were being videotaped.

As a result of the pilot test the following actions were taken:

- The video cameras distances from the force platform and the lens height were set to the optimal locations.
- A wood platform was built and placed under the force platform to provide more stability.
- A second wood platform was built for the assisting nurse to be at the same height as the participant who was standing on top of the platform.
- RPEs Data Collection forms were simplified.
- No experimental procedure problems were identified.

3.7. Experimental Procedures

The experiment was conducted in four phases as shown in Figure 8: Pretest, Training, Posttest 1, and Posttest 2. This section explains how each of the phases were conducted and what they comprised.

	Pretest	Training	Posttest 1	Posttest 2
Group 1	O_1	Video	O_2	O_3
Group 2	O_1	Lecture/Practice Training	O_2	O_3
Group 3	O_1	No training	O_2	O_3

Figure 8. Experimental Design. (O_x indicates experimental observations taken during the three testing phases. Each subject group performed the eight treatments indicated in Table 5.)

3.7.1. Pretest. Upon arrival, the participants received verbal and written information about the experiment, and were given an informed consent to be read and signed. The participants were required to complete a screening questionnaire to account for the control variables noted above. At this point, participants were asked to change their clothes and wear black tight pants and a long sleeve shirt that were provided. White round dots were placed at the participant's shoulder, elbow, wrist, hip, knee, and ankle joints (in the sagittal and frontal planes) to ease subsequent postural analysis.

Once the participants were prepared and all the anthropometric data (height and weight) was recorded, they were introduced to the entire procedure, the bed settings, the force platform functions, and the purpose of the video cameras. Participants were also instructed on how to rate their perceived exertion and how to use the Borg's 10-point RPE Scale.

Participants were asked to perform the two patient handling tasks at the two levels of the Patient's Dependence factor and the two levels of the Assistance factor. The experiment consisted of 8 experimental treatments. Participants were able to practice the handling tasks before data was collected to allow them to become familiar with the tasks and process. As an initial step, participants were told to stand in a straight position on top of the platform and wait for an initial beep to start the task. After the initial beep,

participants performed the task and returned to the straight position until they heard the second or final beep.

Each treatment condition lasted approximately 5 to 10 seconds. Each task was videotaped for postural data analysis. Immediately after each patient transfer, the participants rated their perceived exertion using the Borg 10-point Rating of Perceived Exertion (Borg, 1970). A rest period of at least 1 minute, or as requested, was allowed before starting the next task.

3.7.2 Training. In the second phase, 16 out of 24 participants participated in two different training programs (Video and Lecture/practice Training Program). The training programs were held in the Industrial Ergonomics Laboratory except for the lecture presentation of the Lecture/Practice Training program, which was held in a conference room. The training programs took place on different dates and followed the protocols as discussed in Section 3.3.1. The other eight participants served as the control group; thus they did not receive training on lifting techniques.

3.7.3 Posttest 1. The third phase (Posttest 1) was performed within 72 hours after receiving the training condition. The same experimental procedures, as in the Pretest, were followed. In this phase no forms needed to be filled out and the explanation given was minimal. Participants' postures and ratings of perceived exertion were measured as described earlier.

3.7.4 Posttest 2. The last phase (Posttest 2) was conducted four to six weeks after receiving the training program. As done in phase one and three, the respective procedures were followed and measures were taken again.

3.8. Data Analysis

After each experimental session, the analyst retained the participant's informed consent form, health and history questionnaires, videotapes, all data files, and the completed RPEs data collection sheet. Data analysis was performed over two main categories: biomechanical model and psychophysical methods. Posture was analyzed as

part of the Biomechanical Model, since its data was obtained from the 3DSSPP™ biomechanical model, but results are presented separately.

3.8.1 Biomechanical Model. This section describes how the 3D SSPP™ input data was obtained. The anthropometric data used was the height (cm) and weight (kg) of each participant. The hand force data was derived from the readings of the force platform. This type of system is noise sensitive and could be affected by any unpredictable contact with the force platform. For that reason a second order low pass Butterworth filter was employed to eliminate the noise from the force signals. After an extended trial and error process it was determined that cutoff frequency (fc) of 7 Hz provided the most reliable signal. Required hand force data for the biomechanical model includes the magnitude of the force, as well as horizontal and vertical angles for each hand (right and left). The readings from the force platform represent the force in the *x*, *y*, and *z* axes for both hands.

The total force for both hands was calculated as:

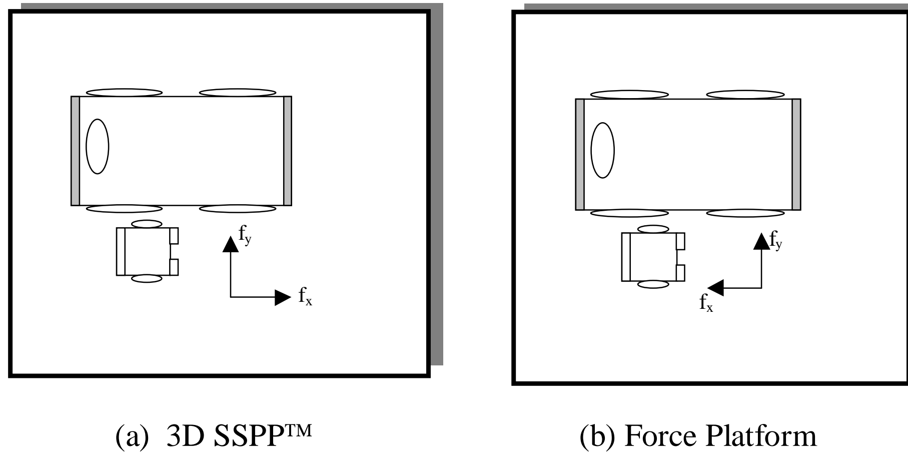
$$F = \sqrt{fx^2 + fy^2 + fz^2} \tag{3-1}$$

The total force was assumed to be evenly distributed over the two hands therefore, force in the right and left hand was assumed to be F/2 for each.

Once the forces were filtered and the total force calculated the maximum positive peak force in the *z* axis for the wheelchair to bed task was determined as well as the minimum negative peak force in the *x* axis for the lift up in bed task. F_z maximum was used for the wheelchair to bed task since the maximum force occurs while lifting the patient up from the chair and/or placing the patient down in the bed. F_z in the force platform convention goes up. For the lift up in bed task, f_x minimum was used since the greatest amount of force occurs in this axis while moving or sliding the patient up in bed and f_x in the force platform convention goes to the right. In this study only the two previous peak force were used to analyze the tasks.

The sign convention for the *x*, *y* and *z* axes was not the same for the force platform system and the 3D SSPP™ biomechanical model. Also, the wheelchair to bed task was performed differently than the lift up in bed task since the starting position was first to the

side of the bed facing the chair and then facing the bed. This forced a change in f_x for f_y in the wheelchair to bed task. Therefore, proper adjustments and change in signs had to be done. Figure 9 presents the positive convention for the force platform system and the 3D SSPP™.



(a) 3D SSPP™ (b) Force Platform

Figure 9. Positive sign convention for the f_x, and f_y force components. F_z positive convention (not illustrated) goes upward for the 3D SSPP™ and downward for the force platform.

In addition to the magnitude force for each hand, the hand force direction was represented by a horizontal and vertical angles. The horizontal angle (H), which represents the angle between the force vector and the vertical x-z plane, was calculated using the following formula:

$$H = \tan^{-1}\left(\frac{fx}{fy}\right)$$

If $f_x > 0$ and $f_y > 0$ then $H' = H$

If $f_x \leq 0$ and $f_y > 0$ then $H' = H + 180°$

If $f_x \leq 0$ and $f_y \leq 0$ then $H' = H - 180$

If $f_x > 0$ and $f_y < 0$ then $H' = H$ (3-2)

The vertical angle (V) is the angle between the force vector and the horizontal x-y plane. It was calculated using the following formula:

$$V = \cos^{-1}\left(\frac{fx^2 + fy^2}{\left(\sqrt{fx^2 + fy^2 + fz^2}\right)}\right)$$

If $F_z > 0$ then V' = V

If $F_z < 0$ then V' = -V (3-3)

To extract the 15 joint angles needed to represent the posture that correspond to the peak force, both force platform readings, and videos were used. From the force platform readings the time, where the peak force occurred was obtained. This procedure was followed due to the need to provide the information needed for the video image capture equipment. Once the correct time was determined, the posture was frozen and a hard copy was obtained. After having the printouts of the postures corresponding to the peak forces, the 15 angles that represented the posture were calculated. In order to calculate the angles, lines were drawn throughout the picture of the participant's joints that were marked with the white dots. Angles were calculated using a protractor.

Due to limitations in the study not all the 15 angles could be calculated. Estimates of those angles that could not be calculated were done by matching the picture with the oblique view of the biomechanical model program. The program permitted a change in camera view for more accurate results. Once all the biomechanical input data was calculated it was entered in the software program. After joint angle estimates were done, a sensitivity analysis was performed to evaluate the changes in the results or dependent measures. Figures 10 and 11, actual printouts obtained from the video editing software and an oblique view of the wheelchair to bed task obtained from the 3D SSPP™, present the similarity in working postures of both pictures.

Figure 10. 3D SSPP Oblique view for the wheelchair to bed task with two person assistance

Figure 11. Video edited printout for the wheelchair to bed task with two person assistance

3.8.2. Statistical Analysis. The analysis was performed for the 192 tasks per session, for a total of 576 analyzed postures. Descriptive statistics (mean and standard deviation) were computed to characterize the raw data. A multivariate analysis of variance (MANOVA) using Wilk's Lambda criterion was used to test if the dependent variables derived from the biomechanical model for the Pretest, differences between Posttest 1 and Pretest, and differences between Posttest 2 and Posttest 1 were statistically significant. If the MANOVA found significance in the Training effect or an interaction with Training, an analysis of variance (ANOVA) for all dependent variables was conducted.

The differences between Posttest 2 and Posttest 1 evaluated the retention of information presented on the training programs. The following null hypothesis tested the retention of information: "RPEs, postural measures and biomechanical measures will not change after a short period of time". Therefore, no significant differences are expected, corresponding to a failure to reject the null hypothesis. However, a significant result could represent a favorable value as a result of continued learning or a nonfavorable value as a result of forgetting what was learned. Figure 12 shows a graphical representation of the possible directions for a significant difference. The three possible directions are continued learning, retention, and forgetting.

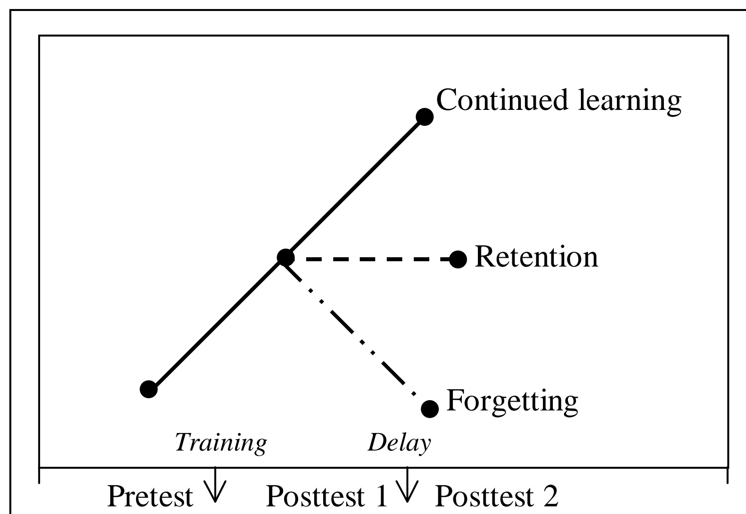


Figure 12. Possible directions of the dependent measures after a short period of time (4-6 weeks; Posttest 2 – Posttest 1).

In Figure 12, it is assumed that an increase in the value of the dependent measure represents a desirable change after training. It is important to notice that the direction of a desirable change depends upon each dependent measure (See Table 8). In other words, an increase in the value would not always represent a desirable change; instead it could represent forgetting. Therefore, continued learning should be described as a change in the direction of training.

Table 8. Favorable changes for each dependent measure

	Dependent Variable	**Favorable change**
RPE	Whole body	Decrease
	Shoulders	Decrease
	Low Back	Decrease
Postural Measures	Included knee angle	Decrease
	Included hip angle	Increase
	Included elbow angle	Decrease
	Torso angle	Increase
	Horizontal distance	Decrease
Biomechanical Measures	L5/S1 compressive force	Decrease
	L5/S1 shear force	Decrease
	L5/S1 disc moments	Decrease
	Shoulder moments	Decrease
	Shoulders strength capability	Increase
	Torso strength capability	Increase

The MANOVA and ANOVA were done using a statistical package (Minitab™ 11.0) at a $\alpha = 0.05$ level of significance. Finally, if Training or one of its interactions was significant a least significance difference comparison (LSD) post hoc analysis for level differences was conducted. The least significance difference (LSD) contrast analysis was analyzed using the JMP™ statistical software at an $\alpha = 0.05$ significance level.

3.8.3 Psychophysical Methods. Psychophysical assessment was derived from the participants ratings of perceived exertion (RPEs). For each experimental condition in each session, participants gave an RPE for the whole body, shoulders, and low back.

A MANOVA, ANOVA, and post hoc tests were also used to test if the whole body, shoulders and low back ratings of perceived exertion.

CHAPTER 4. RESULTS

The results were divided into three main categories: Ratings of Perceived Exertion (RPE), Posture, and Biomechanical Measures. These categories were subdivided as Pretest, Posttest 1 – Pretest, and Posttest 2 – Posttest 1. The Pretest section intended to obtain an initial measure or baseline to determine if there were initial differences between the training groups. The difference between posttest 1 and the pretest (Posttest 1 – Pretest) addressed the training effect on the groups that participated in a training program to determine if training had an influence on behavior. It evaluated original learning after the training condition based on changes in RPE, posture and biomechanical stress. The Posttest 2 – Posttest 1 section determined whether the participants who participated in the training programs remembered what they had learned after a short period of time.

4.1 Psychophysical Method: Ratings of Perceived Exertion

4.1.1 Pretest. For the RPE a MANOVA test was conducted to determine if the RPE were significantly different between the training groups. Table 9 provides the output of the MANOVA.

Table 9. Statistical results from the MANOVA test for the RPE to test differences between the training groups and for interactions of Training with other independent variables during the Pretest session.

Independent Variable	F-value	Degrees of Freedom	P-value
Training	0.771	6, 38	0.597
Task x Training	1.300	6, 38	0.277
Assistance x Training	0.973	6, 38	0.443
Dependence x Training	0.880	6, 38	0.510

The lack of significance in the MANOVA for the Pretest session indicates that no significant differences existed between the different training groups prior to training.

4.1.2. Posttest 1 – Pretest: Original Learning. Table 10 summarizes descriptive statistics for the RPE grouped by training groups and dependent measures, for comparison. The whole body RPE decreased by 0.599 on average, the shoulders by 0.991 (the largest decrease) and the low back by 0.735 (t-test, Ho: $\mu = 0$, Hi: $\mu < 0$; $p < 0.001$ for all the RPEs).

Table 10. Means and standard deviations from the whole body, shoulders and low back RPE for the difference between Posttest 1 and Pretest.

	RPEs		
Training	**Whole body**	**Shoulders**	**Low Back**
Video	-0.99 (1.7)	-1.49 (1.9)	-1.02 (2.3)
Lecture/Practice	-0.21 (1.6)	-0.73 (1.8)	-0.55 (1.9)
No Training	-0.71 (1.8)	-0.95 (2.1)	-0.86 (2.3)

Table 11 provides the output of the MANOVA for the Training effect and its second order interactions. A significant difference was found on the Training effect (p = 0.001).

Table 11. Statistical results from the MANOVA and ANOVA tests for the RPE to test the differences between Posttest 1 and Pretest. ANOVAs were performed on the main effects or interactions found to be significant under the MANOVA. Statistically significant results are indicated by an " * ".

			ANOVAs		
Independent Variable	**Parameter**	**MANOVA**	**Whole body**	**Shoulders**	**Low Back**
Training	F	4.631	13.43	8.05	1.83
	DF	6, 38	2, 21	2, 21	2, 21
	p	0.001*	<0.001*	0.003*	0.185
Task x Training	F	0.984	-	-	-
	DF	6, 38	-	-	-
	p	0.450	-	-	-
Assistance x Training	F	0.518	-	-	-
	DF	6, 38	-	-	-
	p	0.791	-	-	-
Dependence x Training	F	0.971	-	-	-
	DF	6, 38	-	-	-
	p	0.493	-	-	-

Based on the MANOVA results, p-values <0.001 and 0.003 were reported for the whole body and shoulders RPE. A statistically significant difference does exist between the levels of the Training factor for these RPE. Figures 13 and 14 present the graphs for the significant RPE differences.

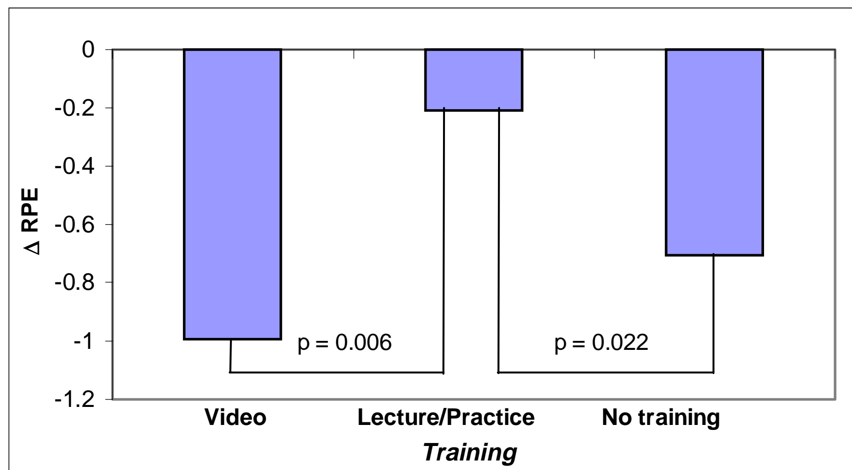


Figure 13. Differences between Posttest 1 and Pretest for the whole body RPE for the Training effect. Significant differences are indicated by their corresponding p-values.

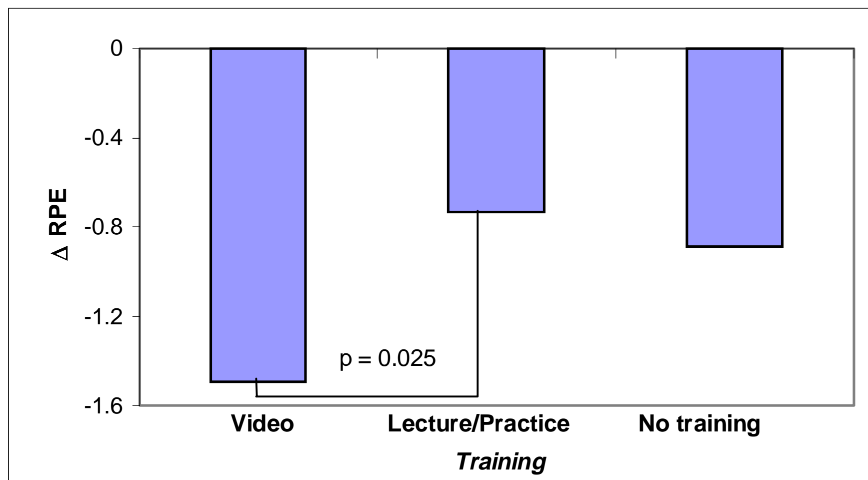


Figure 14. Differences between Posttest 1 and Pretest for the shoulders RPE for the Training effect. Significant differences are indicated by their corresponding p-values.

For the whole body and shoulders RPE the levels of the Training effect were statistically different. In both cases, the Video group had the largest decrease in RPEs compared to the Lecture/Practice group ($p = 0.006, 0.022$). The No training group also decreased their whole body RPE when compared to the Lecture/Practice group ($p = 0.025$).

The Dependence factor was also significant on the MANOVA ($p = 0.001$) for the three dependent measures whole body, shoulders, and low back ($p < 0.001$, 0.001, and 0.005 respectively). For the whole body RPE the means for the semi-dependent and dependent levels were –0.210 and –1.053; for the shoulders, -0.632 and –1.442; and for the low back –0.373 and –1.187. The overall means suggested that the dependent level had higher decreases in the RPE than the semi-dependent level.

4.1.3 Posttest 2 – Posttest 1: Retention. Descriptive statistics calculated for the difference between Posttest 2 and Posttest 1 for all the experimental treatments grouped by training are presented in Table 12. Whole body RPE decreased by 0.353 on average, the shoulders increased by 0.047 and the low back decreased by 0.235 (t-test, Ho: $\mu = 0$, Hi: $\mu \neq 0$; $p < 0.001$, 0.640, 0.023 respectively). The whole body and low back had favorable changes in RPE (continued learning). For the shoulders RPE no significant change occurred.

Table 12. Means and standard deviations for the whole body, shoulders and low back RPE for the difference between Posttest 2 and Posttest 1.

	RPEs		
Training	**Whole body**	**Shoulders**	**Low Back**
Video	-0.16 (1.16)	0.37 (1.26)	-0.05 (1.36)
Lecture/Practice	-0.44 (0.98)	0.14 (0.83)	-0.15 (1.01)
No Training	-0.47 (1.58)	-0.37 (1.80)	-0.21 (1.80)

Although Training was not significant as a main effect, the Assistance x Training interaction was significant (p-value = 0.024). Table 13 provides the full output of the MANOVA and ANOVA tests for the Training effect and its second order interactions.

Table 13. Statistical results from the MANOVA and ANOVA tests for the RPE to test the differences between Posttest 2 and Posttest 1. ANOVAs were performed on the main effects or interactions found to be significant under the MANOVA. Statistically significant results are indicated by an " * ".

			ANOVAs		
Independent Variable	**Parameter**	**MANOVA**	**Whole body**	**Shoulders**	**Low Back**
Training	F	1.952	-	-	-
	DF	6, 38	-	-	-
	p	0.062	-	-	-
Task x Training	F	0.563	-	-	-
	DF	6, 38	-	-	-
	p	0.757	-	-	-
Assistance x Training	F	2.793	5.28	7.17	4.81
	DF	6, 38	2, 21	2, 21	2, 21
	p	0.024*	0.014*	0.004*	0.019*
Dependence x Training	F	1.933	-	-	-
	DF	6, 38	-	-	-
	p	0.100	-	-	-

From the ANOVA results, p-values of 0.014, 0.004 and 0.019 were found for the whole body, shoulders and low back RPE Assistance x Training interaction respectively. Therefore, the results for all the RPE are significantly different for different combinations of Training and Assistance level. Figure 15, 16 and 17 illustrate the Assistance x Training interaction for the whole body, shoulders and low back RPE.

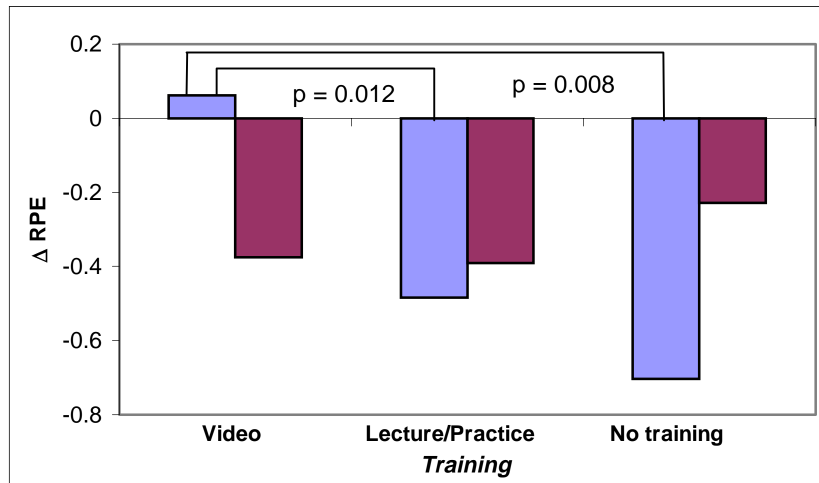


Figure 15. Differences between Posttest 1 and Posttest 2 for the whole body RPE from the Assistance x Training interaction. Significant differences are indicated by their corresponding p-values.
☐ One person, ■ Two person

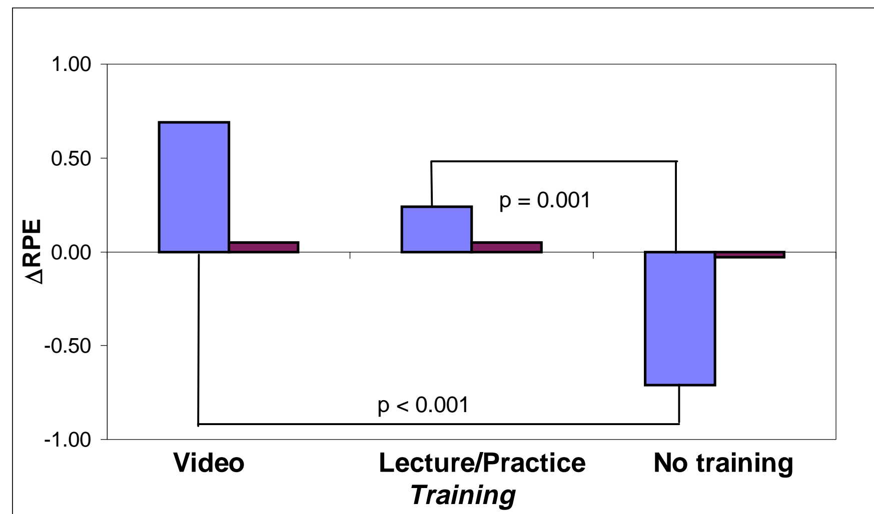


Figure 16. Differences between Posttest 1 and Posttest 2 for the shoulders RPE from the Assistance x Training interaction. Significant differences are indicated by their corresponding p-values.
☐ One person, ■ Two person

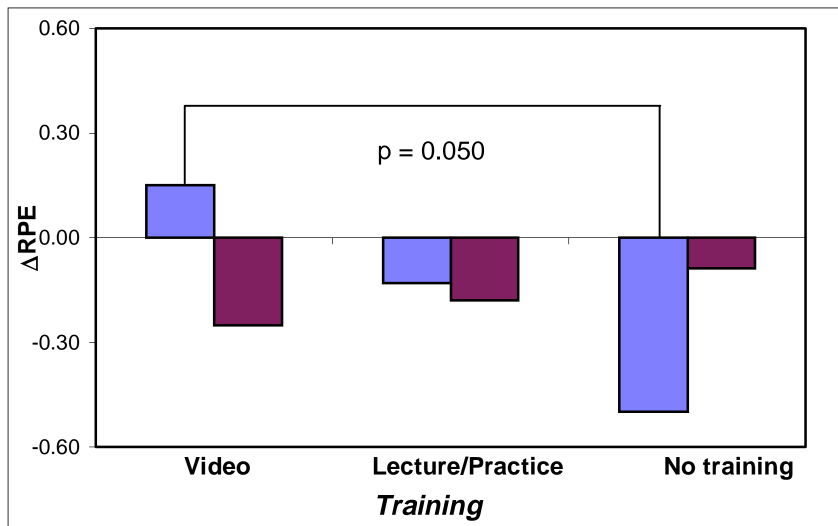


Figure 17. Differences between Posttest 1 and Posttest 2 for the low back RPE from the Assistance x Training interaction. Significant differences are indicated by their corresponding p-values.
■ One person, ■ Two person

In Figure 15, differences between the training groups can be observed for the one-person assistance. In this case, the Lecture/Practice and No training group had larger decreases in the whole body RPE than the Video group.

As seen in Figure 16, the differences (Posttest 2 – Posttest 1) for the shoulders RPE tend to increase for the Video and Lecture/Practice training while decreasing for the No training group when using the one person assistance. Although not significant, the average changes in RPE for the Lecture/Practice group were smaller. When performing the two-person assistance there were no observable differences among the groups. For the Low Back RPE there was a noticeable decrease between the training groups for both assistance techniques except for the one-person assistance on the Video group (Figure 17). As in the shoulders RPE, the Lecture/Practice group had a decrease in the low back RPE.

Based on the post hoc analysis for the shoulders RPE, there is a significant difference between Video and No training ($p < 0.001$) and Lecture/Practice and No training ($p = 0.001$) when using the one person assistance. The No training group showed a reduction on the RPE while the training groups increased (Figure 16). For the Low Back RPE there was a significant difference between Video and No training ($p = 0.050$)

for the one-person assistance (Figure 17). There were no significant differences in shoulder or low back RPE between the training groups for the two-person assistance.

4.2 Postural Measures

4.2.1. Pretest. The MANOVA test used to evaluate posture is the same analysis used for the Biomechanical Measures section (Section 4.3). All variables had to be tested under the same analysis since all came from the same source, the 3D SSPP™ software. Table 14 provides the output of the MANOVA and ANOVA tests for Training and the interactions with the other dependent variables.

Table 14. Statistical results from the MANOVA and ANOVA to evaluate difference between the training groups in the postural dependent measures during the Pretest. ANOVAs were performed on the main effects or interactions found to be significant under the MANOVA. Statistically significant results are indicated by an " * ".

			ANOVA				
Independent Variable	**Parameter**	**MANOVA**	**Hip**	**Knee**	**Elbow**	**Torso**	**Horizontal**
Training	F	2.271	1.34	7.39	0.17	1.29	0.64
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.030*	0.283	0.004*	0.844	0.295	0.537
Task x Training	F	1.448	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.196	-	-	-	-	-
Assistance x Training	F	0.660	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.831	-	-	-	-	-
Dependence x Training	F	0.925	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.572	-	-	-	-	-

Although no dependent measure was expected to be significant, the included knee angle p-value was significant (p = 0.004), indicating that an initial difference existed between the three training groups. Figure 18 illustrates the included knee angle for the three training groups during the Pretest session.

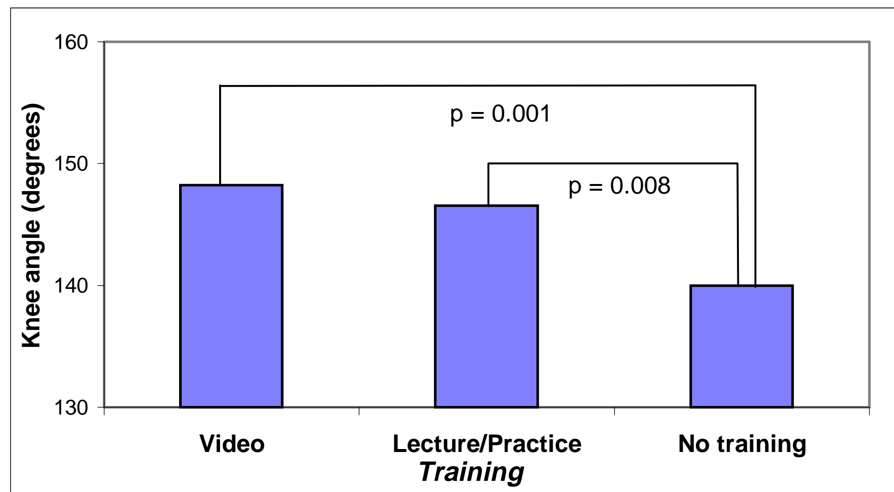


Figure 18. Included knee angle results for the three training groups during the Pretest session. Significant differences are indicated by their corresponding p-values.

As it can be seen from Figure 18, the Video and Lecture/Practice group performed similarly and no difference can be established. However, the No training group seems to have significantly smaller (7.4°) included knee angles than the other two groups.

The existence of significant differences between the three training groups was further investigated using an ANOVA to confirm that the variations found were not due to anthropometric differences. Table 15 shows the results of the ANOVA for the participants' height and weight.

Table 15. Statistical results from the one-factor ANOVA for the height and weight

	Source	**F**	**SS**	**MS**	**F-ratio**	**P-value**
Height	Training	2	62.0	31.0	0.92	0.415
Weight	Training	2	182.8	91.4	1.93	0.171

No significant differences were found in the height and weight of the three training groups. Also, after plotting the data it was found that several outliers in the No training group could have decreased the average included knee angles.

4.2.2. Posttest 1 – Pretest: Original Learning. In Table 16, descriptive statistics calculated for the experimental conditions are summarized and grouped by training and dependent measures, for comparison. The included hip and torso angles increased 2.93 and 1.371 on average and the horizontal distance by –1.31 (t-test, Ho: $\mu = 0$, Hi: $\mu > 0$, p-values = 0.025, 0.035, and 0.062); the included knee and elbow angles decreased on average by 3.86, and 6.02 (t-test, Ho: $\mu = 0$, Hi: $\mu < 0$, p-values = 0.001, 0.002).

Table 16. Means and standard deviations for the postural measures for the difference between Posttest 1 and Pretest.

	Included angles (°)				
Training	**Hip**	**Knee**	**Elbow**	**Torso angle (°)**	**Horizontal distance (cm)**
Video	6.96 (7.8)	-3.52 (15.9)	-11.14 (23.0)	2.88 (10.8)	-1.27 (10.8)
Lecture/Practice	5.11 (24.2)	-9.94 (17.3)	-6.16 (26.6)	3.16 (17.1)	-1.44 (11.0)
No Training	-3.27 (18.4)	1.88 (17.1)	-0.77 (19.0)	-2.22 (11.9)	-0.40 (10.6)

Table 17 provides the output of the MANOVA and ANOVA tests for the Training effect and the second order interactions with Training.

Table 17. Statistical results from the MANOVA and ANOVA tests to evaluate the postural dependent measures for the differences between Posttest 1 and the Pretest. ANOVAs were performed on the Training effect or interactions found to be significant under the MANOVA. Statistically significant results are indicated by an “ * ”.

			ANOVAs				
Independent Variable	**Parameter**	**MANOVA**	**Hip**	**Knee**	**Elbow**	**Torso**	**Horizontal**
Training	F	5.575	6.27	17.91	6.70	4.31	4.84
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21
	p	< 0.001*	0.107	< 0.001*	0.006*	0.215	0.079
Task x Training	F	1.763	0.35	2.71	5.38	0.92	1.38
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.046*	0.706	0.090	0.013*	0.415	0.274
Assistance x Training	F	0.232	6.68	1.82	0.13	4.23	2.60
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.044*	0.006*	0.067	0.875	0.029*	0.098
Dependence x Training	F	1.017	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.485	-	-	-	-	-

The MANOVA shows statistical significance in the Training effect and Task x Training and Assistance x Training interactions. Based on the ANOVA results, p-values of <0.001 and 0.006 were reported for the included knee angle, and included elbow angle Training effect. A statistically significant difference does exist between the levels of the Training factor for these postural measures. For the Task x Training interaction the elbow angle had a significant p-value of 0.013. Finally, for the Assistance x Training interaction the included hip angle as well as the torso angles were found to be significant with p-values of 0.006 and 0.029. Figures 19, 20, 21, 22 and 23 present the graphs for the significant dependent measures.

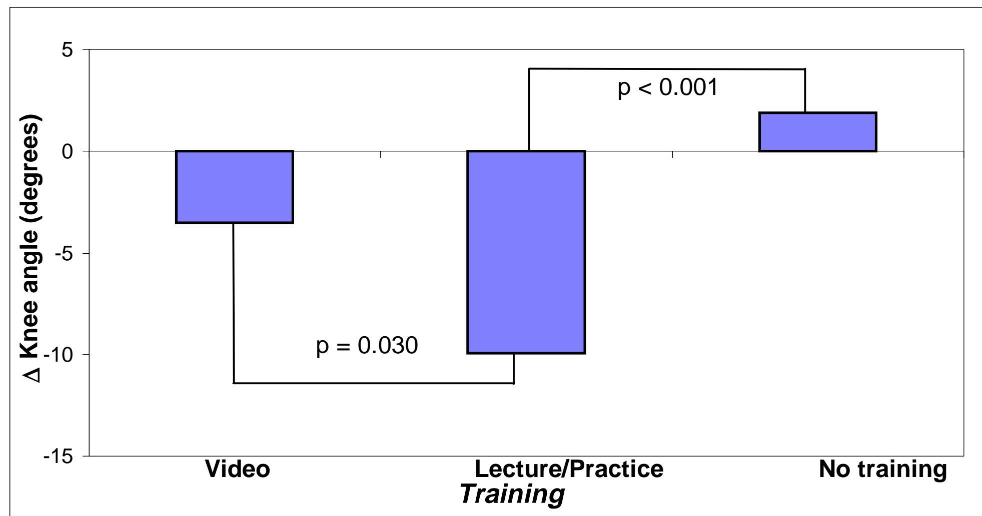


Figure 19. Differences between Posttest 1 and Pretest for the Training effect on the Included knee angle. Significant differences are indicated by their corresponding p-values.

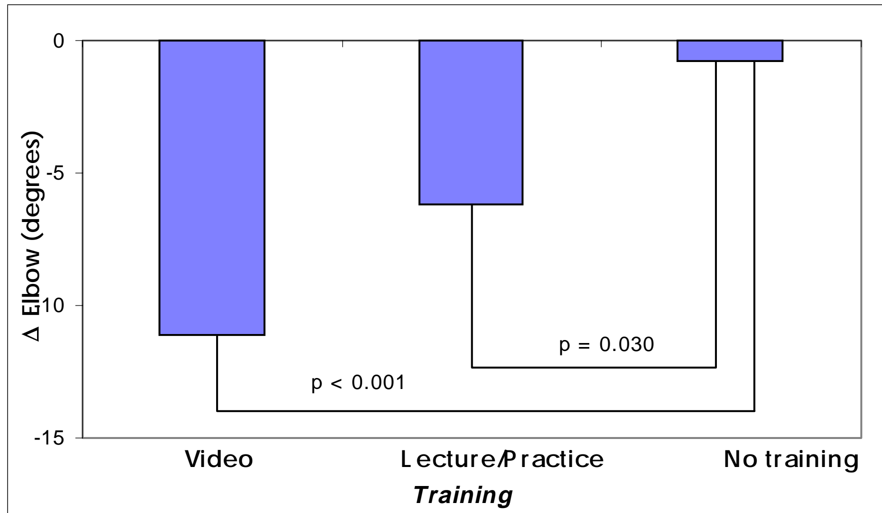


Figure 20. Differences between Posttest 1 and Pretest for the Training effect on the Included elbow angle. Significant differences are indicated by their corresponding p-values.

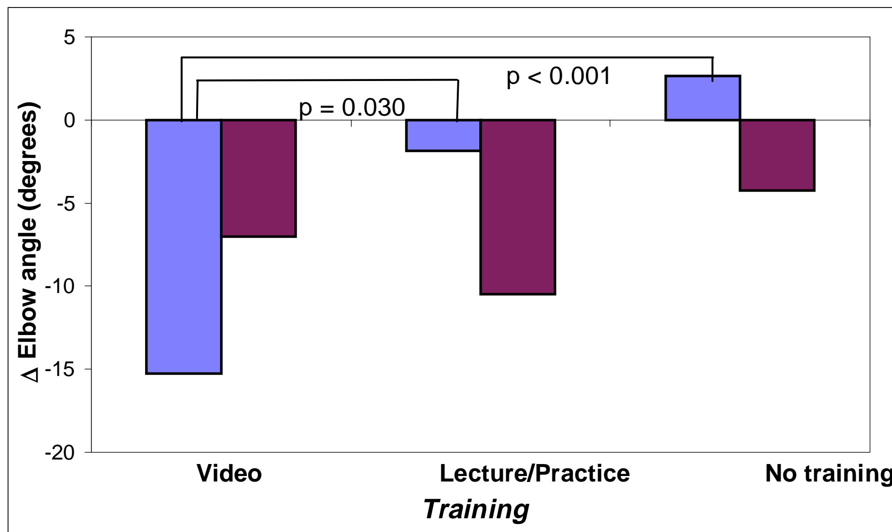


Figure 21. Differences between Posttest 1 and Pretest for the Task x Training interaction on the Included elbow angle. Significant differences are indicated by their corresponding p-values. ■ Wheelchair to bed, ■ Lift up in bed

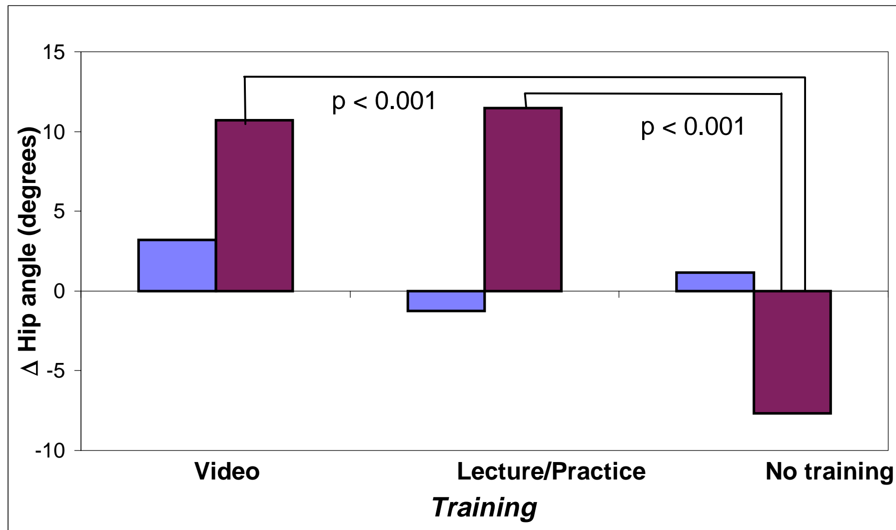


Figure 22. Differences between Posttest 1 and Pretest for the Assistance x Training interaction on the Included hip angle. Significant differences are indicated by their corresponding p-values. ☐ One person, ☐ Two person

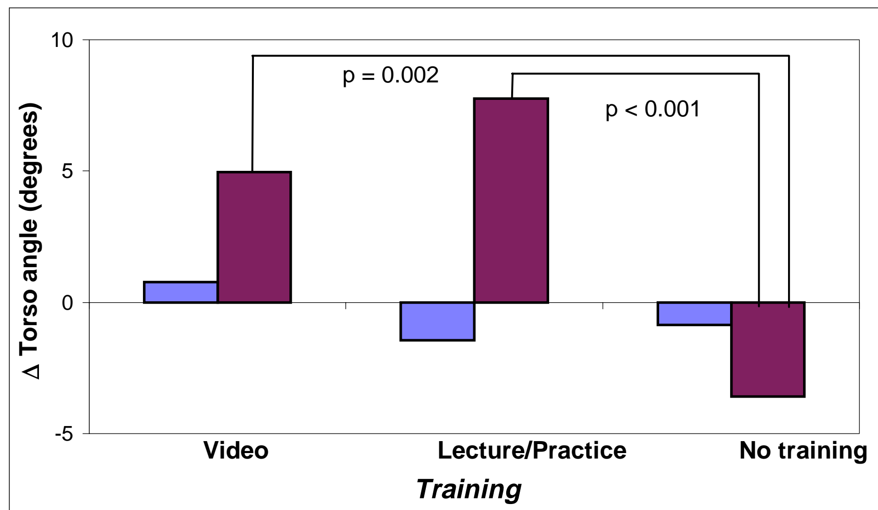


Figure 23. Differences for the Posttest 1 and Pretest for the Assistance x Training interaction on the Torso angle. Significant differences are indicated by their corresponding p-values. ☐ One person, ☐ Two person

Figure 19 shows that the Lecture/Practice group had the largest decrease in knee angles. For the Training effect on the included elbow angle both training groups had a reduction on this measure when compared the control group (Figure 20). The Video group had the largest decrease in the elbow angles.

As it can be seen in Figure 21 the wheelchair to bed task had a larger decrease in elbow angle for the Video group and a smaller decrease for the Lecture/Practice group. In contrast, for the lift up in bed task, the Video group had a small decrease in elbow angle while the Lecture/Practice group had a large decrease. For the hip angles and the torso angles the Assistance x Training, there was no observable difference among the groups when using the one-person assistance (Figures 22 and 23). However, for the two-person assistance a large increase was found.

From the post hoc analysis, it can be concluded that the levels of the Training factor are significantly different for the included knee and elbow angles (Figure 19 and 20). For the included knee angle the Lecture/Practice group was significantly different than the Video and No training group ($p = 0.030$, and < 0.001). The included elbow angles were significantly different for the Lecture/Practice and Video group when compared to the No training group ($p < 0.001$, and 0.030). For the included elbow angle Task x Training interaction, there are no significant differences among the groups for the lift up in bed task. But, for the wheelchair to bed task the Video group was significantly different than the Lecture/Practice and No training groups (See Figure 21).

Although the included hip angle was not significantly different for the one-person assistance among the training groups, it was significantly different for the two-person assistance specifically for the No training group (See Figure 22). The No training group had a decrease in hip angle while the training group hip angle increased. Similarly, the torso angle had no significant differences for the one-person assistance while the No training group had a decrease on torso angles for the two-person assistance (See Figure 23).

Since the postural measures were found to be strongly influenced by training, the reliability of these measures had to be evaluated. A Pearson correlation test was performed on the included knee angle, included hip angle, included elbow angle and torso angle to test how reliable the instrument used to measure the angles was. A random

sample of the 24 pretest conditions was chosen. From each of the 24 pretest conditions, 3 subjects were selected at random, and 4 of the angles recalculated. These recalculated numbers were correlated with the original values. Table 18 shows the correlation values (r), the mean difference as well as the maximum and minimum differences for the included knee, hip, elbow and torso angles.

Table 18. Pearson correlation and descriptive statistics for the postural angles.

	Pearson Correlation	**Mean difference**	**Minimum difference**	**Maximum difference**
Included knee angle	0.944	1.67	0	9
Included hip angle	0.946	0.54	0	7
Included elbow angle	0.989	1.13	0	5
Torso angle	0.985	1.20	0	0

The correlations were found to be high, suggesting that the measurement instrument is reliable as well as the measurements taken (postural angles).

There were two three-way interactions that were statistically significant in the MANOVA. These are Task x Assistance x Training and Assistance x Dependence x Training ($p = 0.007$ and 0.0032). For the horizontal distance, and included elbow angle, the Task x Assistance x Training interaction was significant ($p = 0.042$, and < 0.001). For the Assistance x Dependence x Training the hip angle, and elbow angle were significant ($p = 0.036$ and 0.005).

Although the objective of the study was to analyze training and its effects, it is important to mention that Task, Assistance and Dependence main effects were found to be significant in the MANOVA ($p < 0.001$, $p < 0.001$, and $p < 0.001$). Table 19 shows for which dependent variables the Task, Assistance and Dependence factors were significantly different.

Table 19. P-values from the ANOVA test main effects for the difference between Posttest 1 and Pretest. Statistically significant results are indicated by an "*".

Dependent Variable	P-values		
	Task	**Assistance**	**Dependence**
Included hip angle	0.047*	0.147	0.447
Included knee angle	0.037*	0.745	0.200
Included elbow angle	0.308	< 0.001*	0.026*
Torso angle	0.027*	0.047*	0.760
Horizontal distance	0.025*	0.865	0.002*

4.2.3. Posttest 2 – Posttest 1: Retention. For the differences between Posttest 2 and Posttest 1, Table 20 summarizes descriptive statistics calculated for the each dependent measure and grouped by training, for comparison. Although some means increased and other decreased (indicating both favorable changes) all the values were considered small, suggesting retention. The included hip, knee and torso angles increased by 2.49, 7.76 and 2.04, respectively (t-test, $Ho{:}\mu = 0$, $Hi{:}\ \mu \neq 0$, p-values = 0.098, 0.300, 0.019); the included elbow angle and horizontal distance decreased by 6.14 and 0.98, respectively (t-test, $Ho{:}\mu = 0$, $Hi{:}\ \mu \neq 0$, p-values = <0.001, and 0.160).

Table 20. Means and standard deviations for the postural measures (differences between Posttest 2 and Posttest 1).

Training	Included angles (°)			Torso angle (°)	Horizontal distance (cm)
	Hip	**Knee**	**Elbow**		
Video	1.02 (18.8)	-3.28 (15.5)	-6.02 (18.8)	2.05 (11.7)	-2.05 (9.2)
Lecture/Practice	1.02 (25.0)	24.97 (13.2)	-3.41 (26.2)	2.00 (12.5)	-0.44 (10.5)
No Training	5.44 (17.9)	1.58 (14.7)	-9.00 (18.4)	1.46 (12.0)	-0.46 (9.4)

The MANOVA and ANOVA tests results for the Training effect and its interactions with other independent variables are presented in Table 21. Although the Training factor was not significant, the Task x Training interaction was significant ($p < 0.001$).

Table 21. Statistical results from the MANOVA and ANOVA tests to evaluate the postural dependent measures for the difference between Posttest 2 and Posttest 1. ANOVAs were performed on the Training effect and interactions found to be significant under the MANOVA. Statistically significant results are indicated by an "*".

			ANOVAs				
Independent Variable	**Parameter**	**MANOVA**	**Hip**	**Knee**	**Elbow**	**Torso**	**Horizontal**
Training	F	1.382	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.227	-	-	-	-	-
Task x Training	F	2.582	1.45	1.64	0.41	1.10	0.18
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.015*	0.257	0.217	0.666	0.351	0.839
Assistance x Training	F	1.619	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.133	-	-	-	-	-
Dependence x Training	F	0.613	-	-	-	-	-
	DF	22, 22	-	-	-	-	-
	p	0.871	-	-	-	-	-

None of the dependent variables were found to be significantly different. Therefore, a statistically significant difference does not exist for the Task x Training interaction.

Although the objective of the study was to analyze training and its effects, it is important to mention that the Task factor was found to be significant in the MANOVA ($p < 0.001$). Table 22 shows for which dependent variables Task was significantly different.

Table 22. P-values from the ANOVA test for the Task factor for the difference between Posttest 1 and Pretest. Statistically significant results are indicated by an "*".

	P-values
Dependent variable	**Task**
Included hip angle	0.025 *
Included knee angle	0.178
Elbow angle	< 0.001 *
Torso angle	0.417
Horizontal distance	0.047 *

4.3. Biomechanical Measures

4.3.1 Pretest. Table 23 provides the output of the MANOVA and ANOVA tests to determine if the three training groups are initially different.

Table 23. Statistical results from the MANOVA and ANOVA tests to evaluate the biomechanical dependent measures during the Pretest session. ANOVAs were performed on the Training effect and interactions found to be significant under the MANOVA. Statistically significant results are indicated by an "*".

			ANOVAs					
			L5/S1 forces		Moments		Strength Cap.	
Independent Variable	**Parameter**	**MANOVA**	**Compressive**	**Shear**	**L5/S1**	**Shoulder**	**Shoulders**	**Torso**
Training	F	2.271	0.70	3.30	0.64	3.51	2.02	0.46
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.030*	0.509	0.083	0.538	0.048*	0.158	0.639
Task x Training	F	1.448	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.196	-	-	-	-	-	-
Assistance x Training	F	0.660	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.831	-	-	-	-	-	-
Dependence x Training	F	0.925	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.572	-	-	-	-	-	-

The MANOVA found the Training factor to be statistically significant ($p < 0.001$). For the Training factor, the shoulders moments were the only dependent measure with a significant p-value ($p = 0.048$), thus a statistically significant difference does exist between the training groups for this variable. Figure 24 presents the graph for the shoulder moments.

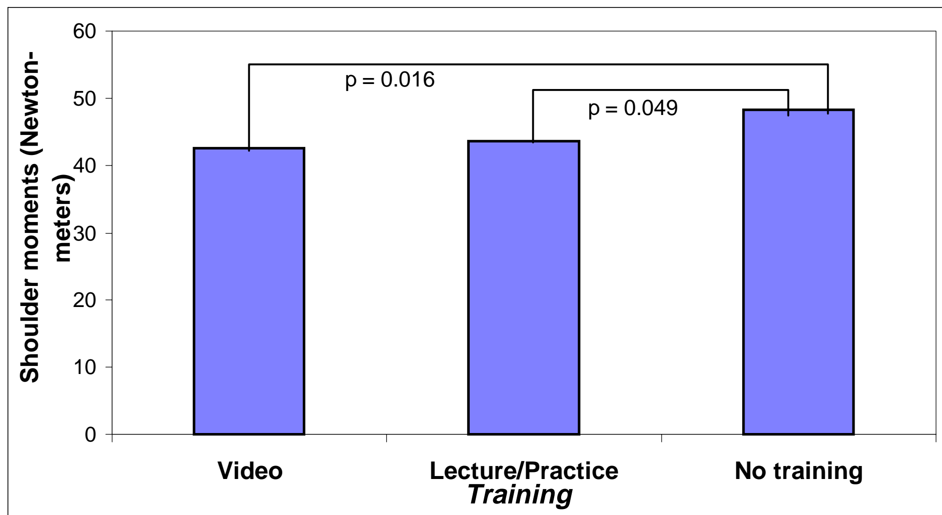


Figure 24. Shoulder moment results for the three training groups during the Pretest session. Significant differences are indicated by their corresponding p-values.

From the graph it can be said that the Video and Lecture/Practice group performed similarly and no difference can be established. However, the No training group seems to have significantly higher shoulder moments than the other two groups. The magnitude of the difference is 5.2 Nm. (See Table 14 for ANOVA on anthropometric differences)

There were several interactions for some dependent variables that, although they were not significant in the MANOVA, were significant in the ANOVA. For the shoulders strength capability, the Task x Training and Dependence x Training interactions were significant ($p = 0.012$, and $p = 0.011$). In the Task x Training interaction the wheelchair to bed task had a higher percentage in strength capability for the shoulders meaning that this task was less stressful than the lift up in bed task for the three training groups. Similarly, the Dependence x Training interaction had higher percentages for the population shoulders strength capability when moving a semi-dependent patient. The Dependence x Training interaction was also significant ($p = 0.019$) for the L5/S1 compressive force. In this case the Video and Lecture/Practice training groups had significantly different results ($p = 0.006$) for the semi-dependent level. The Video group had lower compressive forces than the Lecture/Practice group during the Pretest when moving a semi-dependent patient.

Although the objective of the study was to analyze the effect of training on the working behaviors, it is important to mention that Task, Assistance and Dependence factors were found to be significantly different in the MANOVA ($p < 0.001$, $p < 0.001$, and $p < 0.001$). Table 24 shows that Task, Assistance and Dependence were significantly different for all the dependent variables.

Table 24. P-values from the ANOVA test for the Task factor during the Pretest. Statistically significant results are indicated by a "*".

	P-values		
Dependent Variable	**Task**	**Assistance**	**Dependence**
L5/S1 compressive force	< 0.001 *	< 0.001 *	< 0.001 *
L5/S1 shear force	0.053 *	0.049 *	< 0.001 *
L5/S1 moment	< 0.001 *	0.043 *	< 0.001 *
Shoulder moment	< 0.001 *	< 0.001 *	< 0.001 *
Strength Capability Shoulders	< 0.001 *	0.002 *	< 0.001 *
Strength Capability Torso	< 0.001 *	< 0.001 *	< 0.001 *

In general, for all the dependent variables the main effects (except Training) were statistically significant. Therefore, the biomechanical stress is affected by the task performed, the assistance technique used, and the patient level of dependency.

4.3.2. Posttest 1 - Pretest: Original Learning. Table 25 summarizes descriptive statistics for the three training groups and dependent measures. These values indicate relatively big changes in behaviors for some of the dependent variables. The ones worth noting are: shear force for the Lecture/Practice group, 15% change; shoulders strength capability for the Lecture/Practice group, 34% change; shoulder moments for the Video group, 10% change; L5/S1 compressive force and moments for the Video group, 8% change. Overall the means and p-values for the t-test (Ho: $\mu = 0$, Hi: $\mu < 0$) are: for the L5/S1 compressive force, -169.65, $p = 0.007$; L5/S1 shear force, -21.25, $p = 0.027$; shoulder moments; 2.29, $p = 0.92$; L5/S1 moments, -5.70, $p = 0.045$; shoulders strength capability, -5.22, $p = 0.031$; and torso strength capability, -4.74, $p = 0.067$.

Table 25. Means and standard deviations for the biomechanical measures for the difference between Posttest 1 and Pretest.

	L5/S1 force (N)		Moments (Nm)		Strength Capability (%)	
Training	**Compressive**	**Shear**	**Shoulder**	**L5/S1**	**Shoulders**	**Torso**
Video	-245.17 (1045.3)	-15.67 (129.2)	-4.22 (20.7)	-11.36 (49.1)	2.97 (39.3)	0.69 (42.4)
Lecture/Practice	-179.10 (790.3)	-62.19 (181.3)	9.53 (21.6)	-3.07 (48.8)	-14.72 (40.1)	-5.19 (44.2)
No Training	-84.67 (995.9)	14.05 (132.1)	1.58 (22.0)	-2.68 (41.1)	-3.91 (34.4)	-9.74 (44.6)

To evaluate biomechanical stress a MANOVA was conducted to test which factors and interactions were statistically significant. Table 26 provides the output of the MANOVA and ANOVA tests for the Training effect and the second order interactions with Training.

Table 26. Statistical Results from the MANOVA and ANOVA tests to evaluate the biomechanical measures for the difference between Posttest 1 and Pretest. ANOVAs were performed on the Training effect and interactions found to be significant under the MANOVA. Statistically significant results are indicated by an "*".

			ANOVAs					
			L5/S1 forces		Moments		Strength Cap.	
Independent Variable	**Parameter**	**MANOVA**	**Compressive**	**Shear**	**Shoulder**	**L5/S1**	**Shoulders**	**Torso**
Training	F	5.575	0.43	4.16		0.64	1.01	1.34
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21	2, 21
	p	< 0.001*	0.655	0.030*		0.536	0.057	0.284
Task x Training	F	1.763	0.51	0.30		2.24	1.13	0.40
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.046*	0.609	0.745		0.076	0.343	0.673
Assistance x Training	F	0.232	0.61	1.38		1.62	0.60	2.26
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.044*	0.554	0.274		0.221	0.556	0.129
Dependence x Training	F	1.017	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.485	-	-	-	-	-	-

P-values of 0.030 and 0.002 were reported for the L5/S1 shear force and shoulder moments respectively for the Training effect. A statistically significant difference does exist between the levels of the Training factor for the L5/S1 shear force and shoulder moments. Figure 25 and 26 present the graphs of the Training effect for the L5/S1 shear force and shoulder moments respectively.

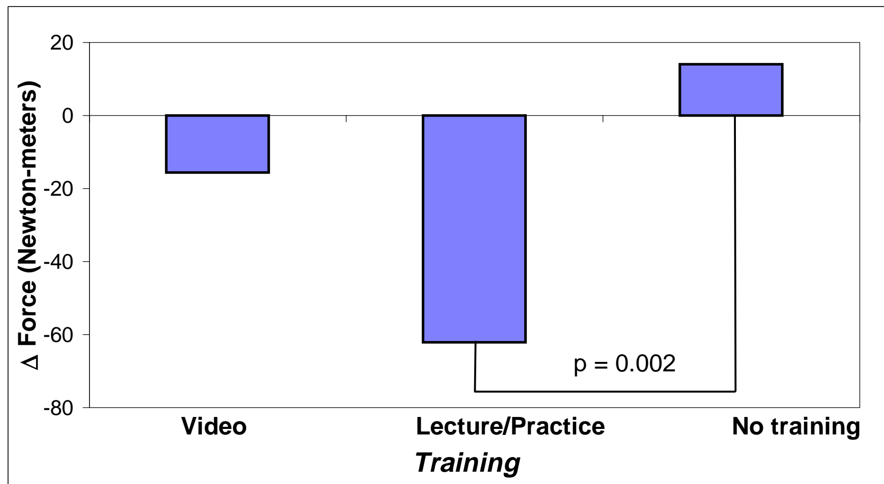


Figure 25. Differences between the Posttest 1 and Pretest for the Training effect on the Shear force. Significant differences are indicated by their corresponding p-values.

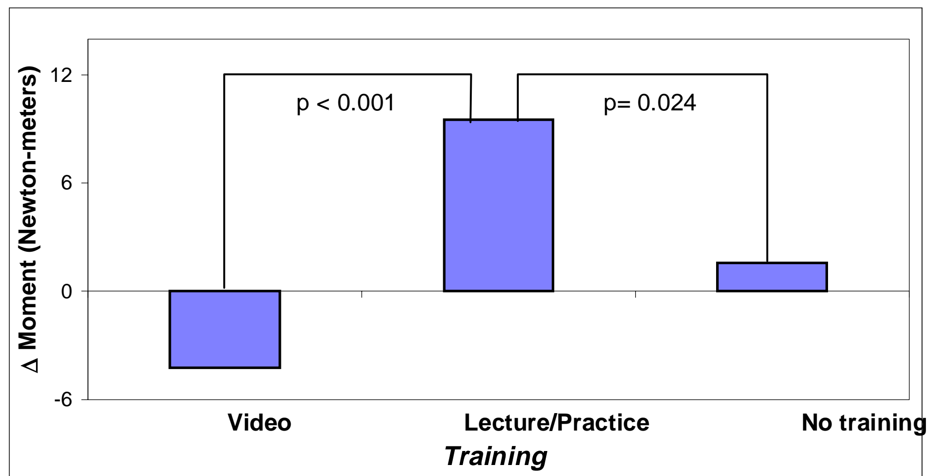


Figure 26. Differences between the Posttest 1 and Pretest for the Training effect on the Shoulder moments. Significant differences are indicated by their corresponding p-values.

As seen in Figure 25, the Lecture/Practice group had the greatest difference indicating a reduction on the L5/S1 shear force. For the shoulder moments (Figure 26) the Video group showed a reduction while the Lecture/Practice group had an increase. It seems that the three training groups are different in the two significant dependent variables.

There was one three-way interaction for some dependent variables that although they were not significant in the MANOVA had p-values < 0.05 in the ANOVA. For the L5/S1 shear force and for the L5/S1 moment, the Task x Dependence x Training interaction was significant (p = 0.034, and p = 0.018).   In the L5/S1 shear force, the semi-dependent level of the Dependence factor had an overall increase in shear forces for the two tasks. The Lecture/Practice group presented a decrease in shear force for the wheelchair to bed task. For the dependence level of the Dependence factor, the Video and Lecture/Practice group had a decrease in the L5/S1 shear force for both tasks, wheelchair to bed and lift up in bed. Similarly, the moments at the L5/S1 disc show that when the passive patient acted as a semi-dependent patient there was a increase in the moments for the Video group for the wheelchair to bed task and an increase for the Lecture/Practice group in the lift up in bed task.   For the dependence level, there was an overall decrease in the shear force for all the tasks and training groups. Figures 27 and 28 show the graphical representation of the Task x Dependence x Training interaction.

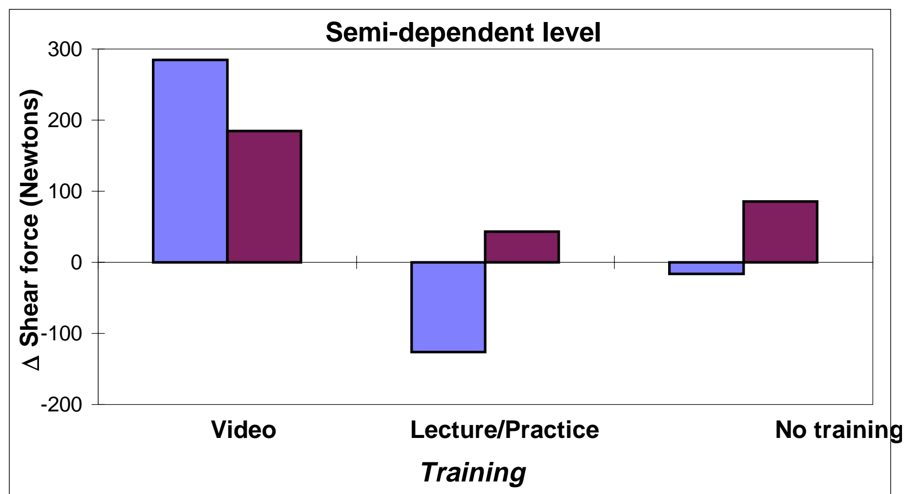


Figure 27. Differences between Posttest 1 and Pretest for the Task x Dependence x Training interaction on the L5/S1 shear force (semi-dependent level).
Wheelchair to bed task, Lift up in bed task

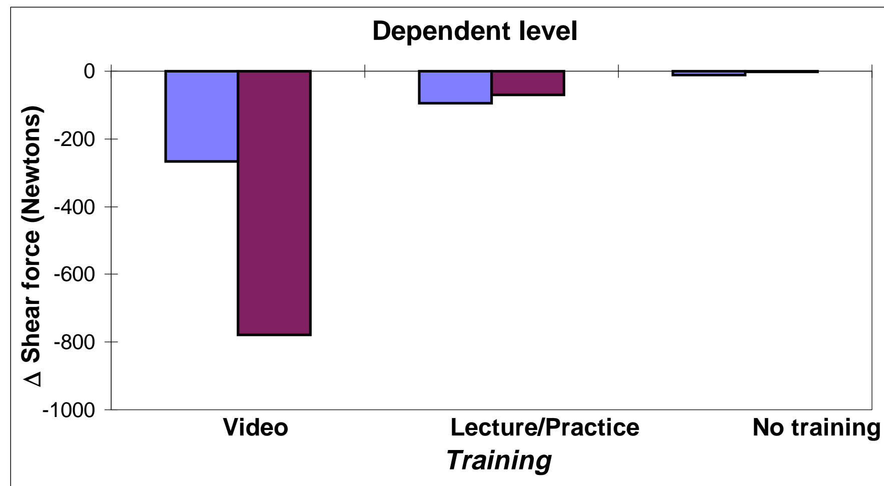


Figure 28. Differences between Posttest 1 and Pretest for the Task x Dependence x Training interaction on the L5/S1 shear force (dependent level).
□ Wheelchair to bed task, ■ Lift up in bed task

Although the objective of the study was to analyze training and its effects, it is important to mention that Task, Assistance and Dependence factors were found to be significantly different in the MANOVA ($p < 0.001$, $p < 0.001$, and $p < 0.001$). Table 27 shows for which dependent variables the Task, Assistance and Dependence factors were significantly different.

Table 27. P-values from the ANOVA test for the significant main effects for the difference between Posttest 1 and Pretest. Statistically significant results are indicated by a "*".

	P-values		
Dependent Variable	**Task**	**Assistance**	**Dependence**
L5/S1 compressive force	0.063	0.509	0.014 *
L5/S1 shear force	0.002 *	0.655	0.032 *
L5/S1 moment	0.126	0.567	0.160
Shoulder moment	0.468	0.051 *	0.004 *
Strength Capability Shoulders	0.242	0.126	0.028 *
Strength Capability Torso	0.012 *	0.462	0.075

The Dependence factor seems to be the effect that influences the most the dependent measures.

4.3.3. Posttest 2 – Posttest 1: Retention. Table 28 summarizes descriptive statistics (means and standard deviations) calculated for the eight experimental conditions, which are grouped by training groups and dependent measures, for comparison. In general, for most of the dependent measures, the means are small which indicate consistent behaviors immediately after training and after a short period of time. Overall the means and p-values for the t-test (Ho: $\mu = 0$, Hi: $\mu \neq 0$) are: for the L5/S1 compressive force, 27.63, $p = 0.630$; L5/S1 shear force, 30.15, $p = 0.002$; shoulder moments, -0.070, $p = 0.830$; L5/S1 moments, 0.690, $p = 0.830$; shoulders strength capability, -0.96, $p = 0.710$; and torso strength capability, -1.17, $p = 0.680$). Shear force was the only significant result implying that forgetting occurred.

Table 28. Means and standard deviations for the biomechanical measures for the difference between Posttest 2 and Posttest 1.

	L5/S1 force (N)		**Moments (Nm)**		**Strength Capability (%)**	
Training	**Compressive**	**Shear**	**Shoulder**	**L5/S1**	**Shoulders**	**Torso**
Video	11.50 (650.8)	8.25 (126.6)	1.15 (12.2)	-2.66 (33.8)	-4.30 (30.0)	-3.19 (34.5)
Lecture/Practice	65.24 (805.8)	58.41 (155.2)	-0.73 (26.4)	2.81 (49.5)	2.77 (39.6)	-0.13 (44.3)
No Training	28.90 (910.7)	23.80 (119.1)	-0.62 (18.9)	1.91 (44.8)	-1.36 (35.6)	-0.20 (37.2)

Although the Training factor was not significant, the Task x Training interaction was significant ($p < 0.001$). Table 29 provides the output of the MANOVA and ANOVA tests for the Training effect and its interactions.

Table 29. Statistical results from the MANOVA and ANOVA tests to evaluate the biomechanical measures for the difference between Posttest 2 and Posttest 1. ANOVAs were performed on the Training effect and interactions found to be significant under the MANOVA. Statistically significant results are indicated by an "*".

			ANOVAs					
			L5/S1 forces		Moments		Strength Cap.	
Independent Variable	**Parameter**	**MANOVA**	**Compressive**	**Shear**	**L5/S1**	**Shoulder**	**Shoulders**	**Torso**
Training	F	1.382	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.227	-	-	-	-	-	-
Task x Training	F	2.582	8.33	1.16	3.91	8.39	1.16	0.77
	DF	22, 22	2, 21	2, 21	2, 21	2, 21	2, 21	2, 21
	p	0.015*	0.002*	0.334	0.036*	0.002*	0.334	0.475
Assistance x Training	F	1.619	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.133	-	-	-	-	-	-
Dependence x Training	F	0.613	-	-	-	-	-	-
	DF	22, 22	-	-	-	-	-	-
	p	0.871	-	-	-	-	-	-

The MANOVA results show significance in the Task x Training interaction between the biomechanical measures. The p-values for the L5/S1 compressive force, L5/S1 moments and shoulder moments were significant. That is, a statistically significant difference does exist between the levels of the Task x Training interaction. Figure 29, 30, and 31 present the graphs of the Task x Training interaction for the L5/S1 compressive force, L5/S1 disc and shoulder moments respectively.

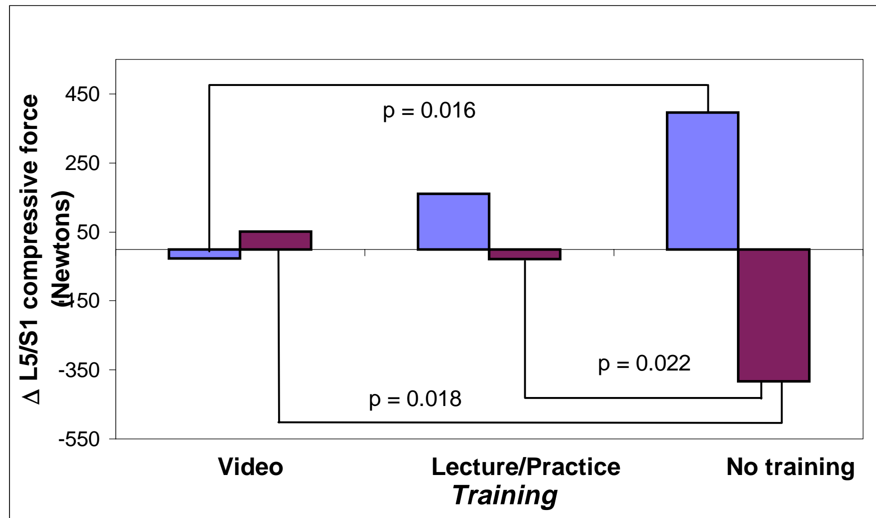


Figure 29. Differences between Posttest 2 and Posttest 1 for the Task x Training interaction on the L5/S1 compressive force. Significant differences are indicated by their corresponding p-values. Wheelchair to bed task, Lift up in bed task

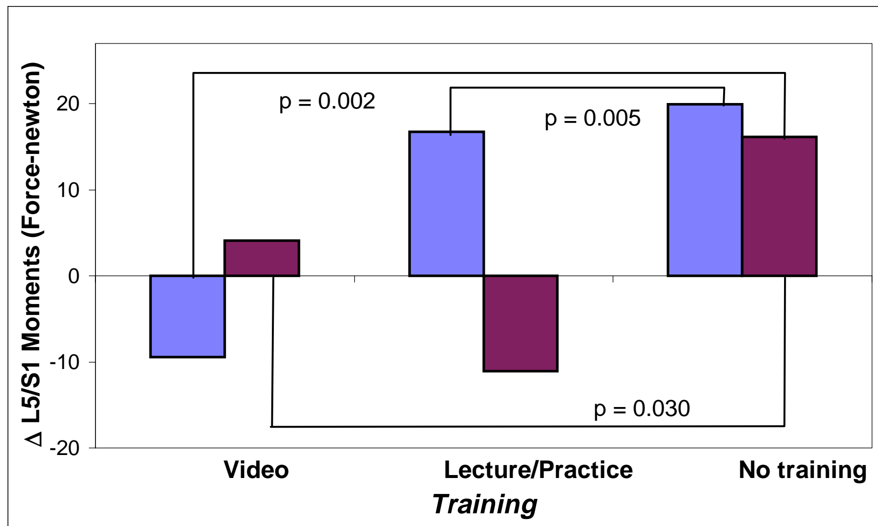


Figure 30. Differences between Posttest 2 and Posttest 1 for the Task x Training interaction on the L5/S1 disc moments. Significant differences are indicated by their corresponding p-values. Wheelchair to bed task, Lift up in bed task

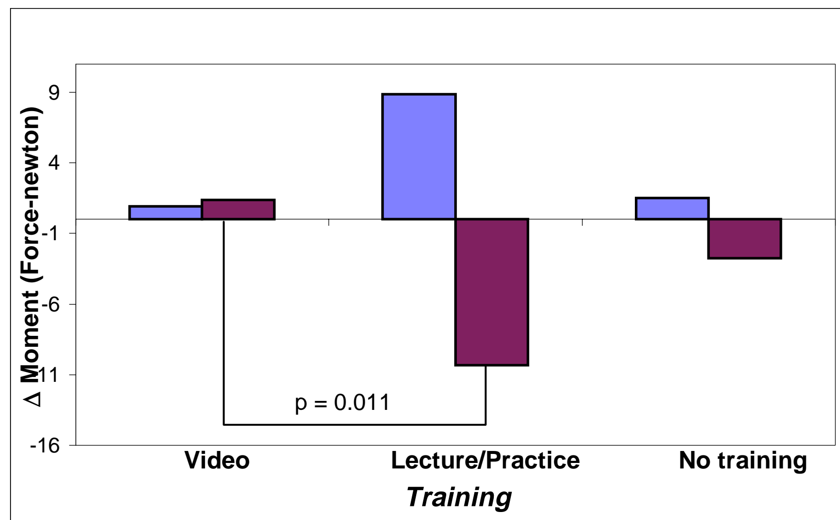


Figure 31. Differences between Posttest 2 and Posttest 1 for the Task x Training interaction on the shoulders moments. Significant differences are indicated by their corresponding p-values. ☐ Wheelchair to bed task, ☐ Lift up in bed task

As it can be seen in Figures 29, 30, and 31 the wheelchair to bed task had larger increases on the compressive forces and moments than the lift up in bed task (especially for the Lecture/Practice group). Based on the post hoc analysis, there is a significant difference between the Video and No training group for the wheelchair to bed task for the L5/S1 compressive force (See Figure 29). For the lift up in bed task, both the Video and Lecture/Practice group had significantly different compressive forces than the No training group which had a significantly larger decrease.

The Lecture/Practice group had a significantly larger decrease in the L5/S1 moments for the wheelchair to bed task than the Video and No training group, which had increases. For the lift up in bed task, the Video and No training group are significantly different (See Figure 30). Finally, for the shoulder moments the only significant difference was the Video and Lecture/Practice group in the lift up in bed task. In this case, the Lecture/Practice group had a significantly larger decrease in shoulder moments than the other groups (See Figure 31).

Although the objective of the study was to analyze training and its effects, it is important to mention that the Task factor was found to be statistically significant in the

MANOVA ($p < 0.001$). Table 30 shows for which dependent variables the Task factor was significant.

Table 30. P-values from the ANOVA test for the Task effect for the difference between Posttest 1 and Posttest 2. Statistically significant results are indicated by a "*".

	P-values
Dependent variable	**Task**
L5/S1 compressive force	0.003 *
L5/S1 shear force	0.093
L5/S1 moment	0.008*
Shoulder moment	0.001 *
Strength Capability Shoulders	0.142
Strength Capability Torso	0.484

CHAPTER 5. DISCUSSION

Several facts motivated an investigation into whether training can modify or change nurses working behaviors to reduce musculoskeletal injuries. Nursing professionals are among the occupational groups with the highest incidence rates of musculoskeletal injuries, especially those of the back. These injuries seem especially related to moving and transferring patients. Many researchers have stated that proper training on patient handling techniques and ergonomics represents a solution for this problem. Other experts believe that training in proper body mechanics and patient handling procedures has not been effective in reducing the incidence of low back injuries. The inconsistency of the results of many personnel training programs makes the interpretation of the success and effectiveness of personnel training programs very difficult. Therefore, the question still is, *can training change or modify working behaviors?*

Most studies related to training effectiveness have focused on long term reduction in existing injury rates, ignoring its effectiveness to modify working behaviors over a short period of time. Furthermore, only a small number of training methods can be considered to be adequate and/or appropriate. As a result, it still needs to be determined whether or not training *can have an effect after a short period of time, and whether the type of training affects the working behaviors.*

For a training program to be effective as a mean for reducing musculoskeletal injuries, it must first modify worker behaviors and biomechanical stresses to a measurable degree. The ratings of perceived exertion, postural angles and biomechanical measures were analyzed to evaluate whether training programs had the potential to positively influenced them.

The results suggest that training did influence certain aspects of working behaviors. All the postural angles used to evaluate working postures were statistically significant (included knee angle, included hip angle, included elbow angle, and torso angle). Training also had an effect in reducing spinal forces (shear force) and joint moments (shoulder moments). The whole body and shoulder ratings of perceived exertion showed differences between the training groups.

Although differences were found between the Video and Lecture/Practice training groups, it was difficult to conclude which training method was optimal. For some dependent measures the Video group had larger differences that favored it, while for others the Lecture/Practice group seemed to perform better.

After a short period of time (four to six weeks) training still influenced the participants working behaviors, especially the postural measures. The shoulders and low back RPE were different as well as the compressive forces and joint moments. These dependent measures were not positively influenced immediately following training, therefore the difference found does not explain or imply retention after a short period of time.

The following discussion includes the interpretation of the statistically significant dependent variables, their implications on training as well as comparisons with previous studies. Possible limitations of the study affecting the results are also discussed.

5.1. Pretest

As stated previously, results from the Pretest session were analyzed to determine if the three training groups were initially uniform and ensure that no differences existed among them. It was expected that none of the dependent variables for the Training effect would to be significant, and no significant RPE differences were found between the training groups. The included knee angle was significant due to differences in the No training group, which had significantly lower included knee angles than the other groups. This means that the No training group adopted more of a squat posture. Therefore, the groups were not initially uniform based on the included knee angle. It was also found that the No training group had higher shoulder moments than the other two groups. This implies that the No training group held the patient farther away from their bodies than the other groups.

The existence of significant differences among the three training groups was further investigated using an ANOVA to determine if the variations found were not due to anthropometric differences. No significant differences were found in the height and weight of the three training groups, and the anthropometric characteristics therefore, not likely the source of the initial differences. After plotting the data, it was found that

several outliers could have decreased and increased the average included knee angle and the shoulder moments for the No training group respectively. Also, the magnitude for the included knee angle and the shoulder moment, 7.4° and 5.2 Nm respectively, are considered small enough so as not to restrict the interpretation of the results obtained from the study or in further interpretations.

5.2. Posttest 1 – Pretest: Original Learning.

The whole body and shoulder's RPE showed significant differences for the Training effect. The Video group had greater decreases on the whole body and shoulders RPE than the Lecture/Practice training group. This indicates that training, especially the Video group had changes in the workload perception immediately after training. The control group also presented large decreases in the RPE when compared to the Lecture/Practice group.

The end result of this analysis is that the null hypothesis "whole body, shoulder, and low back ratings of perceived exertion during patient handling activities will not be affected by the training program(s)", has been rejected. But, the data presented fail to provide evidence regarding the effect of training on the low back ratings of perceived exertion.

As for the postural measures, training caused specific changes in working postures. The Lecture/Practice group had significantly greater decreases in the included knee angles. This indicates that the Lecture/Practice group adopted more of a squat-like posture as a result of the training. The changes in posture could be a result of the training received on how to properly use the back and the legs. These results confirm the findings by Hellsing et al. (1993) who reported a decrease in knee angles (more knee flexion) for the group who received a 3-day intensive course on patient handling techniques.

Some significant differences were also found in the included elbow angles for the Training effect and when the Task x Training interaction (the effect of training depends on the task performed). The interaction showed that for the lift up in bed task the levels of the Training factor were not significantly different while for the wheelchair to bed task the Video group had an even greater decrease in elbow angle than the other groups. This means that the Video group further minimized the included elbow angles to hold the

patient closer to their body for the wheelchair to bed task. In this case the training seems to influence the participants working behaviors.

The Assistance x Training interaction was found to be significant for the included hip angle and the torso angle meaning that the effect of training depends on the type of assistance provided. The interaction analysis for the included hip angle interaction showed that for the one person assistance the levels of the Training factor were not significantly different, while for the two person assistance the No training had a significant decrease in the included hip angles than the other groups. The Video and Lecture/Practice groups had larger increases in the included hip angles. This most likely means that training helped increase the included hip angles to keep the back straight. This effect was observed for the two-person assistance (and especially for the lift up in bed task) probably since they don't have to reach with their hands under the patient's back when compared to the one-person assistance (reaching under the patient's back caused the participant to flex the trunk). Similarly, the torso angle Assistance x Training interaction showed that for the one person assistance the levels of the Training factor were not significantly different while with two person assistance the No training group had significant decreases in the torso angle. As in the included hip angle, this means that the participants who received training were trying to keep their backs straight. In other words, larger included hip angles and torso angles imply that the body was closer to an erect position. Although no significant differences were expected in the control group, there were differences (favorable changes) for the included hip angle and torso angle as it was mentioned. These differences could be an effect caused by learning through practice, intrinsic learning (after performing the tasks in several occasions they found better ways to do it), and even a random event. These findings agree with Hellsing's study (1993) who reported a reduction in torso angles (less trunk flexion) where the nurses adopted an erect position since the training emphasized keeping their backs straight and using their legs.

These results led to a rejection of the null hypothesis, "working postures, specifically the included hip, included knee, included elbow and torso angles, and horizontal distance during patient handling activities will not be affected by the training program(s)". The included knee angle, included hip angle, the included elbow angle, the

torso angle as well as the horizontal distance were affected by the training program. This implies that training can be effective in changing or modifying working postures.

Some biomechanical measures were significantly affected by training such as the L5/S1 shear force and the shoulder moments. The Lecture/Practice group had significantly larger decreases in shear forces than the Video group. Reductions on the shear force are probably directly related to the more upright posture. This is supported by the non-significant difference in hand forces between the training groups.

The Lecture/Practice group had significant increases in shoulder moments while the Video group had only a small decrease, which was not significant. The control group had no significant differences. For the Lecture/Practice group this could mean that they were increasing the horizontal distance by increasing the included elbow angles or applying more force. An ANOVA was conducted on the total force data obtained from the force platform system. The total force was statistically non-significant for the Training effect ($p = 0.231$) and for its interactions. Therefore, the increases in the shoulder moments could not be explained by changes in hand forces.

These results reject the hypothesis that states that the "biomechanical stress during patient-handling activities, specifically the compressive and shear forces at the lumbrosacral disc, the lumbar and shoulder joint moments, and the strength capability at the shoulders and torso, will be affected by the training program(s)". The L5/S1 shear force and the shoulder moments were affected by the training program. For the compressive force, L5/S1 disc moment and for the strength capabilities the null hypothesis failed to be rejected.

Among all the dependent measures evaluated, the postural angles as well as the spinal forces and joint moments were the most useful to evaluate changes in behavior. The postural angles presented observable modifications in the posture. The biomechanical measures also provided useful information based on their sensitivity to changes in hand loads and postural changes. The strength capability is not a normally distributed variable; it is insensitive to small changes in the input data but not to large changes. Changes in the RPE for the control group can be observed probably due to the effect of factors such as practice and intrinsic learning.

5.3. Posttest 2 – Posttest 1: Retention.

Another important aspect of the study was to test retention after a short period of time (4-6 weeks). No significant differences were expected in the dependent variables that were significant immediately following training implying that the variables that were positively influenced by training are still being influenced by training after a short period of time (since they had the same values or no changed occurred). If a dependent measure is found to be significant it could mean that either a positive or negative change occurred after a short period of time. In this case the measure must be individually evaluated. Table 31 shows all the dependent measures with their respective significance or nonsignificance after a short period of time and its interpretation.

Table 31. Comparison of significant results for the differences between Posttest 1 and Pretest and Posttest 2 and Posttest 1. Significant results are indicated by an "*".

	Dependent Variable	Posttest 1 - Pretest	Posttest 2 - Posttest 1	Interpretation
RPE	Whole body	*	*	Continued learning
	Shoulders	*	*	Continued learning
	Low Back		*	Continued learning
Postural Measures	Included Knee angle	*		Retention
	Included Hip angle	*		Retention
	Included Elbow angle	*		Retention
	Torso angle	*		Retention
	Horizontal distance	*		Retention
Biomechanical Measures	L5/S1 compressive force		*	Continued learning
	L5/S1 shear force	*		Forgetting
	Shoulder moments	*	*	Continued learning
	L5/S1 moments		*	Continued learning
	Shoulders Strength Capability			No change
	Torso Strength Capability			No change

Short-term retention of training was first evaluated using the RPE analysis. For the RPE the Assistance x Training interaction was found to be significant after a short period of time. This includes significant differences on the whole body, shoulders and low back RPE. The two-person assistance had no significant differences among the levels of the Training factor for the shoulders RPE while the No training group had significant decreases for the one-person assistance when compared to the other groups. This might occur because the two-person assistance is easy to perform, therefore it is hard to reduce

the RPE after training. The differences in the RPE imply a positive influence for the training groups after a short period of time.

None of the postural dependent variables were found to be statistically significant after a short period of time. Therefore, it is probable that training could have positively influenced the working postures and behaviors even after a short period of time. In other words, the participants retained the postures assumed after training (keeping a back straight and holding the patients close to their bodies).

The L5/S1 compressive force, L5/S1 moments and the shoulder moments were significantly different among the levels of the Task x Training interaction. The Lecture/Practice group had reductions on the L5/S1 moments probably due to a reduction in distance to keep the load close to the body. Similarly, the Lecture/Practice group also had a significant reduction on the shoulder moments for the lift up in bed task most likely for the same reasons.

Although it is beyond the scope of this study to clearly identify which training method helped nurses retain more information, the findings suggest that the Lecture/Practice group seemed to retain more of what they learned. The Lecture/Practice group had better results (favorable changes) than the Video group in six out of eight significant dependent measures. In a similar study, Chaffin et al. (1986) concluded that the types of lifting behaviors most susceptible to alterations are the ones simple to learn and to remember.

5.4 Limitations of the study

Certain factors affected the results of this study. Issues regarding the length of the training, the equipment used and possible confounding influences on subjective perception. Some of the most relevant sources of errors and/or limitations are listed next.

- Static models, as the 3D SSPP, neglect the effects of acceleration and inertia on the body leading to an underestimation of the forces and moments generated on the body. However, the patient handling tasks are relatively slow and controlled motions offering a simple and relatively accurate means for performing a static analysis.
- The fact that the participants in the second and third session already knew which tasks were more difficult and stressful could have affected their subjective ratings. That is,

the original experience could have affected the perception of the tasks and the effort or force exerted by the participants even after training. Subjective measures could be greatly influenced by the participants' psychological perception and reaction to different working conditions.

- The dots on the clothing kept moving and/or sticking out and this affected the calculation of the angles. Also, at times, when drawing the angles on the paper print outs it was hard to tell where the dots were at since they could have been covered in the picture by the patients hand, or sometimes the bed. As a result, some of the angles needed to be estimated.
- Only one single peak force was analyzed per event based on one of the force components' maximum reading. This means that the point where the total maximum force occurred was not necessarily analyzed.
- To some extent the platform limited certain motions. For example, when getting closer to the bed the participants were not capable of getting as close as they wanted since they were not allowed to have their feet off the platform.

5.5 Recommendations and Future Research

- A three video camera approach would have provided the necessary information to more precisely compute the angles that could be observed only from a top view.
- Another limiting factor could be the sample size (N) of the study. Although a sample size of 24 subjects was employed, a larger sample would help reduce variability.
- Each individual's aerobic capacity and strength are physical characteristics that could have been measured. This analysis can help in the interpretation of the results since the forces are affected by the inter-individual strength variability.
- In order to validate the results, which are obtained by simulating semi-dependent and dependent patients, it might be necessary to conduct the same test by employing a dummy or real person of the corresponding height and weight as a dependent patient. It is expected that the results obtained from this new approach would provide more accurate data regarding the behavior of a dependent patient.

- It is most likely that the differences observed after training are due to the content of the training program. However, the duration of the two training programs was different, implying that the effect of duration of the training programs was not isolated from its content. Therefore, it remains unanswered if the time spent on the training programs could have an effect on the dependent measures.

Although the Lecture/Practice training was found to be the best approach there are factors that could be further evaluated to confirm that this type of training leads to less biomechanical stress than the Video training. As a recommendation for future research, the duration of the training should be controlled to specifically evaluate whether time or the content of the training influenced the working behaviors the most. Also, larger sample sizes and the use of a dynamic model would help to obtain more accurate or reliable results. The use of a motion analysis system would also help on a more comprehensive evaluation of the effect of training on the working postures.

CHAPTER 6. CONCLUSION

As an assumed precursor to reduce musculoskeletal injuries, training is a potential modifier of working behaviors. This study has shown that a training program on patient handling techniques can lead to some changes in nurses working behaviors (especially for their working postures). These changes in behavior were most evident for the whole body and shoulder RPE, included knee, elbow, hip, and torso angles, shear forces and shoulder moments; these were positively influenced by training. Although the L5/S1 compressive force, the lumbrosacral disc and the low back RPE were nonsignificant immediately after training they were significant after a short period of time following training. These differences were due to changes in the control group. This study did not reveal any changes 4-6 weeks after training in the postural angles (postural angles were significant immediately after training). No significant differences following a 4-6 weeks delay imply that training might have still influenced working behaviors after a short period of time (as a result of retaining the information presented during training). Thus, postural influences occurring as a result of training, might be expected to continue at least as long as several months.

After analyzing all the significant dependent measures that involved differences between the Video and Lecture/Practice training groups the Lecture/Practice training led to the best results (positive changes) six out of eight times. Therefore, it is probable that lectures on biomechanics, back injury prevention methods and hands-on practice are the best approach to reduce strenuous efforts on the L5/S1 disc and shoulders leading to a reduction of low back and shoulder injuries. Regardless of which of the two training methods proved to be more effective, this study has shown that training, by positively influencing behavior, has the potential to provide benefits in terms of changing working postures, and reducing biomechanical stress.

CHAPTER 7. REFERENCES

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APPENDIX A

Topic Outline: Lecture/Practice Training Program

1. **Purpose**
   Understand your back.
   Learn proper posture and body mechanics for safer lifting.
   Reduce the risk of back pain and muscle injury.

2. **Introduction**
   Workplace injuries
   - 76 % of all workplace injuries
     - 47% involved the back
     - 25% involved the neck and upper limbs

3. **Introduction (cont'd)**
   Low back pain (LBP)
   - 8 out of 10 people experience LBP sometime in their lives.
   - 40% of nurses LBP complaints are related to patient handling.
   - 16% of the new muscle injuries (including back injuries) are related to patient handling.

4. **Structure of the body**
   - Musculoskeletal System
     - Bones (links)
     - Articulations (joints)
     - Connective Issues
       - Muscles
       - Tendons
       - Ligaments

5. **Structure of the spine**
   - Vertebral Column
   - Central support structure of the trunk
   - Components
     - Vertebrae
     - Disks
     - Facets
     - Muscles
     - Ligaments
   - Curvature, Posture
   - Mobility

6. Causes of MSDs

- Risk factors
  - Personal factors
  - Workplace factors
  - Environmental factors

7. Personal factors

- Age
- Gender
- Weight
- Height
- Fitness level
- Previous injury
- Education
- Smoking

8. Workplace factors related to injuries

- Lifting, lowering, pushing, pulling, carrying, holding
- Weight and size of the load to be moved
- Distance load is to be moved
- Frequency and duration of the task

9. Environmental factors

- Climate
  - Heat
  - Cold
- Slips and falls

10. Main Causes of Back Pain

- Acute or cumulative events
- Physical workload
- Postural stress
- Unaccustomed work

11. How to prevent injuries to the muscles and the back

Proper posture and movements
Body mechanics
Equipment and assistive devices

12. Summary

- Keep the object close to your body, always in front; don't twist.
- For lifting, keep the trunk up and the knees bent.
- Minimize the distance through which the person must be moved.
- All movement should be smooth and planned.
  - Jerking and acceleration should be minimized

Topic Outline: Video Training

1. **Proper Body Mechanics**

    1.1. Bent your knees

    1.2. Keep back straight

    1.3. Think twice

2. **Patient Handling Demonstrations**

    2.1. Moving Patient in Bed

        2.1.1. Lift up in Bed

    2.2. Patient Transfer Techniques

        2.2.1. Wheelchair to bed

        2.2.2. Bed to wheelchair

        2.2.3. Wheelchair to toilet

        2.2.4. Toilet to wheelchair

APPENDIX B

I. Procedure for wheelchair to bed transfer using one person assistance.

STEPS
1. Explain to the patient the steps involved in the move. 2. Adjust bed height at lowest setting if adjustable. 3. Position wheelchair close and parallel to bed. 4. Lock wheelchair and remove armrest nearest the bed if possible. 5. Swing away both legs rests. 6. Slide patient to front of wheelchair, by pulling on knees and having them lean backward. 7. Stand the patient up a. Put arms around patient's chest and clasp hands behind patient's back. b. Bend knees and keep back straight. c. Place leg farthest to wheelchair between your legs. d. Use body weight to lift patient by leaning back. 8. Pivot toward bed a. Keep back straight. b. Bend your knees. c. Pivot patient toward bed keeping hands clasp around the patient. 9. Assist patient into sitting position in the edge of the bed. a. Bend patient toward assistant keeping assistant' knees bend. b. Lower patient into the edge of the bed. c. Slide patient into center of the bed keeping the same position. 11. Assist patient in laying down a. Place one arm behind patient's neck with hand supporting shoulder blade b. Place other hand under knees c. Swing legs up onto bed while gently lowering patient on their side. d. Turn patient onto back. 12. Adjust wheelchair's features a. Replace armrest. b. Raise patient's legs. c. Swing leg rest into position.

II. Procedure for wheelchair to bed transfer using two person assistance.

STEPS
1. Explain to the patient the steps involved in the move.
2. Adjust bed height at lowest setting if adjustable.
3. Position wheelchair close and parallel to bed.
4. Lock wheelchair
5. Remove wheelchair armrest nearest the bed if possible.
6. Swing away both legs rests.
7. Lift patient from wheelchair to bed
a. Person 1 approach patient from behind the wheelchair.
b. Person 1 place knee nearest bed on the bed.
c. Person 1 put arms around patient's chest.
d. Person 1 grasps patient's wrists.
e. Person 2 stands at patient's feet.
f. Person 2 raises patient's legs to a straight position.
g. Person 2 place arms under patient's knees
h. Keep back straight.
i. Bend your knees.
j. Person 1 and Person 2 simultaneously lift patient.
k. Lower patient into the edge of the bed.
l. Slide patient into center of the bed keeping the same position.
8. Assist patient in laying down
a. Place one arm behind patient's neck with hand supporting shoulder blade.
b. Place other hand under knees
c. Turn patient onto back.
9. Adjust wheelchair's features
a. Replace armrest.
b. Raise patient's legs.
c. Swing leg rest into position.

III. Procedure for moving a patient up in bed using the one person assistance.

STEPS

1. Explain to the patient the steps involved in the move.
2. Adjust bed height below your waist if adjustable.
3. Adjust bed into flat position.
4. Assume position to move patient.
    a. Stand facing the head of the bed.
    b. Point feet in the direction patient is to be moved.
    c. Place one foot forward.
    d. Flex knees.
5. Move patient up in bed.
    a. Place one arm under shoulders.
    b. Place the other arm under hips.
    c. Ask patient to push with feet and elbows if able.
    d. Slide patient toward head of bed.

IV. Procedure for moving a patient up in bed using the two person assistance.

STEPS
1. Explain to the patient the steps involved in the move. 2. Adjust bed height below your waist if adjustable. 3. Adjust bed into flat position. 4. Assume position to move patient. a. Stand facing the head of the bed. b. Point feet in the direction patient is to be moved. c. Place one foot forward. d. Flex knees. 5. Move patient up in bed using a draw sheet a. Put the head of the bed down. b. Adjust top of the bed to waist or hip level of the shorter person. c. Person 1 and 2 simultaneously grasp the draw sheet, pointing one foot in the direction the patient is to be moved. d. Lean in the direction of the move, using your legs and body weight. e. On the count of three, lift and pull the patient up. f. Repeat step 5 if required.

APPENDIX C

HEALTH AND HISTORY QUESTIONNAIRE

NAME:____

ADDRESS:____

TELEPHONE NUMBER:________________________ E-MAIL:_____________________

I. RESPONDENT INFORMATION

1. What is your gender? ❑ Male ❑ Female
2. What is your age? _______

II. MEDICAL HISTORY: BACK OR SHOULDER PAIN

During the **last month**,

3. Have you had back or shoulder pain lasting more than 30 minutes? ❑ Yes ❑ No
4. Have you had any severe back or shoulder pain (no matter how brief) which made you stop what you were doing? ❑ Yes ❑ No
5. Have you taken medication for back or shoulder discomfort? ❑ Yes ❑ No

During the **last year**,

6. Have you suffered from any back or shoulder problems? ❑ Yes ❑ No
7. Have you ever had surgery because of back or shoulder problems? ❑ Yes ❑ No
8. Have you been hospitalized because of back or shoulder problems? ❑ Yes ❑ No
9. Have you had any joint dislocations, broken bones, or other physical injuries? ❑ Yes ❑ No
10. Have you ever suffered from any musculoskeletal injuries? ❑ Yes ❑ No
11. Specify if any:_____________________________________

III. KNOWLEDGE ON TRAINING, ERGONOMICS, AND BIOMECHANICS

12. Have you ever received training in how to transfer or move patients?
    ❑ Yes ❑ No
13. Have you ever had experience (more than 3 months) with lifting or handling heavy objects or materials?
    ❑ Yes ❑ No
14. Have you ever received training or instructions on proper lifting techniques?
    ❑ Yes ❑ No
15. Do you have any knowledge of or experience with ergonomics?
    ❑ Yes ❑ No
16. Do you have any knowledge of or experience with biomechanics?
    ❑ Yes ❑ No
17. Do you have any knowledge of or experience with back injury prevention methods?
    ❑ Yes ❑ No

Signature and Date____

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants of Investigative Projects

Investigator(s): Noris Torres and Dr. Maury Nussbaum, Faculty Advisor

I. Purpose of this research

The purpose of this research is to examine activities performed by nurses such as moving, lifting, and handling patients. The study will contribute to the further understanding of how nurses perform these tasks and how forces are distributed over the body. Twenty-four subjects will participate in the experiment.

II. Procedures

The experiment will be divided in three sessions and it will be conducted in the Industrial Ergonomics Laboratory (Whittemore Hall) at the Virginia Polytechnic Institute and State University. In each session, you will be observed while carrying out eight different patient handling tasks and will require approximately 2 hours. After reading this informed consent, if you decide to participate in the experiment you will be asked to sign the form and to fill out a brief questionnaire.

In the first session, you will be able to perform the handling tasks before data is collected to allow you to get familiarized with the tasks. You will be allowed to have rest breaks of at least 1 minute between each transfer or as much as necessary. Each transfer task will be videotaped. Immediately after each patient transfer, you will be asked to rate your perceived level of exertion using a written scale, and this will be explained to you before starting the experiment. The second session will consist of the same procedures (performing eight patient handling tasks) but it will be held within 72 hours after the first session is completed. The third session will be conducted five weeks after completing the second session. As you did in sessions one and two, you will be videotaped and asked to rate your perception of the level of exertion.

III. Risks

The primary risk involved with performing these manual exertions is musculoskeletal strain or sprain. The tasks to be performed in the experiment are comparable to real nursing tasks. The largest physical loads are expected at the shoulders and low back, and it is in these body parts that the likelihood of pain exists. The most probable negative outcome is localized muscle soars, probably with a 1 to 2 day delayed onset. More serious, though also much less likely is the risk of an acute back or shoulder strain. We expect that these outcomes are unlikely. However, it is important that you take as much rest as you feel is necessary. Further, you should report to the experimenter any pain or discomfort that you experience during the experiment.

IV. Benefits of this project

There are no direct benefits to you from this research, other than payment. No promise or guarantee of any benefits to you (other than payment) has been made to encourage you to participate in this experiment. However, you may find the experiment interesting.

V. Extent of Anonymity and Confidentiality

The information collected in this research as well as the results will be treated as confidential. At no time will the researchers release results that can identify a particular subject (other than using a coding scheme as noted below) of the study to anyone other than individuals working on the project without your written consent. Anonymity will be strictly enforced. After you have participated, your names will be separated from the data. A coding scheme will be employed to identify the data by a subject number only (e.g., Subject #1).

While performing the patient handling tasks, your movements will be videotaped. The videotapes recorded will be securely stored in a filing cabinet in the Industrial Ergonomics Laboratory. Only the investigator, Noris Torres, as well as the Faculty advisor, Dr. Maury Nussbaum, will have access to the videotapes. The videotapes will be erased shortly after completion of the research project.

VI. Compensation

You will be paid $5.00 per hour for the time you actually spend in the experiment. Payment will be made immediately after you have finished each session.

VII. Freedom to Withdraw

You are free to withdraw from this study at any time without penalty. If you chose to withdraw, you will be compensated for the portion of the time of the study in which you participated.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University, by the Department of Industrial and Systems Engineering.

IX. Subject's Responsibilities

I voluntarily agree to participate in this study and understand I can quit at any time.

X. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

______________________________ __________________________

Signature Date

Should I have any questions about this research or its conducts, I may contact:

Noris Torres (540) 552-3969
Investigator

Dr. Maury Nussbaum (540) 231-6053
Faculty Advisor

H.T. Hurd (540) 231-5281
Chair, Institutional Review Board, Research Division

APPENDIX D

I. BORG'S CR-10 RATING OF PERCEIVED EXERTION SCALE

(From: Borg, 1982)

Instructions

Throughout this session you will be performing several patient handling tasks. Immediately after each patient transfer you will be asked for a rating. You will use the rating scale shown below to describe how you feel your whole body, shoulders, and lower back was stressed or how difficult you perceived the patient handling task to be.

The scale goes from 0 to 10 where, 0 stands for "Nothing at all" and 10 for "Extremely strong". "Nothing at all" means that your body, shoulders and lower back feel as you have done no work at all. "Extremely strong" means that you feel your body have done the heaviest physical work. However, if you feel that the work done was more than "Extremely strong", you can rate your work as "Maximal" represented by a dot. You are permitted to use decimals (i.e. 1.5, 6.3) and also go beyond 10 (i.e. 12, 15).

When using the rating scale:

1. Always start by looking at the words to the right of the numbers and pick the word that describes the workload.
2. Choose a number that goes with the word you picked.
3. Answer verbally by saying the number you picked or pointing out to the scale value.

Be as honest as possible and try not to overestimate or underestimate the numbers.

Borg's Category Rating Scale

0	Nothing at all	
0.5	Extremely weak	(just noticeable)
1	Very weak	
2	Weak	(light)
3	Moderate	
4	Somewhat strong	
5	Strong	(heavy)
6		
7	Very strong	
8		
9		
10	Extremely strong	(almost max.)
•	Maximal	

VITA

NORIS TORRES (*Effects of Training in Modifying Work Methods and Behaviors during common Patient Handling Activities*) was born on November 26, 1973, in Ponce, Puerto Rico. She received her Bachelor of Science in Industrial Engineering from the University of Puerto Rico at Mayagüez in May 1996.

Through her college years she worked in several projects regarding cost and process analysis, facilities layout, time studies as well as ergonomic job analysis at several companies and manufacturing plants in Puerto Rico. These experiences led her to the understanding that most of the actual processes could be improved further more if there were to be combined/assessed continuously with the proper human factors / ergonomics principles.

In August 1996, she came to the Virginia Polytechnic Institute and State University to pursue a Master of Science degree on Human Factors Engineering and Ergonomics awarded with the Scholarship of the Economic Development of Puerto Rico. She is a current member of the Institute of Industrial Engineers, Human Factors and Ergonomics Society, Tau Beta Pi and Alpha Pi Mu.