Investigating the Effectiveness of Posture Coaching and Feedback during Patient Handling Activities in a Student Nursing Population

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Abstract

The daily routine of nurses and other caregivers is physically demanding and in turn, the profession is at a high risk of developing musculoskeletal injuries and/or disorders (MSDs). This thesis has two sections. The purpose of the first section (the pilot study) was to perform a preliminary biomechanical analysis of trunk kinematics and muscle activity during common patient handling activities to aid in the determination of coaching for a follow up feedback study. The second section determined the effects of a feedback intervention (combined verbal and auditory) on trunk kinematics during simulated patient handling tasks in a student nursing population. Nine student nurses participated. Participants performed three commonly used patient-handling tasks before, during and after an intervention session. The largest reductions in trunk angle, acceleration and velocity were found in the most complex transfer, bed-to-chair. The feedback session improved peak kinematics, and this could suggest that the feedback intervention may help reduce the risk of low back pain associated with patient handling. There is a continuing need to ensure that caregivers are properly trained to protect themselves and their patients during patient handling tasks when assistive devices are not available such as in transferring a patient from the bed to the wheelchair.

Keywords: musculoskeletal disorders; feedback; student nurse; patient handling; low back pain

Statement of Originality

I, Ramez Doss, hereby declare that this thesis is, to the best of my knowledge, original, except as acknowledged in the text. I further declare that the material contained in this thesis has not been previously submitted, either in whole or in part, for a degree at this or any other university.

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List of Abbreviations Used

BS	Back School
CORE	Coordination of primary healthcare
EMG	Electromyography
KP	Knowledge of Performance
KR	Knowledge of Results
LBD	Low Back Disorders
LBP	Low Back Pain
MSD	Musculoskeletal Disorders
MVC	Maximal Voluntary Contractions
NIOSH	National Institute for Occupational Safety and Health
NSWHN	National Survey of the Work and Health of Nurses
OHSAH	Occupational Health and Safety Agency for Healthcare
RMS	Root Mean Square
RPE	Rate Perceived Exertion
UOIT	University of Ontario Institute of Technology
WSIB	Worker Safety and Insurance Board

Chapter 1: Introduction

1.1. Overview

Caregivers play an important role within the health care system as they are instrumental in providing and assisting in the provision of optimal health and quality of life for patients. Caregiver is a broad term that can be narrowed to a family member or paid helper who regularly looks after a child, the elderly, the sick or disabled. Nurses and other caregivers frequently care for the sick and injured in hospitals and other health care facilities by assisting patients to mobilise, transfer between positions and perform other activities of daily living such as toileting and showering (Dawson et al., 2007). As such, the daily routine of nurses is physically demanding and in turn, the profession is at a high risk of developing musculoskeletal injuries and disorders (MSD) (Tullar et al., 2010). Compared to other professions, nurses have an increased risk of back pain (Jaromi et al., 2012; Seidler et al., 2009) and six times higher prevalence of back injury (Dawson et al., 2007). In a survey of Canadian nurses by Tullar et al. (2010), 37% said that in the past 12 months, they experienced pain serious enough to prevent them from carrying out normal daily activities. More worryingly, back pain has a major impact on the efficiency of the nursing workforce; one of the primary reasons why nurses leave their profession (Dawson et al., 2007).

Several studies and reports suggest that caregivers are faced with a number of occupational risks and health impacts not only related to ergonomic issues but also psychological distress, patient violence, infectious diseases and fatigue (Health Canada [HC], 2004; Rogers, Buckheit & Ostendorf, 2013; Han, Trinkoff & Geiger-Brown, 2014). Hinton (2010) indicates that psychological distress can be a consequence of lower staffing numbers, high workload and time pressure. Furthermore, a study by Kim et al. (2013) suggests that work-related psychosocial factors play an important role towards the association of staffing level to low back pain (LBP) in hospital caregivers. In addition, psychological distress and adverse working conditions, such as extended hours, can produce fatigue which further exacerbates risk of occupational injury (Han et al., 2014). According to Rogers et al. (2013), an additional risk for healthcare workers includes aging changes, particularly beginning at the age of 40. These changes involve less muscle mass, reduced muscle endurance and intervertebral disc strength, consequently leading to less strength and mobility (Rogers et al., 2013). Despite that the aforementioned risks account for very minimal time-loss claims (HC, 2004), it is still important to look at the number of other risk factors that pertain to nurses and other caregivers for further research in these areas. Musculoskeletal injuries from physically demanding work account for the greatest number of time-loss injuries among healthcare workers (HC, 2004). This thesis will discuss this immense issue, including effective strategies to improve workplace health in this regard.

Evidence-based safe patient handling techniques have become one of the main topics of discussion in the nursing profession to increase patient safety and minimize the risk of injuries among caregivers. There are multiple factors that can deteriorate the effectiveness and efficiency of patient transfers. Obesity, one of the main concerns in North America, results in a substantial increase in the physical workload that caregivers are responsible for handling and transferring (Vieira, 2007). Even though bariatric patients (BMI >40) can place a significant strain on caregivers, Nelson et al. (2003) argues that patient handling techniques can simply be redesigned to improve both caregiver and patient safety. For example, Nelson et al. (2003) suggests: using friction reducing devices for lateral transfers; making bed adjustments for height; and using ceiling-mounted patient lifts. However, both Brown (2003) and Hinton (2010) suggests that although modern mechanical lifting equipment can be beneficial for the well-being of caregivers and patients, a comprehensive safe patient handling program along with policies and procedures that clearly mandate a new method of handling patients is required to ensure success in its application. Without such a program, there is no guarantee that the newly implemented policy and procedure will be instilled and utilized on a day-to-day basis in the workplace (Brown, 2003).

Research has also shown that cumulative strain and damage to the spine occurs when lifting weights greater than only 35 pounds (Rogers et al., 2013). The theory behind cumulative loading is explained in a study by Marras et al. (2014) as repetitive loading of tissues that can weaken tolerance and in turn decrease the ability of the care giver to withstand force over time. However, the adaptation of human tissues has become more resilient and load demands depends heavily on adequate recovery time (Marras et al., 2014). Moreover, it has been suggested that the lack of appropriate rest times can reduce the delivery of nutrients to biological tissues and can increase the risk of injury in turn causing spine damage at submaximal levels of force application (Marras et al., 2014). Holmes et al. (2010) found that patient care activities (i.e. bathing, feeding and dressing) produced large cumulative spine loads when examined in the workplace. Furthermore, Marras et al. (2014) suggests it is crucial to merely understand the number of repetitions, under a variety of loading levels, which will weaken a structure to the point of failure or fatigue for future studies. Mehta, Lavender & Jagacinski (2014) assess the limitations of each individual using the concept that decreased oxygenation levels to a particular muscle results in its fatigue. This work showed that behavioural adaptations (i.e. increase in the amount of forward and lateral bending velocity) of the spine made by each individual performing asymmetric repetitive lifting activities may increase risk of injury.

Substantial costs are associated with LBP (Tullar et al., 2010). These costs envelope a wide range of areas including: medical, rehabilitative and surgical interventions; lost productivity and income from work; as well as the costs of disabling pain and limited daily function (Tullar et al., 2010). Overexertion injuries as a result of lifting, carrying, pulling or pushing, ranked highest in direct costs to businesses in the United States at $13.6 billion dollars whereas indirect costs associated with back injuries were estimated to total $7.4 billion dollars (Rogers et al., 2013). Insurance coverage for back injury in nurses comprises 56.4% of all compensatory costs and 55.1% of all medical costs (Dawson et al., 2007). The issue of back pain in nurses goes far beyond North America and is thus a major concern worldwide. The economic cost of back pain in The Netherlands is estimated to be 1.7% of the gross national product and 0.9% of the total cost of health care (Heneweer et al., 2011). Recent studies conducted in Thailand, United Kingdom, Germany, Tunisia, Brazil, Denmark and Australia demonstrate the global need to further investigate back pain in the nursing profession, especially in a time of fiscal restraint (Kaewthummanukul et al., 2005; Smedley et al., 2003; Seidler et al., 2009; Bejia et al., 2005; Alexandre et al., 2001; Pedersen et al., 2004; Dawson et al., 2007).

Despite all of the efforts made to support nurses and other caregivers, moving an individual can be a high-risk activity and safety is paramount regardless of the setting. For years, a range of intervention strategies have been used in the attempt to reduce this global issue (Hignett, 2003). Even today, researchers and other professional bodies are continuing to produce guidance on the appropriate biomechanics of patient handling (Marras et al., 2014). Mechanical patient handling and transfer devices have been a major focus of injury prevention efforts in the healthcare setting (Nelson & Baptiste, 2006). Numerous facilities have implemented “zero-lift” policies, banning manual lifting (Dawson et al., 2007). Although these devices have been found to reduce injury risk (Tullar et al., 2010; Dawson et al., 2007), nurses often continue to perform physical tasks manually as lifting devices take large amounts of time to use (Keir & MacDonnell, 2003), in turn decreasing productivity. Other intervention strategies include but are certainly not limited to: risk assessment, although not an intervention in itself but has an important role to play as a vital component of an intervention (Hoy et al., 2014); education and training (Brown, 2003; Hinton, 2010); equipment evaluation/design (Smith, Nave & Herljac, 2011; Daniell, Merrett & Paul, 2013); work environment redesign (Nelson et al., 2003); review and change of policies and procedures (Dawson et al., 2007); physical fitness training (Pedersen et al., 2004); and feedback (Huang et al., 2012a).

Unfortunately, despite the numerous intervention strategies available, the systematic review by Rogers et al. (2013) shows that some of these approaches are not effective and that occupational injury continues to be a persistent and costly problem for nursing staff and caregivers. The only solution, according to Hignet (2003), consists of a multifaceted intervention that is based on a risk assessment program. Moreover, if the approach is largely based on technique training, it is unlikely to be successful (Hignet, 2003). Although Hignet (2003) did not define technique training, the articles cited in its systematic review on the topic comprises of educating nursing personnel (in a hospital setting) on the correct form for specific patient transfers while assessing merely the prevalence of musculoskeletal symptoms during the study period (Enkvist et al., 2001; Lagerstrom & Hagberg, 1997; Nussbaum & Torres, 2000). However, McGill, Cannon & Andersen (2014) state that there are no studies evaluating the ability of technique training, also known as feedback or coaching, to influence muscle activity and/or spine load. Understanding this concept is crucial not only to provide insight on appropriate spine health but also to deliver the correct feedback that will potentially be instilled in caregivers in the clinical setting.

The transfer of research evidence into practice can be a challenging obstacle even when the advantages are strong. Despite the lack of success in technique training in most of the articles mentioned in the systematic review by Hignet (2003), particularly for nursing staff and other caregivers, giving the correct feedback to the precise demographic in the right setting is important to accurately be determined. Mitchell et al. (2009) suggested that because LBP remains prevalent before commencing employment, nursing students should be the target of preventative interventions to ensure the effectiveness of its implementation. One way to ensure the application of research evidence into practice, Huang et al. (2012a) proposed to construct a training system in nursing faculties in which nursing students can train themselves on their own at any time. Moreover, this training system is recommended for faculties in various institutions and consists of automatic measurements and evaluations on the performance of nursing students doing varying lifting tasks (Huang et al., 2012a). As a result of these analyses, this training system will also provide instructions that can potentially improve these tasks (Huang et al., 2012a). Although nursing students seem to be the correct demographic to concentrate on in the possible elimination of lifting-related musculoskeletal injuries, the proposal by Huang et al. (2012a) seems to be quite complex and costly.

There are a few issues related to nursing students and their experiences with lifting tasks (Swain, Pufahl & Williamson, 2002). Swain and colleagues found that the transfer of retained knowledge of the correct patient handling techniques into practice, by more than half of the students, was inaccurate, presumably deviating from what was taught in training sessions (Swain et al, 2002). However, despite the complexity of the idea previously mentioned, Huang et al.

(2012b) insists that sufficient training with some type of feedback is important for nursing students to learn and actually utilize the techniques. Another issue presented in the study by Smith et al. (2002), involves the fact that student nurses were more likely not to apply the correct patient handling techniques if they were taught in a lab. Moreover, it has been suggested that nursing knowledge acquired in an authentic clinical context has a better chance of being activated when needed (Smith et al., 2002). Nevertheless, to ensure its application even after being taught in a clinical setting, feedback on the correct patient handling techniques have been found to be an effective method for increasing preventive work for nurses and other caregivers (McGill et al., 2014). Even nearly two to three decades ago, researchers have found that feedback, such as instruction, audiovisual presentations and simulated practice, provides caregivers the awareness and knowledge of the potential injury risks needed to sustain the prevention of musculoskeletal injuries in their workplace (Menckel et al., 1996; Alavosius & Sulzer-Azaroff, 1986). However, because one of the more recent studies have found that there is in fact a lack of technique coaching articles for caregivers (McGill et al., 2014), it is imperative to assess feedback given to the performance of patient handling techniques, particularly by nursing students, in the hope to eliminate musculoskeletal injuries in the clinical environment.

1.2. Research Question

Can a simulation-based educational practice and feedback session in a student-nursing population improve lifting techniques?

1.3. Purpose

A small-scale pilot study (Chapter 3) was conducted to establish a framework of not only the most physically demanding patient handling tasks, but the tasks that may be best suited to feedback training. The purpose of this work was to: 1) determine the level of complexity of each task and the different aspects of coaching/feedback that should be identified and 2) use electromyography (EMG) to determine the musculature that should be targeted when coaching participants in the full-scale research project (Chapter 4).

Study 2 provided simulation based educational practice and feedback to a student nursing population. The long-term goal of this work was to develop learning and skills in the student population, such that optimal handling techniques are implemented at the source. The purpose of this work was to investigate the effectiveness of feedback and posture coaching to improve patient handling techniques (trunk posture) in a student nurse population. The prevalence of injury in nurses remains high despite the vast research done on this topic. Most recommendations to reduce injury risk during patient handling has focused on mechanical lifts (Tullar et al., 2010; Dawson et al., 2007). However, the poor ratio of nurses per patient in many hospitals appears to have a negative influence on mechanical loading device use. A recent article suggested that lifting devices take significantly more time than manual patient transfers (Koppelaar et al., 2012); an important factor towards the disuse of assistive lifts. In order to effectively implement proper lifting techniques before the incidence of chronic LBP, Mitchell et al. (2009) suggested that, because this MSD remains prevalent before commencing employment, nursing students should be the target of preventative interventions. Moreover, it is suggested that experienced nurses develop lifting techniques over time (Holmes et al., 2010), it was proposed that feedback and training as an ergonomic aid would assist in the long-term prevention of musculoskeletal injuries in student nurses. In order to effectively demonstrate the appropriate lifting techniques, student nurses were the primary target for this study, with the hope that these techniques would be instilled in the clinical environment.

1.4. Hypothesis

A feedback and posture coaching intervention will aid student nurses in improving lifting techniques of their patients. Trunk posture will be improved, via reduced trunk flexion, lateral bend and twisting post intervention. Training will not only improve kinematics but also result in more efficient movements. In addition, nursing student participants will perform patient transfers more efficiently by reducing the total time for task complexion, yet also reducing the velocity and acceleration of their trunk movements as a result of the feedback session.

Chapter 2: Literature Review

2.1. Global Prevalence of Back Pain

LBP is a very common health problem worldwide and a major cause of disability consequently affecting performance at work and general well-being. The global burden of LBP is estimated to cause more global disability than any other condition (Storheim & Zwart, 2014; Tate, Yassi & Cooper, 1999; Hoy et al., 2014; Mehrdad et al., 2016). In a recent systematic review by Hoy et al. (2014), it was found that out of 291 conditions, LBP ranked highest in terms of disability and sixth in terms of overall burden. Moreover, the results from this work show that the prevalence and burden from LBP is substantial throughout the world. In fact, the average prevalence of back pain in Western Europe was 15% and it was 14.8% in the North African/Middle Eastern region (Hoy et al., 2014). The lowest rates were found in the Caribbean at 6.5% and in Central Latin America at 6.6% (Hoy et al., 2014). In high income areas, particularly areas of North America, LBP prevalence was 7.7% (Hoy et al., 2014). Reasons for this difference in less developed areas may include decreased knowledge of risk factors, decreased levels of active lifestyle, obesity and a decreased socioeconomic status (Hoy et al., 2014). Irrespective of the economical status of a particular region, Mehrdad et al. (2016) indicated that LBP remains one of the most prevalent occupational disorders across both developed and developing countries.

Despite the vast amount of interventions used to prevent LBP from occurring (Hinton, 2010; Smith et al., 2011; Daniell et al., 2013; Nelson et al., 2003; Pedereson et al., 2004; Huang et al., 2012a), the systematic review by Rogers et al. (2013) shows that some of these approaches are not effective and that occupational injury continues to be a persistent and costly problem for nursing staff and caregivers. These costs envelope a wide range of areas including: medical, rehabilitative and surgical interventions; lost productivity and income from work; as well as the costs of disabling pain and limited daily function (Tullar et al., 2010). Overexertion injuries as a result of lifting, carrying, pulling or pushing, ranked highest in direct costs to businesses in the United States at $13.6 billion dollars whereas indirect costs associated with back injuries were estimated to total $7.4 billion dollars (Rogers et al., 2013). Insurance coverage for back injury in nurses comprises 56.4% of all compensatory costs and 55.1% of all medical costs (Dawson et al., 2007).

LBP continues and seems to actually increase in occurrence even after several decades of research on the topic. In 1981, of the injuries reported by health care workers, 62% were characterized as overexertion injuries (Alavosius & Sulzer-Azaroff, 1986), presumably to the lower back. Village et al. (2005) states that average injury rates among health care workers, particularly to the low back, increased from 9.6 to 10.5 claims per 100 person years for the period of 1995-1999. Freburger et al. (2009) show that the prevalence of LBP more than doubled between 1992 and 2006 in North Carolina. According to Gagnon (2003), even though a large consensus of opinions exists for the prevention of LBP, the application of intervention strategies does not appear simple. Storheim & Zwart (2014) discuss that most articles reveal that existing treatments for LBP have only small effects at best, and that examples such as weight loss and exercise will assist in the prevention of this vast disorder. Furthermore, Hoy et al. (2014) also suggests that with aging and growing populations, LBP can be an enormous burden even in developing countries which is predicted to grow substantially over coming decades.

According to Freburger et al. (2009), in order to fully understand the impact of LBP in a population, other factors, such as socioeconomic status, career burden, and general well-being should be acknowledged. Similarly, Hoy et al. (2014) suggests for further research to be done to increase the understanding of the predictors and clinical course of LBP across different settings and also, to include the ways in which this disorder can be prevented and better managed. However, in another study, Village et al. (2005) suggests to investigate the use of full shift electromyography measures as an indicator of peak and cumulative workload. Moreover, Village et al. (2005) raised that the primary issue to musculoskeletal injuries results from low staffing ratios which will in turn deteriorate resident outcomes, decrease job satisfaction and decrease retention rates. The present study suggests that it is the health care workers who perform tasks in tight spaces who are more likely to have awkward bending and lifting postures and therefore more peak and cumulative loading of the spine and even shoulders. Specific environmental factors that can contribute to the increase in load on the spine include the age and design of the facility, in particular the size of patients' rooms and bathrooms and length of hallways (Village et al., 2005). In some facilities, bathrooms are actually too small for mechanical lifting equipment or two-person lifting which results in assistance provided by single person manual lifts (Village et al., 2005). In addition, Gagnon (2003) indicates that training protocols should be based on workers' knowledge about their jobs as these workers rarely use the handling techniques actually taught in programs and actually question the appropriateness of the techniques. Training based on the observation of the strategies of workers appears promising and inspired this study.

Tullar et al. (2010) discuss their findings on whether occupational safety and health interventions in health care settings have an effect on musculoskeletal health status. Coinciding with other systematic reviews (Choi et al., 2010; Freburger et al., 2009), the authors show that, although exercise provides positive health benefits, training alone is not effective as a pre- or a post-treatment program for LBP. Given the moderate level of evidence found, it is suggested that multi-component patient handling interventions can benefit in the prevention of LBP in nursing personnel (Tullar et al., 2010). Tullar et al. (2010) suggest that a multi-component patient handling intervention includes a policy that defines an organizational commitment in reducing injuries during patient handling, the purchase of mechanical lifts or other assistive devices, and a broad-based ergonomics training program that includes how to effectively and safely perform patient handling techniques.

2.2. Mechanical Low Back Pain

Back pain is considered to be one of the most common complaints as well as the costliest, incurring substantial direct medical costs and indirect societal costs that involve missed work, disability and compensation claims of workers (Chien & Bajwa, 2008). Back injuries are known as a subgroup of MSD, defined as soft-tissue injuries or disorders of one or all of the following: muscles, nerves, tendons, joints, cartilage, or spinal discs (Nielsen, Sigurdsson & Austin, 2009). According to Heyward (2006), most low back problems are a consequence of muscular weakness or imbalance throughout the vertebral column caused by a lack of physical activity. If the musculature around the spine is weak, there will be minimal support for the structure in proper alignment and in turn cause poor posture (Heyward, 2006). Furthermore, excessive weight, poor flexibility and improper lifting habits are a few of the more common modifiable risks towards the contribution of LBP (Heyward, 2006).

The majority of back pain episodes are in fact mechanical (97%), which are assumed to arise from an injury to an area within the vertebral column (Chien & Bajwa, 2008). However, LBP is considered multifactorial and thus other factors such as psychological and social components play a role in the development of this disorder (Frymoyer & Pope, 1978). Mechanical LBP is defined as any type of pain in the back caused by either strain on the muscles surrounding the vertebral column and/or abnormal stress (Chien & Bajwa, 2008). The ligaments, muscles and facet joints of the vertebral column can sometimes become irritated and inflamed for a number of reasons (Chien & Bajwa, 2008), including but not limited to the amount of weight lifted, task asymmetry, lift rate, load position and reach distances (Jang et al., 2007). According to Stevens et al. (2013), injuries particularly to the musculoskeletal system occurs when the load on the tissue exceeds the tissue tolerance. Occupational workers can increase the prevalence of LBP with an increased load or a decrease in tolerance (Stevens et al., 2013). On a daily and continual basis, the lumbar spine is subjected to a multitude of loading combinations including compressive forces, torsional moments and shear forces (Gallagher & Marras, 2012). It can therefore be assumed that amongst the various risk factors pertaining to LBP, investigating the different loading combinations can be beneficial for the cessation of this disorder particularly in the clinical setting.

High incidences of LBP have been found in occupations where workers sit for prolonged periods, where they work in an unnatural posture, with sudden and unexpected motions and with the involvement of dynamic motion in multiple planes (Magora, 1972). Some of the varying high-risk occupations of LBP include nursing aides, practical nurses, truck drivers, garbage collectors, warehouse workers, lumber workers and construction laborers (Mehrdad et al., 2016). However, despite the enormity of the issue present in multiple occupations, Heyward (2006) explains that because the origin of LBP is often functional rather than structural, an exercise intervention designed to develop strength and flexibility in the muscles in question can correct the problem. Moreover, individuals who maintain an active lifestyle develop more bone, ligament and tendon strength and are therefore less likely to strain and potentially develop connective tissue tears (Heyward, 2006). Research has also shown that cumulative strain and damage to the spine occurs when lifting weights greater than only 35 pounds (Rogers et al., 2013). Therefore, an exercise intervention should aid in the musculature ability to sustain the weight and also increase the knowledge of proper lifting techniques. Ergonomic risk factors for other MSDs have been found to be lifting above shoulder level or below knee height (Geiger, 2013). However, specific lifting patterns that cause injury in biological tissues may be a consequence of either a few repetitions of a large load or numerous repetitions of a small load (i.e. cumulative loading) (Davis & Jorgensen, 2005). This type of repeated loading in the workplace is one of the many known risks to increase the likelihood of achieving some type of MSD (Jang et al., 2007).

Alongside the availability of advanced diagnostic equipment (Chien & Bajwa, 2008) as well as the ability to accurately determine the source of pain (Davis & Jorgensen, 2005), the concept of neuromuscular control for the stability of the spine can significantly aid in the etiology and prevention of LBP (Granata & Orishimo, 2001) in varying occupations. On a daily and continual basis, the lumbar spine is subjected to a multitude of loading combinations including compressive forces, torsional forces and shear forces (Gallagher & Marras, 2012). The term compressive force is defined as a type force acting down the long axis of the spine (Gallagher & Marras, 2012). A few authors have suggested spinal compressive loads to be below 3400 N as indicated by the National Institute for Occupational Safety and Health (NIOSH) (Jang et al., 2007; Zhuang et al., 1999; Granata & Orishimo, 2001; Gallagher & Marras, 2012). If the applied load exceeds the failure tolerance or strength of the tissue, injury can occur (McGill, 1996). However, high incidences and risks of injury even at low spinal loads have been found to exist (Granata & Orishimo, 2001). Furthermore, when muscles of the surrounding area in question become fatigued and decrease their supportive nature, the lumbar spine becomes unstable and may suffer strain injuries at compressive loads as low as 88 N (Granata &

Orishimo, 2001). In addition, psychological distress and adverse working conditions, such as extended hours, can produce fatigue which further exacerbates risk of occupational injury (Han et al., 2014). Torsional forces, on the other hand, act as a rotational force around the long axis of the spine (Gallagher & Marras, 2012). Shear forces are defined as two forces acting parallel to each other but in opposing directions (i.e. anterior and posterior) (Gallagher & Maras, 2012). Moreover, occupational tasks such as pushing and pulling are found to be prime examples of shear forces (Gallagher & Marras, 2012). Although compressive forces possess the largest magnitude by far compared to the other types of forces distressing the spine (Gallagher & Marras, 2012), shear forces can also be substantial in part due to the low force needed to injure the weaker spinal structures loaded in shear (Hoozemans et al., 2008).

It is important to note however, that back pain is a symptom associated with various medical conditions, not only mechanical but also non-mechanical, even though these account for only 3% of all back pain cases (Chien & Bajwa, 2008). Chien & Bajwa (2008) explain that non-mechanical cases may include psychological, social and even rheumatologic, vascular, gastrointestinal, renal, infectious or oncologic causes (i.e. fever, unexplained weight loss and neurologic deficits). According to the authors of the present study, non-specific back pain or lumbar strain were diagnoses given to the majority of mechanical back pain issues in the past due to the lack of reliable diagnostic techniques. Today, with technological advances in research in anatomy and in the innervation of spinal structures, mechanical back pain is more appropriately defined in terms of the affected area of the spine (Chien & Bajwa, 2008). However, even with the available and advanced diagnostic equipment, 60% of LBP is idiopathic, meaning of unknown origin (Chien & Bajwa, 2008). The inability to determine the source of pain within the anatomical structure or structures makes it more challenging to identify factors causing the development of pain (Davis & Jorgensen, 2005). In addition, accurate diagnoses are paramount not only for the decision upon the appropriate course of treatment but also for the integration of more successful interventions and preventive techniques.

On that basis, several researchers continuously attempt to determine the types of injuries in the workplace, the various reasons as to why they occur as well as the most effective manner to attenuate or put an end to the risk of MSD (Christensen & Knardahl, 2011; Steffens et al., 2014; Hu et al., 2013; Marras et al., 2014). Many interesting perceptions particularly about mechanical LBP that can potentially aid in its prevention have been noted. Some researchers attempt to identify psychological factors (Christensen & Knardahl, 2011; Chany et al., 2005) and some physical factors (Jang et al., 2007; Katsuhira et al., 2008; Marras et al., 2008) as risks for occupational injuries. Christensen & Knardahl (2011), investigated a series of psychological, social and mechanical work factors as predictors of back pain severity. The authors recruited employees from 28 different organizations, representing a wide variety of occupations, to participate in the study. After they adjusted for some confounding variables, the authors found that the most consistent predictors of back pain were psychological and that mechanical factors were not statistically significant throughout the varying organizations. Specifically, the most robust predictors of back pain were found to be low job control (i.e. de-skilled labour and reduced decision making autonomy) and negatively appraised leadership styles (i.e. empowering leadership) (Christensen & Knardahl, 2011). Rather than looking at modifiable work exposures, Chany et al. (2005) indicated that LBP is a complex disorder that may be represented in part by personality-job mismatch, at the individual level. The present study suggested when the personality type of a worker is incorrectly matched with the job requirements, motor control learning can be affected which should otherwise increase as manual handling experience increases. Moreover, when a personality-job mismatch occurred, the resulting perceived stress manifested itself by increasing a phenomenon known as muscle co-activity which in turn intensified spinal loading during repetitive lifting (Chany et al., 2005). Muscle co-activation is a phenomenon known to activate two or more muscles simultaneously, typically on the same side of a joint (Chien & Bajwa, 2008). Granata & Orishimo (2001) explain that despite the known concept of muscle co-activation leading to better stability of the area in question, there is no evidence to suggest that muscle recruitment changes in response to spinal stability requirements, even through the use of muscle co-activation.

Christensen & Knardahl (2011) did not find mechanical factors as the most consistent predictor for LBP, however, their efforts were concentrated predominately on modifiable work exposures, particularly psychological and social factors. Even though the authors briefly touched on the topic of mechanical exposure factors, their method of analysis was based solely on questionnaires to determine the predictive level for back pain severity. In a systematic review by Tullar et al. (2010), it was noted that MSDs attained in the workplace are largely attributed to lifting activities. In fact, the magnitude of mechanical loading acting on the spine is found to be highly associated with LBP despite the varying risk factors associated with this disorder (Hu et al., 2013). In a study by Steffens et al. (2014), the predictors of LBP were investigated through a questionnaire given to experienced primary care clinicians. The authors designed a questionnaire to obtain information on the level of clinical experience of their participants. The subjects were also asked to nominate the five short- and five long-term exposure factors. Alternative to Christensen & Knardahl (2011), Steffens et al. (2014) found that biomechanical risk factors appear to be the most robust predictor of back pain according to the views of the primary care clinicians. Furthermore, the authors explain that other risk factors, such as psychological factors, were not commonly endorsed as predictors of back pain. The current study leads to conclude that a better understanding of the most robust predictor of back pain will help clinicians provide valid advice in the prevention of LBP as well as improve patient treatment.

According to the views of medical professionals, biomechanical risk factors, such as lifting, prolonged sitting and bending, are crucial factors to be considered for the onset of LBP (Steffens et al., 2014). Hu et al. (2013) investigated more closely one of these important biomechanical risk factors, specifically looking at the effects of stance width and foot posture on the lumbar muscle relaxation responses during trunk flexion. The authors gathered thirteen healthy male volunteers with no known upper/lower extremity disorders. EMG and a magnetic field-based motion tracking system were used to assess muscular activation as well as lumbar and trunk kinematics, respectively. During trunk bending, the increase in stance width and in eversion of the foot caused the lumbar extensor muscles to stop activity earlier (Hu et al., 2013). The authors stipulated that this information is beneficial in the clinical setting as it is suggested that it is important to maintain consistent stance posture particularly during the rehabilitation process of this disorder.

Physical loading on the spine, in particular high peak forces as well as adverse trunk postures and movements, has progressively increased the likelihood of attaining LBP in the workplace (Norman et al., 1998; Santaguida et al., 2005; Hoozemans et al., 2008; Katsuhira et al., 2008; Marras et al., 2009; Chany et al., 2005; Mehta et al., 2014). It is therefore crucial to demonstrate the adverse effects the different types of loads have on the spine in order to prevent occupational workers from developing a MSDs. Shahvarpour et al. (2014), suggested that unexpected loading of the spine is a major risk factor for LBP. The authors investigated preload, sudden load, initial trunk flexed posture, and initial abdominal antagonistic activity on trunk kinematics and back muscles reflex response in twelve asymptomatic male volunteers. The results in the present study assist in the identification of important mechanisms influencing equilibrium and stability of the human trunk. Shahvarpour et al. (2014) demonstrated that despite greater total load, both trunk velocity and trunk acceleration decreased with preload. However, in the initial flexed posture and to some extent when the abdominal muscles were pre-activated, the aforementioned peaks of the trunk movement increased. The authors state that these results demonstrate the distinct effects of pre-perturbation variables on trunk kinematics and risk of injury. Similarly, both Lavender et al. (1989) and Marras et al. (1987) found that if their participants were expecting a sudden load, particularly from a dropped weight, there were anticipatory abdominal muscular activations. They indicated that the resulting muscular activation in preparation of a load can cause large forces on the spine but also increase muscle stiffness and in turn increase trunk stability (Lavender et al., 1989; Marras et al., 1987). It is therefore suggested that additional investigation into the behavior of the human trunk under sudden loads should await future musculoskeletal model studies that are driven by recorded kinematics and loads (Shahvarpour et al., 2014).

The process of injury can be far more complex than the concept of injury created from having a lower tolerance load of tissue than the load applied (McGill, 1996). According to Davis and Jorgensen (2005), this very concept is explained as acute loading where the applied load exceeds the peak tolerance of the spinal structure. The applied load can decrease the tolerance limit of the spine through repetitive or cumulative loading. This phenomenon occurs when repeated applied loads cause micro-injuries consequently reducing the tolerance limit of the spinal structure over time (Davis & Jorgensen, 2005). For example, continuously lifting a load with a rounded back can cause micro-injuries within ligaments and tendons surrounding the vertebral column (McGill, 1996). It is therefore important to note that simply focusing on a single variable that caused the injury may not result in a successful index of risk prevention.

Despite the important advancements made in regards to the different risk factors of LBP, some authors suggest that the results may not be significant as they have been retrieved in the lab (Smith et al., 2011; Katsuhira et al., 2008; Marras et al., 2014). However, examinations that are made in a lab setup typically enables a comprehensive measurement-based methodology, further increasing the reliability of the data retrieved in this setting (Jager et al., 2013). Although Katsuhira et al. (2008) did not test their model in the workplace, the authors found that occupational workers, in particular caregivers, who wore a low back belt decreased spinal load specifically during a patient transfer from the wheelchair to the bed. However, in a study by Agruss et al. (2004), it was suggested that abdominal pressure does not play a role in the reduction of lumbar spine compression and that there is evidence that abdominal pressure may actually increase lumbar compression. Katsuhira et al. (2008) did not measure abdominal and compression forces due to the complex nature of their estimations. Instead, Katsuhira et al. (2008) used low back joint moments as an indicator of low back load during patient transfers by means of force plates to calculate force as well as a 3D motion analysis system to capture kinematic data. According to Zhuang et al. (1999), the use of a force plate may limit the movement of subjects and consequently, the results cannot be inferred to the working population. In specific, caregivers who perform patient transfers while on a force plate will be limited in their movement patterns and as a result, the practices learned while participating in the study will be erroneously connected to patient transfers in the clinical setting (Zhuang et al., 1999).

According to Marras et al. (2014), an increase in recovery time is identified as a predictive factor that has been overlooked in determining an individual’s risk of LBP. The authors gathered data through a prospective field evaluation using an instrumented backpack that was worn by the workers during their normal productivity rates in distribution centers. Marras et al. (2014) thoroughly explain the essence of the backpack that contains handles that emit ultrasound signals and accelerometers that document the travel path of the load relative to the spine as well as trunk motions respectively. This analysis focused on the association between a clinically meaningful decrease in low back kinematic function and cumulative physical exposure characteristics. The uniqueness of the model underlying this analysis is demonstrated by its capability of documenting dynamic load moment exposure not necessarily at the lab but at the worksite (Marras et al., 2014).

Occupational MSDs have been studied extensively and it has been found to be associated with a common notion that the work itself is a major cause of this disorder (Govindu & Babski-Reeves, 2012). Researchers and medical professionals are beginning to realize that occupational LBP are best conceptualized as influenced by a wide range of risk factors (Tullar et al., 2010; Dawson et al., 2007). The literature provides evidence for specific psychosocial factors that may prevent attaining the disorder particularly in the workplace (Christensen & Knardahl, 2011; Chany et al., 2005; Booth-Kewley et al., 2013). These include modifiable work exposures such as leadership styles (Christensen & Knardahl, 2011) as well as a mismatch between an individual's personality type and occupational tasks (Chany et al., 2005). However, Hu et al. (2013) explains that the magnitude of mechanical loading acting on the spine is found to be highly associated with LBP despite the varying risk factors associated with this disorder. Biomechanical risk factors of LBP for varying occupations may include sitting for prolonged periods, working in unnatural postures and sudden and unexpected motions (Magora, 1972), stance width and foot posture (Hu et al., 2013), unexpected loading of the spine (Shahvarpour et al., 2014) and recovery time (Marras et al., 2014). LBP continues to be a ubiquitous condition in various types of workers, therefore, methods to predict and prevent the severity and disabling aspects of this disorder is required.

2.3. Nursing and Back Pain

LBP is shown to be substantial in varying occupations (Mehrdad et al., 2016). However, compared to other professions, nurses and other caregivers have an increased risk of back pain (Jaromi et al., 2012; Seidler et al., 2009) and six times higher prevalence of back injury (Dawson et al., 2007). Based on the most recent statistics from the National Survey of the Work and Health of Nurses (NSWHN), more than one in ten nurses reported severe or unbearable pain, and nearly one-quarter of all nurses stated that their back pain has affected their ability to perform nursing duties (Statistics Canada, 2005). Ontario statistics found that in 2009, the manufacturing industry was associated with the highest number of total claims at 15.5% (Worker Safety and Insurance Board [WSIB], 2010). Meanwhile, both healthcare and social services sectors were second to manufacturing accounting for 13% of total lost time claims as a result of MSDs (WSIB, 2010). Caregivers often care for the sick in hospitals and other health care facilities by performing strenuous activities which include but are not limited to, bathing or dressing a patient, transferring a patient from toilet to wheelchair and lifting a patient up in bed (Huang et al., 2012b). As such, these and other physically demanding tasks may predispose caregivers to a higher risk of injury, particularly to the low back (Van Wyk, Andrews, & Weir, 2010). According to Hignet (2003), patient handling activities have long been acknowledged as major contributors in the high incidence of LBP in caregivers. Learning appropriate techniques, such as proper posture and appropriate manner of lifting, would effectively avert injuries to the low back and other high risk areas (Huang et al., 2012b).

A wide range of patient handling tasks exist which include lifting, transferring and repositioning patients that are typically performed manually (Dawson et al., 2007). Studies by Nelson et al. (2003) and Jager et al. (2013) identified nine of these tasks that place caregivers at high risk of MSDs: raising a patient from lying to sitting in bed, elevating a patient from lying to sitting at the bed’s edge with the nurse at the bed’s long side, moving a lying patient towards the head of the bed with the nurse at the head of the bed, moving a lying patient sideward in the bed, inclining the head of the bed with the patient lying in it, positioning or removing a bedpan, moving a patient seated at the bed’s edge to a chair, and raising a patient from sitting to standing upright. For all nine transfer tasks, Jager et al. (2013) found that lumbar load was high unless the optimal mode of lifting was used, thus reducing disc-compressive forces and load on the spine. For example, in order to reposition a patient to the head of the bed, it is suggested that the nursing aide act at the head of the bed to ensure a more symmetrical posture (Jager et al., 2013). Similarly, in the paper by Huang et al. (2012b), the transfer of a patient from the bed to the wheelchair is studied as it is considered one of the most fundamental lifting techniques used in hospitals and other health care facilities. The authors recruited ten inexperienced nursing students and five experienced nurses serving as observational instructors to observe the lifting task completed by the students. The nursing students were given seven minutes to watch a demo video on how to safely transfer a patient from the bed to the wheelchair. They were then tested on the task with mock patients while the instructors evaluated them on seven different evaluation items. For instance, item six involved the process of assisting the patient to sit in the wheelchair in order to prevent the patient from falling down (Huang et al., 2012b). The researchers investigated whether the nursing students lowered their center of gravity and assisted the patient to bend down prior to sitting down (Huang et al., 2012b). These, amongst other potential cues, can be used as a prevention strategy for MSDs in the workplace (see Section 2.5).

Although several studies attempt to determine the cessation of MSDs in caregivers pertaining to patient handling tasks (Zhuang et al., 1999; Caboor et al., 2000; Jang et al., 2007; Santaguida et al., 2005; Katsuhira et al., 2008; Jager et al., 2013), most researchers face technical ethical issues preventing real data from being inferred to all caregivers (Jager et al., 2013). For instance, in the study by Jager et al. (2013), two female caregivers with extensive professional experience in patient handling techniques served as nurse or patient throughout the study and therefore, no actual cared-for patients were recruited in the investigation of lumbar load. Furthermore, it is important to ensure uniformity of the training conditions, whether it be with mock patients or with consistent verbal feedback cues during patient transfers, to further guarantee the validity of the data (Huang et al., 2012b). Several studies have suggested the use of only one simulated patient for nursing participants to undergo various lifting tasks is required to improve accuracy and reliability (Katsuhira et al., 2008; Skotte et al., 2002; Marras et al., 1999; Gagnon et al., 1987). Direct comparison of the physical demands and spine loads during patient handling across studies can be difficult. For instance, Smith et al. (2011) used a volunteer patient weighing 57kg for their transfer tasks. Belbeck et al., 2014 used an 87th percentile female based on anthropometry and 72nd percentile female for stature. The patient simulated one who is a partial weight-bearing patient (Belbeck et al., 2014). Furthermore, Santaguida et al. (2005) recruited a single patient subject for all testing, however, the patient represented the 95th percentile of all North American women, weighing 89kg.

In order to understand how MSDs impact caregivers requires the quantification of the prevalence of pain as well as the knowledge of the varying risk factors contributing to LBP

(Davis & Kotowski, 2015). In addition, to recognise the influence each specific risk factor has on caregivers, in particular the risks associated with patient handling techniques, one must understand all that is involved in the work environment of caregivers (Hallmark et al., 2014). These work environments may include anything from the design of storage areas, computer work stations and office seating to bed height, caregiving and lifting correlating to LBP (Hallmark et al., 2014). Village et al. (2005) suggested that the primary issue for musculoskeletal injuries results from low staffing ratios, which in turn deteriorates resident outcomes, decreases job satisfaction and decreases retention rates. The authors suggested that it is the health care workers who perform tasks in tight spaces who are more likely to have awkward bending and lifting postures and therefore more peak and cumulative loading of the spine and even shoulders. Smith et al. (2011) describes the development and testing of a tetherless ergonomics workstation that is suitable for studying the physical workload of nursing staff in a clinical setting. The tetherless ergonomics workstation involves a wearable battery-powered module (i.e. worn in a belt across the low back and an adjustable vest) and a base station laptop computer. This wearable computer controls signal acquisition, preprocesses the signals and continually sends the results to the base computer. A pilot study of the device evaluated the topic of the effect of bed height on the physical workload of student nurses while they repositioned a volunteer patient toward the head of the bed. As the bed height was raised, the trunk flexion of the nursing students at both thoracic and lumbar sites as well as lumbar muscular activation all decreased, whereas trapezius and deltoid musculature effort increased (Smith et al., 2011). Furthermore, having the option to adjust bed height can significantly increase the time spent in the safe zone of spinal motion which can consequently influence the compression and shear forces in the lower back (Caboor et al., 2000). Although the injury risks associated with manual patient transfers have been studied extensively, particularly to the low back (Norman et al., 1998; Santaguida et al., 2005; Hoozemans et al., 2008; Katsuhira et al., 2008; Marras et al., 2009; Chany et al., 2005; Mehta et al., 2014), the adoption of similar approaches for other body regions, including the shoulder, are unknown (Belbeck et al., 2014).

According to Jang et al. (2007), self-reported perceived exertion could be used as an important tool in the identification of caregiving activities with high risk of LBP. However, while the evaluated techniques were designed to primarily lower muscular activity in the low back, Belbeck et al. (2014) found that they did not modify the measured physical demands at the area. In fact, during the sit-to-chair and turn toward tasks, Belbeck et al. (2014) found that the low back musculature increased in cumulative normalized muscle activity, indicating an extended period of activity in that region. Although there are a number of authors that are currently studying the risks pertaining to occupational LBP (Norman et al., 1998; Santaguida et al., 2005; Hoozemans et al., 2008; Katsuhira et al., 2008; Marras et al., 2009; Chany et al., 2005; Mehta et al., 2014), the shoulder joint should not be ignored especially when investigating the many different risk factors caregivers are faced with in the workplace.

Several studies have indicated that the transfer of a patient from the bed to the chair is one of the most common transfer tasks performed by caregivers and also one of the most strenuous, particularly on the low back (Huang et al., 2012a; Zhuang et al., 1999; Santaguida et al., 2005; Katsuhira et al., 2008). In order to prevent the risk of LBP during varying patient lifting tasks, it has been suggested that caregivers wear a low back belt which would consequently reduce low back joint moments during these transfers (Katsuhira et al., 2008). Low back joint moments are affected by weight-bearing load on the caregiver when lifting the patient, as well as the caregiver’s trunk-bending angle (Katsuhira et al., 2008). The belt that is suggested by the authors not only comprises of a band of flexible material encircling the waist line to support the low back of the caregiver but also includes hand straps. These hand straps are present around the waist of the caregiver for the patient to grab during any transferring technique in order to decrease trunk-bending angle which may effectively reduce load on the low back (Katsuhira et al., 2008).

Katsuhira et al. (2008) recruited ten student participants and one patient who was told to have normal functioning of the upper extremity only. These students performed four different tasks in which case the belt was worn by both parties (i.e. caregiver and patient), no parties, the patient only and by the caregiver only while standing on a force plate. Despite that the use of low back belts can increase abdominal pressure (Agruss et al., 2014), which can in turn be assumed to decrease the low back compression force, both compression and shear forces were not calculated (Katsuhira et al., 2008). Instead, Katsuhira et al. (2008) used low back joint moment as the indicator for low back load during the various investigated patient transfers.

A concern raised in the study by Katsuhira et al. (2008) involves the use of force plates which may limit the movement of caregivers during varying tasks. In specific, caregivers who perform patient transfers while on a force plate may be limited in their movement patterns and as a result, the practices learned while participating in the study will be erroneously connected to patient transfers in the clinical setting (Zhuang et al., 1999). Furthermore, Katsuhira et al. (2008) instructed the participants to pivot with their feet so as not to twist their trunk during transfer in order to remain on the force plates. As a result, the study did not calculate compression, shear and torsional forces acting on the spine. Zhuang et al. (1999) assessed 12 different transfer methods, including mechanical and non-mechanical techniques and found that more than 10% of the measured spine compression for each task exceeded the NIOSH criterion limit. It is therefore shown that despite the use of assistive devices or the assistance of another caregiver during a patient handling task, transferring residents from bed to chair is very stressful on the spine (Zhuang et al., 1999). The authors suggest that the use of basket-slings and overhead lifts significantly reduce the biomechanical load on the spine of nursing assistants during the accumulation of both the preparation for a transfer (i.e. lifting, rolling and rotating the resident) as well as the actual transfer technique.

In a similar article, Santaguida et al. (2005) proposed that although mechanical lifting devices are recommended to reduce lifting injuries, spinal loads are not minimized for all device types. The authors investigated five lifting devices using five registered experienced female nurses to transfer one mock-patient, who was fully dependent, from the bed to the wheelchair. Even with the use of experienced nurses and unlimited practice time prior to data collection, Santaguida et al. (2005) found that overhead mechanical lifts conveyed lower spinal loads than floor devices during transport. In addition, a large proportion of time was spent in a forward leaning trunk posture (45 degrees or greater) while using either of the lifting devices (Santaguida et al., 2005). After comparing several mechanical lifting devices, the study by Zhuang et al. (1999) suggested that this forward leaning trunk posture is a consequence predominately of the sling application and removal phases of the transfer task. Furthermore, it is suggested that before placing the sling underneath the patient, caregivers should consider rolling the patient away from themselves using a pushing motion as opposed to rolling the patient towards themselves in a pulling motion (Zhuang et al., 1999). While the basket-sling and overhead lifts eliminate the exposure of low-back stress during patient transfers (Zhuang et al., 1999), some devices are shown to actually have the same level of biomechanical stress when compared to the equivalent manual transfer techniques (Santaguida et al., 2005; Zhuang et al., 1999).

Safe patient handling equipment should not be considered the quintessential or all-important strategy towards the reduction of MSDs in the workplace. In fact, the use of such equipment can be deemed unsafe for caregivers and can pose new risks for both caregivers and patients (Elnitsky et al., 2014). The findings in the present study attributed new risks of patient handling equipment to incorrect selection of a particular equipment, damaged or malfunctioning devices and inadequate training on a specific device (Elnitsky et al., 2014). Although mechanical patient handling and transfer devices have been a major focus of injury prevention efforts in the healthcare setting (Nelson & Baptiste, 2006), these devices take significantly more time than manual patient transfers (Koppelaar et al., 2012) and more importantly, most mechanical lifting devices are shown to have complications towards the strategy of reducing LBP risk (Santaguida et al., 2005).

It is important to know that there are multiple factors that can deteriorate the effectiveness and efficiency of patient transfers. Obesity, one of the main concerns in North America, results in a substantial increase in the physical workload of caregivers responsible for handling and transferring these patients (Vieira, 2007). However, the risk of MSDs is not only due to overcoming the body weight of a heavy patient but is increased by the patient’s shape, deformities, level of fatigue, cognitive functioning, cooperation as well as the caregiver’s physical impairments or lower limb function, balance and coordination (Miller et al., 2006). Another issue raised includes patient care activities such as bathing, feeding and dressing, which were found to produce large cumulative spine loads (Holmes et al., 2010) in turn resulting in a higher risk of MSDs (Marras et al., 2014). Furthermore, Marras et al. (2014) also suggested that it is crucial to understand the number of repetitions, under a variety of loading levels, which will weaken a structure to the point of failure or fatigue.

The daily tasks of caregivers are known to involve several repetitions of varying lifting tasks as well as several different sizes and weights of loads (Davis & Jorgensen, 2005). This type of repeated loading in the workplace is one of the many known risks to increase the likelihood of achieving some type of MSD (Jang et al., 2007). Patients, particularly those with cognitive impairment, can be unpredictable and may suddenly become combative, resist efforts or become limp during a transfer causing the caregiver to make sudden unexpected movements (Miller et al., 2006). Pedersen et al. (2004) stated that individuals with existing LBP have altered reaction times to sudden trunk loading in comparison to those who do not have LBP. During a quick-release test, individuals with LBP had increased reaction times for the activation of muscles, therefore increasing the risk of injury and re-injury (Pedersen et al., 2004), particularly in the clinical setting with high amounts of repetitive lifts (Marras et al., 2014). Therefore, the possibility of sudden unexpected movements from certain patients during a transfer task, particularly on nurses with existing LBP, can further exacerbate and damage the structural integrity of the spine (Pedersen et al., 2004). It was demonstrated that it is possible to improve the response to sudden trunk loading in healthy subjects without an increase in pre-activation and associated trunk stiffness (Pedersen et al., 2004). Moreover, an exercise regimen that involves expected and unexpected trunk loading, including balance and coordination exercises, should be considered in order to improve the response to sudden trunk loading by patients and decrease the risk of LBP in nurses (Pedersen et al., 2004).

Reducing injuries related to patient handling can result in considerable economic benefits and prevent significant pain and suffering from caregivers (Miller et al., 2006). Several intervention studies present varying results from the multidimensional studies that are known to be the most effective to any form of training in isolation as ineffective strategies (Dawson et al., 2007). Nevertheless, this is a nascent area of research in need of further improvements particularly in relation to the selection of the most suitable subjects, the timing and duration of interventions and the reliability with which interventions are implemented.

2.4. Holistic Effects of Patient Handling Strategy

Intervention strategies have met little success in preventing and reducing injuries in the low back which consequently emphasizes the persistence of the global problem (Gagnon, 2003). Gagnon (2003) explains the reasons to be one or a few of the following: the lack of control conditions and appropriate measurement techniques; inadequate training methods either for their lack of applicability or lack of rationale; and the lack of consideration for adaptability to suit variations in task, workplace and worker. Choi et al. (2010) emphasizes the aforementioned uncertainty by elaborating that despite the vast research done on LBP, it remains unclear whether exercise, either as part of a treatment or a post-treatment program, can reduce back pain. The authors developed a systematic review to compare research done on these two time periods. Choi et al. (2010) indicate that there is moderate quality evidence that post-treatment exercise programs can prevent the recurrence of back pain. This review portrays the necessity of studies that better validate the measurement of recurrences of back pain through supervised and non-supervised post-treatment exercise programs.

On a similar note, Dawson et al. (2007) provided another systematic review on interventions to prevent back pain specifically in nursing personnel. The review identified moderate level of evidence that training on patient handling techniques in isolation is not effective whereas multidimensional interventions are effective. However, similar to Tullar et al. (2010), there was no strong evidence found to support any specific strategies or any firm conclusions. The authors suggest the need for randomised controlled studies to provide high quality evidence regarding the effectiveness of interventions to prevent back pain and injury, particularly in nursing personnel.

In addition, the review by Smith et al. (2014) identified that core stability exercises for LBP offer very minimal benefits in the short and medium term while no significant benefits were found in the long term when compared with any alternative treatment or control. By contrast, the review by Searle et al. (2015) demonstrated that coordination/stabilisation interventions in fact had the greatest effect in reducing pain associated with chronic LBP when compared with other modalities. The authors further explained that the variability found in the clinical efficacy of exercise interventions may be due to the number of different exercise interventions available, inconsistent recommendations on the topic of intensity and duration of exercise, supervised or unsupervised programs and patient adherence to these exercise interventions.

Although the numerous strategies designed to support nurses and other caregivers, moving an individual is a high-risk activity and safety is paramount regardless of the setting. Patient handling activities have been strongly associated with a high incidence of MSDs, particularly to the low back in caregivers (Hignett, 2003). Stevens et al. (2013) suggested that the maximum amount of weight for patient handling is 35 pounds under ideal conditions. Moreover, considering the percentage of the patient population in healthcare settings weighing less than 35 pounds is quite small, different methods other than lifting patients are needed to control the risk for MSDs (Stevens et al., 2013). Certain transfers completed by one person consistently exceed the spinal load limit (3400N set by NIOSH), even doubling the limit in some cases (Belbeck et al., 2014). For example, a caregiver performing a patient transfer from a supine position on a bed to an upright position in a chair has an estimated spinal compression force of 4751 N, considerably higher than the recommended load (Jang et al., 2007). During a two-person task of rotating a resident to a sitting position on the edge of the bed, the average back compression force was 3487 N (Zhuang et al., 1999).

For years, a range of intervention strategies have been used in the attempt to perfect, reduce or even eliminate manual transfers of patients (Hignett, 2003). Even today, researchers and other professional bodies are continuing to produce guidance on the appropriate biomechanics of patient handling (Marras et al., 2014). Furthermore, mechanical patient handling and transfer devices have also been a major focus of injury prevention efforts in the healthcare setting (Holmes et al., 2010). Other intervention strategies include but are not limited to: risk assessment, used as a vital component of an intervention (Hoy et al., 2014); education and training (Brown, 2003; Hinton, 2010); equipment evaluation/design (Smith, Nave & Herljac, 2011; Daniell, Merrett & Paul, 2013); work environment redesign (Nelson et al., 2003); review and change of policies and procedures (Dawson et al., 2007); physical fitness training (Pedersen et al., 2004); and feedback (Huang et al., 2012a). Despite the various types of intervention strategies that have already been investigated, the issue of occupational MSDs still persists. According to Wells (2009), the data retrieved from surveys, published sick leave as well as lost time, show the extent of the issue in regards to how far behind researchers are in determining the prevention of this disorder.

Many researchers have suggested replacing manual patient handling with mechanical assistive options through the introduction of mechanical floor and ceiling lifts to reduce the prevalence of occupational MSDs (Tullar et al., 2010; Dawson et al., 2007; Santaguida et al., 2005; Village et al., 2005; Marras et al., 1999). In the literature review by Stevens et al. (2013), several investigated studies demonstrated that using mechanical equipment decreases the spinal load on caregivers. Numerous facilities have consequently implemented “zero-lift” policies, banning manual lifting (Dawson et al., 2007) in order to reduce the risk of injury to staff (Occupational Health and Safety Agency for Healthcare [OHSAH], 2006). A Memorandum of Understanding was signed in 2001, in British Columbia, between the Healthcare Unions and Employer which stated the following:

> All parties agree to establish a goal of eliminated all unsafe manual lifts of patients/residents through the use of mechanical equipment, except where the use of mechanical lifting equipment would be of risk to the well-being of the patients/residents. The employer shall make every reasonable effort to ensure the provision of sufficient trained staff and appropriate equipment to handle patients/residents safely at all times…If the use of mechanical equipment would be a risk to the well-being of the patients/residents, sufficient staff must be made available to lift patients/residents safely (OHSAH, 2006).

The benefits of using mechanical lifts for patient handling tasks such as repositioning, lateral transfers and vertical lifts is prevalent in the literature (Stevens et al., 2013; Tullar et al., 2010; Dawson et al., 2007; Santaguida et al., 2005; Village et al., 2005; Marras et al., 1999). Logically speaking, mechanical lifting devices are known to minimize large external loads during patient handling tasks (Santaguida et al., 2005). These devices may also decrease total lost time claims from MSDs and decrease the likelihood of caregivers leaving their profession as a consequence of an injury (Evanoff et al., 2003). Reducing the magnitude of the external load is sometimes not an option and maintaining good body biomechanics is sometimes difficult (Santaguida et al., 2005), particularly during various and repetitive tasks (Marras et al., 2014) and awkward postures and movements in cramped patients' rooms and bathrooms (Village et al., 2005). Therefore, designing the appropriate intervention to potentially replace manual patient handling techniques with mechanical options is deemed important (OHSAH, 2006). Moreover, these interventions should also show the effectiveness of these approaches and their favourable cost benefits (OHSAH, 2006).

Although some mechanical devices have been found to reduce injury risk, nurses often continue to perform physical tasks manually as lifting devices take large amounts of time to use, in turn decreasing productivity (Holmes et al., 2010). If caregivers are paid on a production system of compensation, this reduction in productivity can negatively affect the views of this intervention resulting in its abandonment (Reid & Mirka, 2006). Although it is important to train staff on the use of mechanical lifts or on any newly developed intervention strategy for that matter, Reid & Mirka (2006) demonstrated that the training type needs to be considered in order to prevent the disuse of the strategy. After comparing two different types of training approaches, it was found that the learning curve modelling technique generated a good fit between the actual and predicted productivity levels as a function of time (Reid & Mirka, 2006). In the short-term, the authors study showed that an interactive training procedure compared to a “see-one-do-one” protocol is significantly beneficial in the increase of caregiver productivity. Another strategy to promote the use of mechanical devices involves the identification of a “staff champion” defined as a caregiver who has experienced a work-related lifting injury (Pellino et al., 2006). This individual is more motivated to use the devices and can therefore serve as an instructor in orientations, particularly for new employees and during annual safety reviews (Pellino et al., 2006). In addition, Geiger (2013) suggested that the use of physical therapists as part of an ergonomic intervention is necessary to promote appropriate handling and transferring guidelines for specific patients. Physical therapists can also be used to encourage physical exercise in order to facilitate lifting tasks and encourage other preventive movement strategies (Geiger, 2013).

According to the literature review of the Occupational Health & Safety Agency for Healthcare (OHSAH) (2006), a few of the studies that examined the effectiveness of using mechanical equipment indicated potential increased risks of cumulative loading despite their use.

The forward leaning trunk position that nearly all caregivers are found to be in, particularly during the sling application and removal phases of the transfer task, is known to be attributed to a high risk of LBP (Zhuang et al., 1999). The authors therefore suggest that before placing the sling underneath the patient, caregivers should consider rolling the patient away using a pushing motion as opposed to rolling the patient towards in a pulling motion (Zhuang et al., 1999). While the basket-sling and overhead lifts completely eliminate the exposure of low-back stress during patient transfers (Zhuang et al., 1999), some devices are shown to actually have the same level of biomechanical stress when compared to the equivalent baseline manual transfer techniques (Santaguida et al., 2005; Zhuang et al., 1999). Through an investigation of varying mechanical lifting devices, Santaguida et al. (2005) showed that overhead mechanical lifts conveyed lower spinal loads than other mechanical devices. Zhuang et al. (1999) explained that the higher spinal load in floor lifts is due to the transportation of this type of device from one area to another, regardless of the setting.

Other benefits ceiling lifts have over floor devices include ease of use, storage and both patient and caregiver safety (Santaguida et al., 2005). In other words, ceiling lifts have solved many of the issues related with mechanical devices as they require minimal physical effort to maneuver, are readily available as they are stored in patients' rooms and they do not need a significant amount of space to operate (Miller et al., 2006). Although ceiling lifts involve costly room renovations, it may improve caregiver compliance as the device is always accessible in the room rather than the caregiver trying to determine the device's location and setting it up prior to use (Pellino et al., 2006). However, safe patient handling equipment should not be considered the quintessential or all-important strategy towards the reduction of MSDs in the workplace. In fact, the use of such equipment can be deemed unsafe for caregivers and can pose new risks for both caregivers and patients (Elnitsky et al., 2014). The findings in the present study attributed new risks of patient handling equipment to incorrect selection of a particular equipment, damaged or malfunctioning devices and inadequate training on a specific device (Elnitsky et al., 2014). Although mechanical patient handling and transfer devices have been a major focus of injury prevention efforts in the healthcare setting (Nelson & Baptiste, 2006), these devices take significantly more time than manual patient transfers (Koppelaar et al., 2012) and more importantly, most mechanical lifting devices are shown to have complications towards the strategy of reducing LBP risk (Santaguida et al., 2005).

An effective strategy may be to combine the use of ceiling lifts for patient handling tasks with an appropriate training program (Ronald et al., 2002). This program would be used to educate caregivers on the proper use of the equipment as well as an alternate lifting technique in the circumstance that the staff is uncomfortable with its use or the equipment malfunctions (Ronald et al., 2002). It is suggested that although modern mechanical lifting equipment can be beneficial for the well-being of caregivers and patients, a comprehensive safe patient handling program along with policies and procedures that explicitly mandate a new method of handling patients is required to ensure success in its application (Brown, 2003; Hinton, 2010). Without the program, there is no guarantee that the newly implemented policy and procedure will be instilled and utilized on a day-to-day basis in the workplace (Brown, 2003). If there is no space or there are no available resources for the implementation of mechanical lifting devices, future interventions should include an educational program with emphasis on ergonomics to decrease the level of dependence on patient lifts (Ronald et al., 2002). The combination of both exercise and educational components can also be used as part of an intervention for the long-term deterioration of back pain in nursing personnel (Ronald et al., 2002).

The study by Garg & Kapellusch (2012) consisted of an efficacious study of a pre- and post-intervention design in seven nursing facilities. Pre-intervention data was collected prior to the date mechanical devices were used for that facility which ranged from three to six months (Garg & Kapellusch, 2012). Post-intervention data was collected 36 to 60 months after patient-transferring devices were used (Garg & Kapellusch, 2012). The authors found that the implementation of an ergonomics program alongside the use of mechanical lifting equipment to be effective in reducing injuries associated with patient lifting tasks, lost workdays, modified-duty days and workers' compensation costs. A similar multifaceted program by Nelson et al. (2006) focused on high-risk hospital units, in turn potentially offering the most opportunity for improvement, which yielded a reduction in both lost workdays and injury rates. Even though injury rates decreased nine months after the multifaceted intervention had been implemented in 23 high-risk hospital units, this risk factor only decreased for 15 out of the 23 units, while seven units reported a slight increase in injury rate and one unit was unchanged (Nelson et al., 2006). Nevertheless, after the intervention had been executed, the perceived stresses among nursing personnel were low and a vast majority of patients felt more comfortable and safer with their transportation through mechanical devices (Garg & Kappellusch, 2012).

A final segment from the Memorandum of Understanding indicates that if mechanical lifts are believed to be unsafe, other caregivers must be made available to assist in the manual transfer of the patient (OHSAH, 2006). Elnitsky et al. (2014) attributed new risks of patient handling equipment to incorrect selection of particular equipment, damaged or malfunctioning devices and inadequate training on a specific device. The aforementioned statement by the OHSAH yields several issues that are typically present in healthcare facilities. First and foremost, inadequate staffing is generally present and poses a barrier to the completion of additional duties other than care for the inpatient (Stanton, 2004). As a result, the study by Stanton (2004) addresses the growing caregiver workload, rising rates of burnout and job dissatisfaction. In addition to giving care to patients, nurse perceptions of inadequate staffing levels are most likely related to the expectation of performing non-nursing tasks such as delivering and retrieving food trays, transporting patients, housekeeping duties and ancillary services (Stanton, 2004). One of the many leading factors to occupational MSDs results from low staffing ratios which in turn can also deteriorate resident outcomes, decrease job satisfaction and decrease retention rates (Village et al., 2005). It will therefore be challenging to essentially recruit extra help from co-workers if the mechanical device is deemed high risk for use. If the appropriate equipment is not readily available, caregivers begin to get frustrated as work processes are delayed which results in feelings of guilt and annoyance because patient care cannot be met in an efficient manner (OHSAH, 2006). The other concern this raises is the extra time needed to retrieve additional assistance, in the situation that a piece of mechanical equipment is considered dangerous, while the inpatient waits to be cared for. The use of overhead ceiling lifts is considered the preferred method in the reduction of patient handling injuries and is also favoured by caregivers over other types of mechanical lifts (OHSAH, 2006).

The implementation of multifaceted programs using patient handling mechanical equipment and other interventions has consistently shown a reduction in compensation costs, injury incidence rates and lost work days in varying healthcare facilities (Stevens et al., 2013). However, if interventions are based solely on technique training it is unlikely that there will be a positive change in the reduction of occupational MSDs (Hignett, 2003). Changing the culture of safety for safe patient handling has been proven to be challenging as it takes time and continuous attention for sustainability to ensure proper implementation (Stevens et al., 2013). According to

Wells (2009), most of the published intervention studies on patient handling represent efficacy studies. The problem is that the numerous investigations made in regards to varying interventions take place in the lab or workplace settings under well-controlled and even ideal conditions (i.e. organizations are carefully selected and the interveners are highly competent) which leaves the concern and question of whether the intervention itself is efficacious, particularly if the effects of the research is not positive (Wells, 2009). However, Stevens et al. (2013) stated that as multifaceted interventions are shown to be beneficial, in order to improve the sustainability of interventions, these strategies need to address engineering, administrative and behavioral controls for reducing occupational injury and associated costs.

Despite some studies founding technique training ineffective for decreasing occupational MSDs (Hignett, 2003; Enkvist et al., 2001; Lagerstrom & Hagberg, 1997; Nussbaum & Torres, 2000), a small number of studies suggest successful intervention for improving the method used to transfer patients (Johnsson, Carlsson, & Lagerstrom, 2002; Gagnon, 2003; Resnick & Sanchez, 2009). Even though Johnsson et al. (2002) hypothesized that one training method would be more effective in the learning and retention processes of patient handling techniques as opposed to a traditional way, both techniques were found to be successful. In the current study, training focused on work technique, musculoskeletal problems, job strain and the experience of both the caregiver and the transferred individual. However, instead of a generic course on appropriate biomechanics to prevent occupational injuries, the new model of learning encapsulated both theoretical and practical parts (Johnsson et al., 2002). The main goal of the theoretical component was for the participants to learn a model of analysis in which the caregiver would ultimately analyze various situations and apply newly developed knowledge (Johnsson et al., 2002). Caregivers would be able to use this tool to choose the optimal patient handling method taking into consideration several factors (i.e. caregiver capability, the resources and needs of the patient and the possibilities and limitations of the environment) (Johnsson et al., 2002). Even after a six-month follow-up, participants showed improved transfer techniques and experienced greater comfort during the transfer (Johnsson et al., 2002).

In addition, Gagnon (2003) indicates that training protocols should be based on workers' knowledge about their jobs as these workers rarely use the handling techniques taught in programs and actually question the appropriateness of the techniques. It is argued that the correct manner of teaching proper biomechanical principles is based on the observations of contrasting strategies of expert and novice workers where the focus should predominately be on handling load maneuvers (i.e. load tilts, positioning of hand and foot displacement strategies) (Gagnon, 2003). Similarly, the study by Nelson et al. (2003) indicated that caregiving tasks can simply be redesigned by a panel of experts to improve safety by using new patient handling technologies and work practice controls. The redesigned tasks were then compared to a randomized group performing standard procedures and found to have significant differences in back and shoulder muscular activity, forces on the lumbar spine, shoulder joint moments and perceived comfort (Nelson et al., 2003). Based on the results of the study, recommendations are made on the correct manner of performing these redesigned patient handling tasks (Nelson et al., 2003). These recommendations include using friction reducing devices for lateral transfers, using ceiling mounted patient lifts, making bed adjustments for height and moving laterally along the bed as opposed to twisting (Nelson et al., 2003). Furthermore, Resnick & Sanchez (2009) compared classroom training to contextual or practical training and consequently portrayed that biomechanical training for both methods had positive effects, particularly towards observed torso postures. It was noted however that contextual training was a little more effective in reducing awkward postures and improving compliance with safe practices (Resnick & Sanchez, 2009). Irrespective of the practical method of teaching appropriate biomechanical patient lifting patterns, merely educating caregivers in the classroom has been shown to have little to no improvements in the task (Johnsson et al., 2002; Gagnon, 2003; Resnick & Sanchez, 2009).

Several authors argue that multifaceted interventions bring success to the ultimate goal of eliminating occupational injuries (Hignett, 2003; Jaromi et al., 2012; Rossignol et al., 2000; Alexandre et al., 2001; Warming et al., 2008). The review by Dawson et al. (2007) identified a moderate level of evidence that training on patient handling techniques in isolation is not effective whereas multidimensional interventions are effective. However, similar to Tullar et al. (2010), there was no strong evidence found to support any specific strategies or any firm conclusions. The authors therefore suggested the need for randomised controlled studies to provide high quality evidence regarding the effectiveness of interventions to prevent back pain and injury, particularly in nursing personnel.

Although physical exercise is not considered a multifaceted intervention, it has an important role to play as a vital component of an intervention. Pedersen et al. (2004) maintained that it can fine-tune the response to sudden trunk loading among nursing personnel who are typically exposed to these types of trunk perturbations. The participants received ten 45-minute training sessions during a 4-week period, with which the training focused on reactions to a variety of expected and unexpected sudden trunk loadings (i.e. balance and coordination exercises). Participants also underwent baseline and finish line testing for reaction to sudden trunk loading which entailed applying a horizontal force to the subject’s upper back through cost-effective, complex but greatly elucidated equipment. Pedersen et al. (2004) found that the training had an impact on the subject’s reaction to sudden trunk loading. Stopping time decreased significantly in the training group in comparison to that of the control group. An improved stopping time is shown to decrease the risk of low back injuries since a faster reaction could decrease the energy accumulated before the trunk's forward movement slows (Pedersen et al., 2004). In addition, trunk flexion in response to a perturbation decreased in subjects with faster stopping times, indicating that training reduces the risk of LBP (Pedersen et al., 2004). Exercise is shown to be a learned behaviour that protects the spine by activating the correct muscles surrounding the core of the human body, thus decreasing the load on the low back especially during sudden trunk loading (Pedersen et al., 2004). The review by Searle et al. (2015) identified a small but significant effect for exercise, specifically coordination/stabilisation exercise interventions, and the treatment of non-specific chronic LBP. Moreover, there is evidence that the lumbar multifidus and transverse abdominis musculature contribute to the stability in the lumbo-pelvic region and assist with support of the spine (Hides et al., 2011), particularly when stability is challenged during unexpected loading of the spine (Pedersen et al., 2004). In fact, it is believed that the stability of the lumbar spine is at risk during the dysfunction of the aforementioned muscle groups consequently increasing the stress and load on the joints and ligaments of the spine (Hodges & Richardson, 1996). The study by Hodges & Richardson (1996) found that participants with LBP demonstrated delayed transverse abdominis response to visual stimulus, indicating a deficit of motor control resulting in inefficient stability of the spine.

The results of the study by Warming et al. (2008) coincide with that of Pedersen et al. (2004) in that a physical training-induced programme alongside technique training have an influence in minimizing LBP disability. However, when compared to a control group, whether implementing transfer technique alone or in combination with physical fitness training, there were no known significant differences according to self-reported LBP, pain level, disability and sick level even at a 12-month follow up (Warming et al., 2008). Nevertheless, the individual randomised intervention subgroup showed significant improvement in LBP disability throughout the range of calculated measures suggesting that physical training could in fact be an additional component towards the reduction of LBP among caregivers (Warming et al., 2008).

Jaromi et al. (2012), believed that an important preventive or even therapeutic method towards LBP disorders in caregivers is through participation in a specific spine training program known as Back School (BS). The BS program consists of both an educational and an ergonomical component which includes information relevant to the disease, body mechanics, and stress as well as exercises to protect the spine through proper muscle activation during the awkward positions present in patient transfers (Jaromi et al., 2012). Passive therapies (i.e. TENS, massage, ultrasound and heat therapies) are suggested to be ineffective for the rehabilitation of LBP in caregivers and also for prevention (Jaromi et al., 2012). Therefore, participating in active therapy (i.e. BS) is shown to significantly decrease the pain intensity levels and improve body posture during patient handling (Tullar et al., 2010). Nursing volunteers in the passive therapy group underwent successful rehabilitation and pain was only relieved in the short term; indicative of the follow-up sessions done at six and 12 months' post-study (Jaromi et al., 2012). In comparison, nursing volunteers in the BS program experienced improved body posture and significantly decreased pain in both the short-term and long-term (Jaromi et al., 2012). It is therefore clear that load on the spine can be decreased through learned behaviour, which is the basis of an effective physical training program (Tullar et al., 2010). Jaromi et al. (2012) also crucially concluded that the effects experienced after participation in BS can include improved spine function, fewer recurrent LBP episodes and a decreased number of days off work. More importantly, the BS program does not involve expensive or complex technology, the main reason for its popularity (Jaromi et al., 2012). A further advantage to physical exercise or active therapy is that it progresses general health and can decrease the risk of MSD symptoms along with many chronic diseases (Tullar et al., 2010).

The randomized controlled trial by Rossignol et al. (2000) compared standard care with a program for the coordination of primary health care (CORE) for the treatment of LBP. The concern with primary care comes from the specific role of referring patients to a specialist or to specialized rehabilitation services when there are no known improvements in functional status (Rossignol et al., 2000). This highlights the limitations of primary care in the management of LBP rather than to provide practical tools to enable physicians before referrals are made (Rossignol et al., 2000). Current clinical guidelines have been done poorly in providing tools and guiding physicians in primary care. Rossignol et al. (2000) continue to state that it has been shown through previous research that primary care can be improved by simplifying rather than adding to health care. Despite effective randomization, the intervention group contained fewer men and more subjects with a history of compensation for back pain or with disabling back pain which favoured this group; hence the positive results for CORE guidelines. In addition, regardless of a modest effect on return to work, this intervention had a significant benefit in terms of symptom reduction and improved physical function after six months (Rossignol et al., 2000). Furthermore, Rossignol et al. (2000) provided evidence suggesting that the intervention was cost effective, an important criterion for future implications for the rehabilitation and the prevention of MSDs in caregivers. On a similar topic of altering specific guidelines, Van Wyk, Andrews, & Weir (2010) suggested that there is a gap in the training approaches between student nurses and staff nurses in manual patient transfers. This gap needs to be addressed in both these academic and clinical environments (Van Wyk et al., 2010). One way to narrow the aforementioned gap is by increasing training time of a participatory ergonomics approach which will in turn allow student nurses to gain greater knowledge and confidence of their patient handling skills prior to the clinical environment (Van Wyk et al., 2010). Knowledge gained in this way will be useful in implementing a revised curriculum that assists student nurses, in particular, with the expectations and confidence needed for proper patient lifting techniques, given that inadequate training may increase the risk of work-related MSDs.

Providing effective care for LBP may depend less on strict adherence to a specific set of intelligent guidelines in comparison to exercise and ergonomic interventions (Tullar et al., 2010). In the randomized trial by Alexandre et al. (2001), they recognized that strategies should include an ergonomic approach to reduce MSD symptoms. With that being said, Alexandre et al. (2001) established a specific exercise program with an educational ergonomic approach for nursing personnel with LBP for at least six months. Subjects in the treatment group of the study underwent a 45-minute exercise program, twice a week, including strength and flexibility exercises conducted during working hours for four months. On the other hand, subjects in the control group received only a 45-minute class during working hours on the topic of anatomy of the spine and patient transfer technique. Alexandre et al. (2001) indicated that the frequency and intensity of back pain among caregivers in the lumbar as well as the cervical regions decreased significantly in the group that experienced exercise and ergonomic interventions (Alexandre et al., 2001). These results are portrayed at two distinct retrospective periods; last two months and last seven days of the intervention. This supports the findings of other studies, suggesting that an exercise program with an ergonomic approach could reduce or even prevent MSDs in caregivers.

It is well known that in order to decrease the number and severity of MSDs in caregivers, implementing a culture of safety for safe patient handling through multifaceted programs has shown widespread success (Stevens et al., 2013; Jaromi et al., 2012; Hignett, 2003; Nelson et al., 2006). If the approach is predominately based on technique training, the goal of reducing MSDs in the workplace is unlikely to be successful and an alternative method is suggested (Hignett, 2003). In the literature review by Stevens et al. (2013), several investigated studies demonstrated that using mechanical equipment decreases the spinal load on caregivers. However, ceiling lifts in particular have gained popularity over floor lifts as they require minimal physical effort to maneuver, are readily available as they are stored in patients' rooms and they do not need a significant amount of space to operate (Miller et al., 2006). There have been barriers towards the use of ceiling lifts because of resistance to change, the increase in time needed for transfer and the limitation of space in some hospital rooms (Pellino et al., 2006). It is suggested that although modern mechanical lifting equipment can be beneficial for the well-being of caregivers and patients, a comprehensive safe patient handling program along with policies and procedures that explicitly mandate a new method of handling patients is required to ensure success in its application (Brown, 2003; Hinton, 2010). According to Wells (2009), in order to successfully implement and ensure sustainability of a specific strategy to reduce MSDs, knowledge and practice gaps must be identified. It was suggested that there is a gap in the training approaches between student nurses and staff nurses in manual patient transfers which crucially needs to be addressed in both the academic and clinical environments (Van Wyk et al., 2010). In fact, Mitchell et al. (2009) suggested that because LBP remains prevalent before commencing employment, nursing students should be the target of preventative interventions to ensure the effectiveness of its implementation. In order to ensure application and sustainability of a particular approach, even after being taught in a clinical setting, feedback on the correct patient handling techniques have been found to be an effective method for increasing preventive work for nurses and other caregivers (McGill et al., 2014).

2.5. Using Feedback for Motor Learning

Many studies have demonstrated that the lifting and handling patterns of individuals can have substantial impacts on spinal loads, resulting in LBP which is shown to cause more global disability than any other condition (Storheim & Zwart, 2014; Marras et al., 1999; Keir & MacDonnell, 2003; Tate, Yassi & Cooper, 1999; Jaromi et al., 2012; Seidler et al., 2009; Lavender, 2000). It is therefore suggested that coaching lifting techniques can potentially play a critical role in the prevention of occupational MSDs (Lavender, 2000). Although several studies have attempted to determine the cessation of MSDs in caregivers pertaining to patient handling tasks through various interventions (Zhuang et al., 1999; Caboor et al., 2000; Jang et al., 2007; Santaguida et al., 2005; Katsuhira et al., 2008; Jager et al., 2013), relatively few have investigated the use of feedback within this context (Agruss et al., 2004). The effectiveness of providing some type of feedback as a learning variable may assist in reducing or eliminating occupational MSD risk (Agruss et al., 2004). As early as two to three decades ago, researchers had found that various types of feedback, such as instruction, audiovisual presentations and simulated practice, provided caregivers the awareness and knowledge of the potential injury risks needed to sustain the prevention of musculoskeletal injuries in their workplace (Menckel et al., 1996; Alavosius & Sulzer-Azaroff, 1986). One of the more recent studies have found that there is a lack of technique coaching articles, particularly for caregivers (McGill et al., 2014) and it is important to assess feedback given to the performance of motor tasks, such as patient handling, in the hope to eliminate occupational musculoskeletal injuries in the healthcare setting.

In the study by Belbeck et al. (2014), shoulder musculature was investigated during manual patient transfers to determine whether approaches that are intended to avert low back injury negatively affected shoulder demands. The authors looked at five different transfer tasks using 20 nursing students and one patient simulating a partial weight-bearing individual, only supporting himself in a seated or standing position. Participants were first given a chance to complete these tasks based on their best knowledge, were then given a training protocol consisting of graphical and verbal instructions for the best recommended techniques and finally were asked to repeat the tasks again with the new-found knowledge on the correct performance. Belbeck et al. (2014) found that amongst the five patient handling tasks, the sit-to-chair and turn toward tasks were the most demanding for the shoulder. Furthermore, there was a reduction in the rate perceived exertion (RPE) for the right shoulder as well as the low back following training for most tasks.

It is equally as imperative to look at the various types of feedback available before differentiating the most effective type to ultimately provide a sustainable reduction in occupational MSDs. In the context of human motor behaviour, Magill (2011) defined feedback as the information that is presented in the motor activity of an individual that indicates the status of a movement. Although most feedback originates from the sensory system, Agruss et al. (2004) suggested that there is a wide range of extrinsic information that can augment this type of intrinsic information. Extrinsic feedback can be known as information that cannot be given without an external source (Sigrist et al., 2013), while intrinsic feedback is the internal information received during and after the execution of a movement (Agruss et al., 2004). For instance, biofeedback is a type of augmented feedback that uses an instrument to monitor a bodily function, such as a heartbeat or muscle activity in order to regulate it (Magill, 2011).

Another example of augmented feedback is found through the main goal of a rehabilitative program which is to ensure quick and permanent recovery of lost motor function (Sigrist et al., 2012). Therefore, instead of the therapist visually demonstrating the movement, the athlete or patient is to model the movement during or after which the therapist provides corrective feedback if necessary (Sigrist et al., 2012). As for the specific type of feedback given to this patient, therapists typically switch modalities to instruct the motor task depending on the motor feature to be taught and on the individual's motor capabilities (Sigrist et al., 2012). Interestingly, as a result of their professional ability to determine which modality is best suited for each individual at a given time, Geiger (2013) suggested that the presence of therapists in ergonomic programs is crucial and that their absence may comprise a limitation of the potential effectiveness of these programs. These therapists can potentially provide the effective technique coaching of exercises that was found to result in participants adopting a more neutral spine posture throughout their movement patterns (McGill et al., 2014). Regardless, it is widely accepted that the strategy of adapted training that progressively increases task difficulty as an individual acquires skill, particularly through feedback, will ensure success in the motor learning task under investigation (Guadagnoli & Lee, 2004).

Despite the use of therapists or other medical professionals, the issue as to when and what type of feedback should be given to produce the best results for learning and sustaining motor tasks remains controversial. According to Agruss et al. (2004), the general mode of feedback chosen is likely to constrain the manner of which the feedback is presented. Feedback that is given after the outcome of a task, often called Knowledge of Results (KR), has been regarded as a critical component in the acquisition of skills (Salmoni, Schmidt & Walter, 1984). If using KR as the feedback mode, feedback will often be presented as a number, or sometimes even verbally, signifying the extent to which a movement accomplished the intended goal successfully (Agruss et al., 2004). Similarly, Knowledge of Performance (KP) is a feedback mode that assesses the correctness of the actual execution of the movement after its completion (Salmoni et al., 1984). For instance, a gymnast who sees the scores of the judges after completing a routine is known as KR while a gymnast who looks at a computer monitor to see a 3-D model of his or her body completing the routine is an example of KP (Magill, 2011). The importance of this distinction is that it allows the ability to determine the best form of feedback for a specific task in order to maximize motor learning and retention.

If the feedback type is of a continuous nature (i.e. concurrent EMG), it is given in real-time during the execution of a motor task (Sigrist et al., 2013). Some authors have demonstrated quicker responses using this mode of feedback in the improvement of the motor task under investigation (Lavender, 2000; Huang et al., 2012a; Huang et al., 2014). When using concurrent feedback, information is typically presented either in graphical form displaying the relevant signal over time or as an audible tone that changes pitch (Agruss et al., 2004). Irrespective of the timing of feedback, there are several other modes available including visual (screens and head-mounted displays), auditory (speakers and headphones), tactile or haptic (sense of touch and vibrotactile actuators), proprioceptive (Magill, 2011) and a combination of modes, also known as multimodal (Sigrist et al., 2013). Figure 1.0 illustrates the varying types of feedback modes for task-intrinsic feedback and augmented feedback, as well as for the related specific types of each.

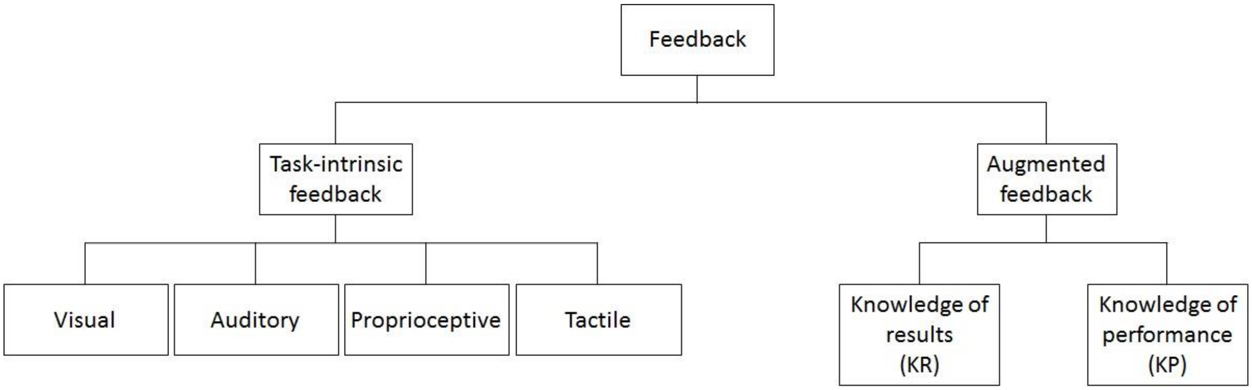

Figure 2.0 Illustration of the varying types of feedback modes that are related to motor learning and performing retrieved from Magill (2011).

In order to design effective training programs that include feedback, Agruss et al. (2004) suggested a few more important factors to consider some of which include, feedback delay time (Salmoni et al., 1984; Winstein, 1991), feedback frequency (Albuquerque et al., 2014; Wulf, Schmidt & Deubel, 1993) and the feedback withdrawal schedule, otherwise known as fading feedback. The main purpose of fading feedback is to provide augmented information while preventing the individual from becoming overly dependent on it (Agruss et al., 2004). Providing individuals with constant feedback may actually increase dependence and in turn degrade learning. One of the many hallmarks of an effective feedback training program is that it will result in a relatively permanent improvement (Winstein, 1991). The effectiveness of these programs can be measured through the retesting of participants after an interval of time without feedback to determine if the newly coached skill has been retained (Agruss et al., 2004). In a study by Lavender (2000), the effect of a lifting task that used a combination of concurrent feedback and coaching was investigated. Participants were asked to perform multiple repetitions of a lifting task under three different conditions in the same order. Feedback was given graphically at the end of the lifting task for the first condition. During the second condition, Lavender (2000) provided participants with an audible tone signifying the magnitude of three-dimensional low back moment vectors during the course of the lifting process. Throughout the third and final condition, the trainee was then asked to perform the lifting task without any feedback to determine the potential sustainability for motor learning to avoid dependence on a specific feedback mode. Lavender (2000) found that after the three conditions had been completed by each participant, side-bending moments were reduced the most with only marginal reductions, but reductions nonetheless, in twisting and forward bending moments.

Agruss et al. (2004) examined the effect of a lifting task using two different modes of feedback that were compared: concurrent EMG and verbal post-lift feedback, alongside a control group that received no feedback. Those participants grouped in either of the feedback modes were asked to produce 40 lifts: ten lifts for pre-training with no feedback, 20 lifts with the specific type of feedback and ten lifts for post-training with no feedback one week after the last training session. During feedback sets, those allocated in the verbal post-lift group were asked to minimize an acceleration index that was delivered to them verbally. This is a mode of feedback known as KR feedback delay time as the information that is given about the participant's lifting task is delayed post-lift which was found to help the subsequent repetition of the task (Salmoni et al., 1984). However, it was indicated in the review by Salmoni et al. (1984) that a very short KR delay degrades motor learning. If KR is given in a short interval from the movement to its provision, motor learning and performance will not be maximized (Winstein, 1991). In contrast, if the feedback is given after each repetition of a particular trial, also known as inter-trial interval delay, increasing both feedback delay time and inter-trial intervals will have a positive effect towards motor learning (Salmoni et al., 1984).

Along the verbal post-lift group, Agruss et al. (2004) also investigated the EMG group which consisted of a unit that produced a tone that rose in pitch as a function of erector spinae, or low back, muscle activation which is a form of KP feedback. Healthy subjects assigned to this group were asked to keep the pitch as low as possible during their lifting task, otherwise feedback would be provided at 100% of the time if there was an increase in erector spinae activation. After assessing lumbosacral loads, Agruss et al. (2004) found both feedback groups experienced two to three times the improvement shown in the control group with no feedback, where the verbal post-lift feedback group produced statistically significant results even after a seven day interval without feedback. It is therefore suggested that the verbal post-lift feedback mode could provide sustainable reduction in risk of MSDs during lifting tasks in healthy and cognitively unimpaired subjects (Agruss et al., 2004).

The phenomenon of feedback frequency can be defined as the number of times or frequency that feedback is provided (Albuquerque et al., 2014). It is widely accepted that for a fixed number of trials, giving KR for only a portion of trials, such as 50%, generally results in more effective retention performance in comparison to giving KR after every trial (Wulf et al., 1993; Albuquerque et al., 2014; Sidaway et al., 2012). In the study by Sidaway et al. (2012), it was suggested that children with physical disability, specifically cerebral palsy, learned a dart-throwing task more proficiently when feedback was given during 50% of the trials during practice than when it was provided on every trial. Interestingly, it is also proposed that children with uninterrupted development who were provided 100% and 62% feedback during practice trials and who were compared to young adults, were found to produce the greatest learning with feedback provided at all trials (Sidaway et al., 2012). In addition, the differences found between the physically disabled children and children with uninterrupted development is explained through the prediction that there is an optimal challenge point in terms of cognitive effort for each individual that yields maximum motor skill learning and retention (Sidaway et al., 2012).

Several studies have mainly focused on the analysis of transfer techniques (Stevens et al., 2013; Pedersen et al., 2004; Jaromi et al., 2012; Rossignol et al., 2000; Hignett, 2003; Van Wyk et al., 2010) and only a few have investigated the approach of KP (Huang et al., 2012a). Huang et al. (2012a), implemented a training system in nursing faculties in which nursing students can train themselves at any time. Moreover, this training system was recommended for faculties in various institutions and consisted of automatic measurements and evaluations on the performance of nursing students doing varying lifting tasks (Huang et al., 2012a). As a result of its analyses, this training system provided feedback to student participants during every trial by presenting right/wrong indications (Huang et al., 2012a). In addition, at the end of the lifting task, a video was automatically provided to correct certain wrong procedures of the lift (Huang et al., 2012a). In another study by Huang et al. (2012b), system accuracy was determined to be up to 85% compared to using nursing instructors who also evaluated the students in a similar fashion. However, very little empirical research exists on the effectiveness of video replays as an aid for motor skill acquisition (Magill, 2011). In addition, for nursing students to benefit from this mode of feedback, they are likely to require further assistance from an instructor to point out some important information (Magill, 2011). It is therefore suggested that advanced performers (i.e. athletes) would receive greater benefit from observing replays when they receive some type of attention-directing instructions, such as checklists and verbal cues (Magill, 2011). Although nursing students seem to be the correct demographic to concentrate on in the possible elimination of lifting-related musculoskeletal injuries prior to full-time employment, the proposal by Huang et al. (2012a) seems to be quite complex for beginners as well as a costly intervention.

Augmented feedback is shown to be a very important part of learning and fine-tuning motor skills. It is used to facilitate the achievement of an action goal of the skill and/or as motivation for the learner to continue to strive toward the achievement of a goal (Magill, 2011). McGill et al. (2014) stated that there are no studies evaluating the ability of feedback to influence muscle activity and/or spine load. Understanding the concept of feedback is crucial not only to provide insight on appropriate spine health but also to deliver the correct type. The effectiveness of providing some type of feedback as a learning variable may assist in reducing or eliminating occupational MSD risk (Agruss et al., 2004). However, the transfer of research evidence into practice can be a challenging obstacle even when the advantages are strong. Despite the lack of success in technique training in most of the articles mentioned in the systematic review by Hignet (2003), particularly for nursing staff and other caregivers, giving the correct feedback to the precise demographic in the right setting is important to accurately be determined. This will more likely ensure effective motor learning and potential sustainability. Mitchell et al. (2009) suggested that because LBP remains prevalent before commencing employment, nursing students should be the target of preventative interventions to ensure the effectiveness of its implementation. The most effective type of feedback should be determined through varying efficacious studies in the context to assist caregivers, particularly nursing students, prior to full-time employment, in patient transferring tasks. As such, these tasks will be perfected, nursing students will acquire a set of developed motor skills through various types of patient handling tasks and more importantly, occupational MSD injury risk will be widely reduced.

Chapter 3: Pilot Study

Preliminary investigation of muscle activity and kinematics during patient handling tasks

Chapter 3: Pilot Study

3.1. Abstract

The prevalence of musculoskeletal injury within the healthcare profession is very high and nurses experience more injuries than all other occupations. The purpose of this study was to perform a preliminary biomechanical analysis of trunk kinematics and muscle activity during common patient handling activities to aid in the determination of appropriate tasks for a follow up biofeedback study. Muscle activity and postures were measured using surface electromyography (SEMG) and 3D motion capture, respectively, for three male and five female participants. Each participant performed three repetitions for each of the four patient handling tasks: reposition patient; sling under patient; transferring patient from bed to chair; and transferring patient from chair to bed. The largest muscle activity was found in the lumbar erectors and shoulder musculature. The data retrieved from this pilot investigation concludes that the focus for the main student nursing investigation to follow should focus on the lumbar and shoulder musculature in greater detail. Providing biofeedback techniques during these lifting tasks, while specifically looking at these areas of the body, will allow for proper education on lifting mechanics to develop safer patient handling procedures within the healthcare industry.

Keywords: low back; patient handling; biofeedback; biomechanical analysis; kinematics

3.2. Preface

This small-scale pilot study was conducted in order to determine feasibility, time, cost, and effect size. It involved looking at various patient handling tasks and the musculature demands associated with each. This was done to establish a framework of not only the most physically demanding tasks, but the tasks that may best be suited to feedback training. It allowed the researchers to gain a better understanding of the most common patient handling activities and how they are typically performed in the workplace. Specifically, this study was conducted to: 1) determine the level of complexity of each task and the different aspects of coaching/feedback that should be identified and 2) use electromyography (EMG) to determine the musculature that should be targeted when coaching participants. This pilot study was used to determine muscle recruitment strategies and demands for each task such that the researchers could be more knowledgeable when providing guidance for the feedback provided in the follow up study (Chapter 4).

3.3. Introduction

The prevalence of musculoskeletal injury within the healthcare profession is very high (Dawson et al., 2007) and caregivers experience more injuries than all other occupations (Jaromi et al., 2012; Seidler et al., 2009). In fact, compared with other occupations, nurses specifically have an increased risk of back pain and six times higher prevalence of back injury (Dawson et al., 2007). Additionally, Cohen-Mansfield et al. (1996) found that the period prevalence of back injuries in nursing aides to be 64 compared to a period prevalence of 34 in all other occupations combined in long-term care facilities. Low back disorders (LBD) are amongst the most frequently reported workplace injuries (Tullar et al., 2010). Although the etiology of LBD is complex, including physical, psychological and individual factors (Hinton, 2010), patient handling tasks have been accounted for 73-89% of all low back injuries in nurses (Engkvist et al., 2001). Nurses and other caregivers are exposed to awkward postures during patient handling due to the asymmetry of each patient and the unpredictability of patient movements (Hodder et al., 2010a).

On a daily basis, the lumbar spine is exposed to a multitude of loading combinations including compressive, torsional and shear forces (Gallagher & Marras, 2012). The National Institute for Occupational Safety and Health (NIOSH) suggests a spinal compressive load less than 3400 N as a safe action limit (Jang et al., 2007; Zhuang et al., 1999; Granata & Orishimo, 2001; Gallagher & Marras, 2012). However, many biomechanical models of single person patient handling transfers consistently exceed this limit, even doubling the limit in some cases (Belbeck et al., 2014). For example, a caregiver performing a patient transfer from a supine position on a bed to an upright position in a chair has an estimated peak spinal compressive force of 4751 N, considerably higher than the recommended load (Jang et al., 2007). During a two-person task of rotating a resident to a sitting position on the edge of a bed, the average peak spine compression force was 3487 N (Zhuang et al., 1999). Despite estimated compression being lower when performing a two-person patient handling task, forces on the spine are often still large (Marras et al., 1999). In the study by Marras et al. (1999), both one and two (experienced and inexperienced) caregivers were evaluated during various patient handling tasks. It was found that nearly all of these tasks exceeded either spine compression or shear tolerance limits for safe lifting. Even during the two-person tasks that were investigated, including a manual two-person hook and toss method and a manual two-person gait belt method, shear forces were often greater than tolerance limits of 1000 N (McGill, 1996), despite a relatively light weight patient (50 kg) (Marras et al., 1999). The study by Marras et al. (1999) therefore recommended the use of patient transfer devices as a low back pain (LBP) risk intervention.

Zhuang et al. (1999) reported lumbar compression forces of 2698 to 2951 N when using ceiling lifts, which is much lower than forces found for manual transfers using a basket sling. Although, mechanical lifts are recommended as an important intervention to reduce occupational MSDs (Marras et al., 1999), they are not always deemed feasible depending on patient condition, physical space and time constraints (Hodder et al., 2010b). In fact, in a study surveying registered nurses at a local hospital, Byrns et al. (2004) found that only 11% of the nursing staff reported using mechanical lifting devices on a typical day as most of them complained that these devices were unavailable on the unit. Although the study by Marras et al. (1999) examined peak spinal loads and concluded that mechanical lifts are necessary to have an impact on LBP, the authors did not take into account the increased time associated with the use of mechanical assistive devices. Furthermore, they did not assess changes in cumulative loads caused by the use of mechanical lifts. On the other hand, Daynard et al. (2001) found that the increased time it took to complete patient handling tasks while using assistive devices increased cumulative low back compression. In agreement with these findings, Keir and MacDonnell (2003) found that mechanical lifts typically take more time to use and are associated with greater integrated muscle activity than manual transfers.

There is an abundance of work quantifying large spine loads during different patient handling tasks, however, little has been done to help correct these large spine loads. For the most part, biomechanical studies show that multifaceted interventions can reduce loads on the spine, in turn decreasing the risk of occupational injuries (Pedersen et al., 2004; Jaromi et al., 2012; Warming et al., 2008). Although physical exercise is not considered a multifaceted intervention but has an important role to play as a vital component of an intervention, Pedersen et al. (2004) maintained that it can fine-tune the response to sudden trunk loading among nursing personnel who are typically exposed to trunk perturbations. Exercise is shown to be a learned behaviour that protects the spine by activating the correct muscles surrounding the core of the human body, thus decreasing the load on the low back especially during sudden trunk loading (Pedersen et al., 2004; Jaromi et al., 2012).

Electromyography (EMG) analysis of muscle groups, in addition to the erector spinae, may improve the knowledge of overall muscular loading during various patient transfers. Keir & MacDonnell (2003) investigated EMG patterns during manual transfers (i.e. bed to chair), and transfers using floor and ceiling lifts as well as performed a comparison analysis between novice and experienced participants. The authors found that for both experienced and novice participants, the erector spinae was associated with the highest mean muscle activity. However, Keir & MacDonnell (2003) also discovered that there was increased peak muscular activity of both the latissimus dorsi and trapezius muscles for experienced participants (20-25 %MVC and at or below 40 %MVC, respectively) compared to those of the novice participants (at or below 10 %MVC and over 24 %MVC, respectively). Furthermore, Keir & MacDonnell (2003) explain that this type of physiological adaptation may have been a protective strategy by the experienced participants. In a study by Belbeck et al. (2014), participants gained experience performing patient transfers after a feedback intervention and a reduction in exposure of the shoulder and low back musculature across most measures was found. In a lie-to-sit task, for example, the low back exposure decreased by nearly 20% for mean and peak muscle activity averaged across muscles, supporting the use of the recommended techniques for safe patient handling.

The use of biomechanical analysis, simulation and biofeedback may be a valid tool to aid in the education of safe patient handling activities that reduce low back spinal loads. It is thought that training will also reduce activity in certain muscle groups, such as the low back musculature (i.e. erector spinae), associated with improved kinematics during patient handling activities. It is therefore necessary to understand and confirm the specific muscle groups that are used during patient handling tasks in order to better understand the level of feedback that should be given to nursing students (Chapter 4). The purpose of this study was to perform a preliminary biomechanical analysis by analyzing trunk kinematics and muscle activity in order to determine the type of information that needed to be focused on for each of the patient handling tasks for the main study in this thesis (Chapter 4).

3.3. Methods

3.3.1. Participants

Five female and three male participants (weight: 59.82 ± 15.21 kg.; height: 1.65 ± 0.12 m; age: 22 ± 1.36 years) from the University of Ontario Institute of Technology (UOIT) were recruited to take part in this study. Participants had no known history of low back pain in at least the past 12 months and were recruited from the comprehensive health sciences undergraduate programs through an information poster that was portrayed throughout the UOIT campus. This study was approved by the university research ethics board.

3.3.2. Protocol

Each participant performed four patient handling tasks resembling those most commonly used by nurses, including: 1) reposition patient (Figure 3.0), 2) sling under patient (Figure 3.1), 3) transfer patient from bed to chair (Figure 3.2), and 4) transfer patient from chair to bed (Figure 3.3). Task one consisted of placing a sling under the patient by first rolling the patient onto one side, placing the sling directly underneath the patient's side, rolling them over to the other side, pulling the sling out from underneath the patient and finally placing the patient in a lying position. For task two, participants were instructed to count to three, and with aid from a volunteer, simultaneously move the patient from the bottom to the top end of the hospital bed. For task three, participants were told to lift the patient to have them sit in bed, turn their legs to the side of the bed, lift and move the patient to a sitting position in the chair. Task four was the complete opposite of task three. A standard 50th percentile female patient was used for all transfers. The patient was co-operative, partially-weight bearing and had use of the upper body. Each lifting task was performed for three repetitions and was randomly ordered for each participant. For all four transfers, the hospital bed was adjusted to a level that was comfortable for the participant to perform the tasks.

[redacted] [redacted] [redacted]

Figure 3.0 Task 1 – Repositioning a patient.

[redacted]

Figure 3.1 Task 2 – Sling under patient.


[redacted]

Figure 3.2 Task 3 – Transferring patient from bed to chair.

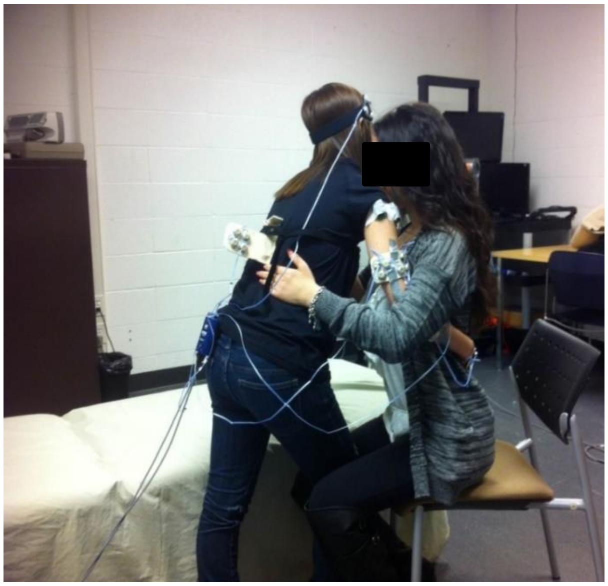
[redacted]

Figure 3.3 Task 4 – Transferring patient from chair to bed.

3.3.3. Surface Electromyography

Muscle activity was monitored using a wireless EMG system (Trigno^{TM}, Delsys Inc., Boston, MA, USA). Eight wireless surface electromyography (SEMG) sensors with parallel bar electrodes separated by a fixed 10 mm inter-electrode distance were used to record, bilaterally from the erector spinae, and unilaterally on the participant’s right side (rectus abdominis, external oblique, anterior deltoid, medial deltoid, posterior deltoid and upper trapezius) (Table 3.0). The skin was prepared by shaving and scrubbing the area with alcohol prior to the placement of each electrode. All electrode placements were confirmed using palpation and manual resistance tests. The Common Mode Rejection Ratio for the system was 92 dB at 60 Hz with an Input Impedance of 10 Ω (Delsys Inc., Boston, MA, United States). All signals were band-pass filtered (20-450 Hz), amplified (Trigno^{TM}, Delsys Inc., Boston, MA, United States) and sampled at a rate of 2000 Hz with a 16-bit analog to digital converter (3D Investigator Data Acquisition Unit, Northern Digital Inc., Waterloo, ON, Canada). Prior to patient handling tasks, maximal voluntary contractions (MVC) were performed for each muscle. Participants were asked to resist against an externally applied force provided by the researcher. In order to prevent muscular fatigue, a minimum of three minutes' rest separated each MVC trial.

The Biering-Sorensen back extension test was used to collect maximum lumbar erector spinae muscle activations. Participants extended against resistance on their shoulders with their body flat on the ground while the lower extremity was fixed. Maximal contractions for the external obliques were accomplished by performing a maximum trunk twisting procedure. The participants were instructed to cross their arms on their chest and while standing, rotate against the resistance applied on the posterior side of the shoulder by the researcher. Maximal contractions for the anterior deltoid were obtained by getting the participants to undergo shoulder flexion while the lab technician resisted. In a similar way, medial deltoid maximal contractions were taken by resisted shoulder abduction. The maximum muscular activation for the posterior deltoid muscle was obtained by getting the participants to push their arm, bent to 90 degrees, back against a wall. Finally, the trapezius muscle was activated maximally by holding down the participants arm while the individual shrugged as high as possible against the resistance.

Table 3.0 Electrode placement for each muscle.

Muscle	**Electrode Location**
Lumbar erector	3 cm lateral to L3 spinous process
Rectus abdominis	2 cm lateral and across from the umbilicus over the muscle belly, parallel to muscle fibers
External oblique	Lateral to the rectus abdominis, directly above the anterior superior iliac spine, half-way between the crest and the ribs, parallel to muscle fibers
Anterior deltoid	Anterior aspect of the arm, ~4 cm below clavicle, parallel to muscle fibers
Medial deltoid	Lateral aspect of the arm, ~3 cm below acromion, parallel to muscle fibers
Posterior deltoid	Posterior lateral surface of the upper arm, 2.5 cm inferior to the posterior margin of the acromion, parallel to muscle fibers
Upper trapezius	Along the ridge of the shoulder, slightly lateral to and one-half the distance between the cervical spine at C7 and the acromion, parallel to muscle fibers

3.3.4. Kinematics

Kinematics were collected using motion capture (3D Investigator, Northern Digital Inc., Waterloo, ON, Canada) sampled at 128 Hz. Custom-molded rigid bodies, containing infrared light emitting markers, were attached to each participant to determine three-dimensional kinematics. These rigid bodies were placed on the hand, forearm, upper arm and inion of the right side as well as the thorax which had markers on the right side from a rigid body that was protruding posteriorly (Figure 3.3). Anatomical landmarks were digitized to create anatomical frames of reference for each segment with joint angles and kinematics measured for biomechanical analysis. Each landmark could then be observed assuming a fixed spatial relationship with the rigid body attached to each body segment. All kinematics were analyzed using Visual 3D (C-motion, V5, Germantown MD, ON) to determine joint angles, velocities and accelerations.

3.3.5. Data Analysis

A root mean square (RMS) smoothing technique (window length 0.13 ms, window overlap 0.06 ms) was used for all EMG signals. For each muscle, muscle activity was normalized to the peak RMS value found during the muscle specific MVC's. Data for each muscle was averaged over the four trials for each participant. Mean muscle activity is presented. Kinematics and EMG of each participant were compared to each other. Note: no statistical tests were conducted. Given the small sample size and that the point of this study was to gain a better understanding of optimal feedback tips, this data was simply used in a descriptive way to guide decisions for study 2 (Chapter 4).

3.4. Results

All EMG results are summarized in Figure 3.4. The rectus abdominis had the lowest average muscle activity throughout all transfers (Reposition: 7.2 ± 1.3 %MVC; Sling under patient: 7.2 ± 1.5 %MVC; Bed-to-chair transfer: 7.7 ± 1.7 %MVC; Chair-to-bed transfer: 8.6 ± 3.2 %MVC). The largest muscle activity was found in the lumbar erectors, particularly during the reposition task (Right lumbar erector: 57.4 ± 6.9 %MVC; Left lumbar erector: 57.4 ± 3.7 %MVC) and in the shoulder musculature, particularly for the posterior deltoid (62.9 ± 11.9 %MVC) and upper trapezius (60.0 ± 15.5 %MVC) muscles during the reposition task. The right and left lumbar erector muscles produced average muscle activations of 57.8 ± 6.8 %MVC and 39.0 ± 5.1 %MVC, respectively. The right lumbar erector muscle had higher muscular activation compared to the left lumbar erector muscle throughout all transfers. During the sling-under task, the right lumbar erector produced 61.9 ± 6.4 %MVC whereas the left lumbar erector produced 23.3 ± 2.4 %MVC. The bed-to-chair and chair-to-bed tasks also produced a similar trend where the right lumbar erector was at 61.2 ± 5.9 %MVC and 49.5 ± 7.6 %MVC, respectively. The left lumbar erector for the bed-to-chair and chair-to-bed tasks produced 36.4 ± 8.1 %MVC and 35.0 ± 6.2 %MVC, respectively.

There were clear differences in muscle recruitment patterns as activity was not the same for the bed-to-chair versus chair-to-bed transfers. The bed-to-chair task had higher muscular activity for the right lumbar erector and the anterior deltoid than during the chair-to-bed task (Bed-to-chair anterior deltoid: 55.7 ± 13.1 %MVC; Chair-to-bed anterior deltoid: 44.8 ± 13.3 %MVC). For the chair-to-bed task there was higher muscle activity for the upper trapezius compared to that of the bed-to-chair task (Chair-to-bed upper trapezius: 44.5 ± 22.8 %MVC; Bed-to-chair upper trapezius: 41.9 ± 12.9 %MVC). The reposition task involved the predominant use of the posterior deltoid (62.9 ± 11.9 %MVC), upper trapezius (60.0 ± 15.5 %MVC) and left lumbar erector muscles compared to the other patient handling tasks. The sling-under condition had the highest activation in the right lumbar erector compared to other patient handling tasks.

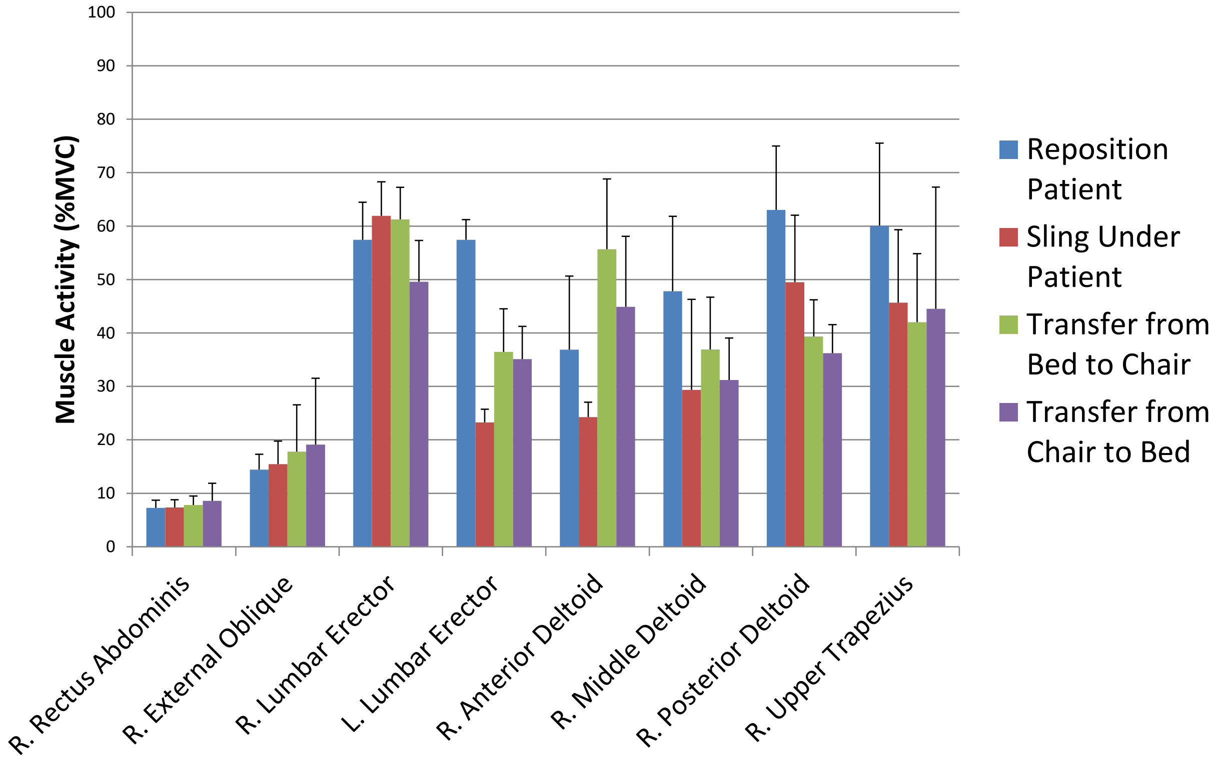

Figure 3.4 Mean muscle activity during each patient handling task.

3.5. Discussion & Conclusion

The nursing profession has been identified as one of the professions at highest risk of musculoskeletal injuries, with patient handling recognized as the leading contributor (Hoozemans et al., 2008). Numerous research studies have concluded that the type of education and training on proper lifting techniques can be ineffective methods of occupational injury prevention (Engkvist et al., 2001; Lagerstrom & Hagberg, 1997; Nussbaum & Torres, 2000). By contrast, other researchers argue that these are important components of injury prevention programmes but only alongside appropriate multifaceted interventions (McGill, Cannon & Andersen, 2014; Garg & Kapellusch, 2012; Nelson & Baptiste, 2006). The current approach of combining continuous EMG and kinematics collection allowed for a better understanding of the muscles used during each patient handling task. As a result, the type of feedback and posture coaching needed to improve body kinematics during each of these tasks could be determined for the full-scale research project, focused on feedback and coaching. This study was used solely to guide the development of appropriate feedback and coaching for the main study in this thesis (Chapter 4) and some valuable insights were obtained.

The results of this pilot study demonstrated that there was low activity found in the abdominal musculature during all of the patient handling tasks when compared to other muscle groups (Reposition: 7.2 ± 1.3 %MVC; Sling under patient: 7.2 ± 1.5 %MVC; Bed-to-chair transfer: 7.7 ± 1.7 %MVC; Chair-to-bed transfer: 8.6 ± 3.2 %MVC). This could indicate the lack of experience and knowledge in safe patient handling tasks for our specific population as the extensors are required to resist the forward bending moment created by flexion of the trunk, and possibly the external task-loads. While no feedback was given during this study, the data portrayed that both the right and left lumbar erector muscles had the highest muscle activity (57.8 ± 6.8 %MVC and 39.0 ± 5.1 %MVC, respectively) during the investigation, regardless of patient transfer task. This overemphasizes the possible risks associated with patient transfers despite being in a laboratory setting with a helpful mock-patient. In fact, a previous study showed that registered nurses rated patient lifting, transferring and turning as the most physically demanding activities specifically to their lower back (Byrns et al., 2004).

High muscle activity in the lumbar erectors, and lower activity in the abdominal musculature, suggests that proper feedback may want to emphasise the utilization of surrounding muscle groups to support and stabilize the spine during various patient transfers. One of the many protective techniques for the spine, apart from stabilizing the core (Richardson et al., 2002), is shown to be leg musculature activation (Hodder et al., 2010b). When transferring a patient from a bed to a wheelchair, it is shown that patient handlers shift their weight between the legs, increasing rectus femoris activation, and in turn decreasing lumbar erectors activity (Hodder et al., 2010b). Therefore, an effective coaching technique would involve discussing the use of leg musculature as a protective strategy to redistribute load away from the lumbar spine, while simultaneously emphasizing spine stabilization via abdominal musculature.

Hodder et al. (2010b) reports peak EMG values that are found to be lower than the current study’s mean EMG values. For example, during the bed-to-chair task, Hodder et al. (2010b) found that novice untrained and novice trained participants produced peak right trapezius EMG values of 50.6 ± 25.2 %MVE and 37.7 ± 20.9 %MVE, respectively. The current study’s mean right trapezius EMG for the same task was found to be at 44.5 ± 22.8 %MVC. Another example is found in both the left and right erector spinae muscles for the reposition task. In the Hodder et al. (2010b) study, novice untrained and novice trained participants produced peak right erector spinae EMG of 40.9 ± 19.5 %MVE and 37.4 ± 17.2 %MVE, respectively. The participants in the current study produced mean right erector spinae EMG of 57.4 ± 6.9 %MVC.

Similar to the current study, novice participants in the Hodder et al. (2010b) study had no previous training in patient handling techniques. The only difference in participants found between the two studies is gender. Where Hodder et al. (2010b) only included female participants, the current study did not, a potential reason towards the higher mean EMG values compared to the peak EMG values in the Hodder et al. (2010b) study. Although Hodder et al. (2010b) had their patients use a transfer belt during the patient transfer from bed-to-chair, Marras et al. (1999) explains that the transfer belt during a single-person lift may have only limited effects on spinal loads and LBP risk. In addition, although Hodder et al. (2010b) demonstrated peak muscle activity of untrained novice, trained novice and experienced participants, the authors showed a small video of the three patient handling tasks that would be performed by the untrained novice participants in the study. This may have had an effect on lowering peak muscle activity, particularly for untrained novice participants, when compared to the mean muscle activity in the current study.

During the repositioning task, participants had increased activity for the posterior deltoid (62.9 ± 11.9 %MVC) and upper trapezius muscles (60.0 ± 15.5 %MVC). There were similar results reported in a study by Keir & MacDonnell (2003) who found that irrespective of the side of the bed or the type of patient transfer, experienced handlers were shown to have higher trapezius activity. It was further explained that this was due to adaptive techniques where shoulder musculature is over-utilized as a protective strategy for the low back (Keir & MacDonnell, 2003). However, asking participants to favour their shoulders while handling a patient can potentially lead to an increased risk of injury to tissues other than those of the low back. Another protective method, particularly for tasks involving a supine patient in bed, Smith et al. (2011) found that as the bed height was raised, the trunk flexion of nursing students at both thoracic and lumbar sites as well as lumbar muscular activation all decreased. Furthermore, in a study by Kee & Seo (2007), it was found that the shoulder was the most prevalent site of injury while the prevalence for the low back was much lower in Korea than that of other countries. Belbeck et al. (2014) found that amongst five patient handling tasks, the sit-to-chair and turn toward tasks were the most demanding for the shoulder.

Given the small sample size and that the purpose of this study was to determine optimal feedback tips, the data was only looked at descriptively to guide decisions for study two. While it was important to investigate the muscles of the upper extremity, EMG was only collected unilaterally due to the limited number of channels available. While no kinematics data was included in this chapter, kinematics was collected using motion capture to ensure correct placement of the cameras for the main study.

This pilot study suggests that the focus for part two, the feedback intervention, should be to observe the lumbar musculature in greater detail during patient handling tasks to aid in the prevention of injury to develop safer patient handling procedures within the healthcare industry. It is crucial to discuss protective strategies for the spine through the use of certain movements and postures in order to decrease lumbar load, and the use leg musculature, particularly when lifting a patient from the bed to the wheelchair. It is also important to minimize lumbar erector activity during other patient handling tasks by adjusting the height of the bed and/or bracing the core. And finally, shoulder musculature should not be ignored, particularly when lifting a seated patient from the side of the bed to the wheelchair.

While most of this could have been predicted from past studies on patient handling, our pilot work ensured that the recommendations transferred to our lab, with our bed, chair and experimental set up. The most effective type of feedback should be determined through varying efficacious studies in the context to assist caregivers, particularly nursing students, prior to full-time employment, in patient transferring tasks. As such, if these tasks can be perfected, nursing students will acquire a set of developed motor skills through various types of patient handling tasks. This could lead to the reduction of spine related occupational MSD. This pilot study, along with a review of the current literature, laid the framework for an evidence based feedback intervention approach that follows in Chapter 4.

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Chapter 4: Manuscript

Investigating the Effects of Posture Coaching and Feedback on Trunk Kinematics during Patient Handling Activities in a Student Nursing Population

Chapter 4: Manuscript

4.1. Abstract

The typical work shift of any type of caregiver is associated with several risks that can lead to musculoskeletal disorders (MSDs). Patient handling tasks account for the greatest contributor towards MSDs among these healthcare workers. The purpose of this study was to determine the effects of a feedback intervention (combined verbal and auditory) on trunk kinematics during simulated patient handling tasks in a student nursing population. Nine student nurses participated. Participants performed three commonly used patient-handling tasks before, during and after an intervention session. The largest reductions in trunk angle, acceleration and velocity were found in the most complex transfer, bed-to-chair. The feedback session improved peak values, and this could suggest that our feedback intervention may help reduce the risk of low back pain associated with patient handling.

Keywords: musculoskeletal disorders; feedback; nurse; patient handling; posture coach

4.2. Preface

The main goal for Chapter 4 was to use the information retrieved from the pilot study (Chapter 3), particularly muscular activation and utilize it in the provision of optimal feedback tips while using the same equipment in the lab during patient handling tasks. Due to several software complications, providing real-time kinematic feedback through the use of Visual 3D (C-motion, V5, Germantown MD, ON) was not possible. Originally, the plan was to provide real-time kinematic feedback via Visual 3D, however an alternative form of feedback (haptic), through the use of the PostureCoach system and a collaboration with Toronto Rehabilitation Institute was established.

4.3. Introduction

The daily routine of caregivers is known to be physically demanding, and the profession has a high risk of musculoskeletal injuries (Tullar et al., 2010). The typical work shift for caregivers can be associated with several known risk factors for injury. Patient handling activities account for the greatest number of loss time claims among healthcare workers (Health Canada [HC], 2004). In a survey of Canadian nurses, 37% said that in the past 12 months they experienced pain serious enough to prevent them from carrying out normal daily activities (Tullar et al., 2010). In 2005, Ontario had about 113,000 nurses which is one-third of the national total. The majority of these nurses (one in three nurses) have said that it is difficult to handle their workload because of their physical health (Shields & Wilkins, 2005). This is not surprising considering the physical demands associated with many patient transfers. Despite all of the efforts made to support nurses and other caregivers, moving an individual can be a high-risk activity and safety is paramount, regardless of the setting. More needs to be done to reduce LBP and improve the safety of caregivers.

Overexertion injuries as a result of lifting, carrying, pulling or pushing, ranked highest in direct costs to businesses in the United States at $13.6 billion dollars whereas indirect costs associated with back injuries were estimated to total $7.4 billion dollars (Rogers et al., 2013). Insurance coverage for back injury in nurses comprises 56.4% of all compensatory costs and 55.1% of all medical costs (Dawson et al., 2007). The issue of back pain in nurses goes far beyond North America and is thus a major concern worldwide (Kaewthummanukul et al., 2005; Smedley et al., 2003; Seidler et al., 2009; Bejia et al., 2005; Alexandre et al., 2001; Pedersen et al., 2004; Dawson et al., 2007). For years, a range of intervention strategies have been used in the attempt to reduce this global issue of musculoskeletal injuries (Hignett, 2003), however injury rates remain high.

Researchers and other professional bodies are continuing to produce guidance on the appropriate biomechanics of patient handling (Marras et al., 2014). Some examples include, but are not limited to: risk assessment, although not an intervention in itself but has an important role to play as a vital component of an intervention (Hoy et al., 2014); education and training (Brown, 2003; Hinton, 2010); equipment evaluation/design (Smith, Nave & Herljac, 2011; Daniell, Merrett & Paul, 2013); work environment redesign (Nelson et al., 2003); review and change of policies and procedures (Dawson et al., 2007); physical fitness training (Pedersen et al., 2004); and feedback (Huang et al., 2012a). Unfortunately, despite the numerous intervention strategies available, the systematic review by Rogers et al. (2013) showed that some of these approaches are not effective and that occupational injury continues to be a persistent and costly problem for nursing staff and caregivers. It is further suggested that training and education must be provided about ergonomic principles and they must be evaluated for successful implementation as a cost-effective option in the workplace (Rogers et al., 2013).

Mechanical patient handling and transfer devices have been a major focus of injury prevention efforts in the healthcare setting (Nelson & Baptiste, 2006). Previous work has evaluated peak spine compression and shear forces during patient handling both in the workplace and in the lab environment. For example, both Holmes et al. (2010) and Village et al. (2005) are infield studies quantifying spine loads. However, the exact manner to reduce these loads on the spine is still unknown. As an intervention strategy for safe patient handling, numerous facilities have implemented “zero-lift” policies, banning manual lifting (Dawson et al., 2007) and implementing the use of assistive devices. Although these mechanical devices can reduce injury risk (Tullar et al., 2010), nurses still perform physical tasks manually as lifting devices take large amounts of time to use, in turn decreasing productivity (Holmes et al., 2010; Keir &

MacDonnell, 2003). Furthermore, Daynard et al. (2001) found that the increased time it took to complete patient handling tasks while using assistive devices increased cumulative low back compression. Both Brown (2003) and Hinton (2010) suggested that a comprehensive safe patient handling program along with policies and procedures that clearly mandate a new method of handling patients is required to ensure success in its application. Without the program, there is no guarantee that the newly implemented policy and procedure will be instilled and utilized on a day-to-day basis in the workplace (Brown, 2003).

Introducing transfer technique with and without the combination of physical fitness training, when compared to a control group, did not show statistically significant differences according to self-reported LBP and days off work (Warming et al., 2008). However, at the same 12-month follow-up, the nurses on the intervention wards had significantly improved their knowledge of transfer technique (Warming et al., 2008). It can therefore be deduced that load on the spine can be decreased through learned behaviour, which is the basis of an effective physical training program (Tullar et al., 2010). Jaromi et al. (2012) also concluded that the effects experienced after participation in the Back School (BS) program can include improved spine function, fewer recurrent LBP episodes and a decreased number of days off work.

Evidence-based safe patient handling techniques and programs have become standard practice in the profession to increase patient handling safety and to minimize the risk of low back injury to caregivers. Despite the lack of success in technique training in most of the articles mentioned in the systematic review by Hignett (2003), giving the correct feedback to the precise demographic in the right setting is important to accurately be determined. According to Wells (2009), in order to successfully implement and ensure sustainability of a specific strategy to reduce MSDs, knowledge and practice gaps must be identified. There is in fact a gap in the training approaches between student nurses and staff nurses in manual patient transfers which crucially needs to be addressed in both the academic and clinical environments (Van Wyk et al., 2010). Mitchell et al. (2009) suggested that because low back pain (LBP) remains prevalent before commencing employment and that changing procedure and motor control techniques for senior caregivers can be difficult, nursing students should be the target of preventative interventions to ensure the effectiveness of its implementation.

Despite the recommendations by Mitchell et al. (2009), there are a few issues related to nursing students and their experiences with lifting tasks as discussed by Swain et al. (2002). The transfer of retained knowledge of the correct patient handling techniques into practice, by more than half of the students deviated from what was taught in training sessions (Swain et al, 2002). This can potentially be due to, what Nussbaum & Torres (2000) explain as, passive instruction, which was criticized for its one-way communication resulting in passive learning without the opportunity for any clarification.

One way to ensure the application of research evidence into practice, Huang et al. (2012a) proposed to construct a training system in nursing faculties in which nursing students can train themselves on their own at any time. Moreover, this training system is recommended for faculties in various institutions and consists of automatic measurements and evaluations on the performance of nursing students doing varying lifting tasks (Huang et al., 2012a). As a result of these analyses, this training system would also provide instructions that can potentially improve these tasks (Huang et al., 2012a). However, despite the complexity of the idea by Huang et al. (2012a), it was also insisted that sufficient training with some type of immediate feedback is important for nursing students to learn and actually utilize the techniques. Nussbaum & Torres (2000) analyzed kinematic differences between passive (i.e. video on safe lifting) and immediate (i.e. training program involving a lecture and practice session) feedback modes. The authors found that the immediate feedback group had larger changes in the included joint angles and horizontal distances than the group following video training, even after a 4-6 week follow-up.

Student nurses are also more likely not to apply the correct patient handling techniques if they were taught in a laboratory (Swain et al., 2002). Immediate feedback given in an authentic or accurately simulated clinical context has a better chance of being used when needed in the workplace (Swain et al., 2002). There is however, a tendency of nursing students to comply with the practices of other staff members in order to be accepted in the ward (Swain et al., 2002). It is therefore suggested that nursing students should be exposed to current technologies available to reduce risk of MSDs in the clinical environment (Nelson & Baptiste, 2006).

Nevertheless, to ensure its application even after being taught in a clinical or simulated environment, immediate feedback on the correct patient handling techniques have been found to be an effective method for increasing preventive work for nurses and other caregivers (McGill et al., 2014). For decades, researchers have found that feedback, such as instruction, audiovisual presentations and simulated practice, provided caregivers the awareness and knowledge of the potential injury risks needed to sustain the prevention of MSDs in their workplace (Menckel et al., 1996; Alavosius & Sulzer-Azaroff, 1986). However, because one of the more recent studies have found that there is in fact a lack of studies analyzing immediate feedback for caregivers (McGill et al., 2014), it is imperative to assess this type of feedback given to the performance of patient handling techniques, particularly by nursing students, in the hope to reduce MSDs in the clinical environment. This research attempts to fill a knowledge gap by evolving our understanding of how to teach safe lifting practices. Experienced nurses perform transfers via techniques developed over time (Holmes et al., 2010). This work will provide simulation based educational practice and biofeedback to a student nursing population, such that optimal handling techniques are implemented at the source. Therefore, the purpose of this work was to investigate the effectiveness of feedback and posture coaching to improve patient handling techniques (trunk kinematics) in a student nurse population.

4.4. Methods

4.4.1. Participants

Nine female nursing students (1.7 ± 0.08 m; 61.7 ± 13.5 kg; 26.1 ± 9.1 years) from the University of Ontario Institute of Technology (UOIT) were recruited to take part in the study. Participants had no history of LBP in at least the past 12 months and were recruited from the undergraduate nursing program through an information poster that was portrayed throughout the UOIT campus (Appendix A). All female students, from first to fourth year in their nursing degree could participate. The nursing program at UOIT involves a wide variety of hands-on experience including clinical placements starting in the first year of the degree. The participants involved in this experiment all received some level of practical work on and off campus, including proper patient handling techniques, despite their year of study. This study was reviewed by and received ethics clearance through the Research Ethics Board.

4.4.2. Protocol

Each participant performed three patient handling tasks: 1) sling under patient (Figure 4.0), 2) repositioning patient (Figure 4.1), and 3) manual transfer of patient from bed to chair, using a standard, mechanically adjustable Hill-Rom Affinity hospital bed (Hill-Rom, Batesville, Indiana, USA) and wheelchair (Figure 4.2). Task one consisted of placing a sling under the patient by first rolling the patient onto one side, placing the sling directly underneath the patient's side, rolling them over to the other side, pulling the sling out from underneath the patient and finally placing the patient in a lying position. Participants were informed that they were not allowed to travel to the other side of the bed during this task. For task two, participants were instructed to count to three, and with aid from a research assistant, simultaneously move the patient from the bottom to the top end of the hospital bed. For task three, participants were told to lift the patient to have them sit in bed, turn their legs to the side of the bed, lift the patient, using their pant waist-line, and move the patient to a sitting position in the chair. A standard patient (73.5 kg, 1.9 m) was used for all transfers. The patient was a co-operative male who was partially-weight bearing and had use of the upper body. Four repetitions of each transfer were completed both pre and post a feedback (intervention) session with rest provided between each condition (Figure 4.4). During the pre-feedback trials, participants were told to perform, to the best of their knowledge, each of the tasks. The tasks under investigation were not randomly ordered and were performed by each participant in the aforementioned sequence (Task 1, Task 2 then Task 3). Participants were only allowed to adjust and set the bed to a comfortable working position at the beginning of each task. The wheelchair was also locked and placed at the correct angle to the bed before Task 3 started, whether for the non-feedback or feedback trials.

Following the pre-feedback trials and a rest period, the intervention session included eight repetitions of each task, in the same order, while a certified personal trainer and ergonomics student provided verbal feedback on posture and lifting mechanics. Examples of the verbal feedback that was given included, but was not limited to: keep patient close, use legs instead of back and keep core engaged. Figure 4.3 demonstrates the visual feedback that was provided to participants to aid in understanding the correct form and technique for the investigated tasks. It has been suggested that a kyphotic-type of curve can increase load on the spine particularly while increasing moment and weight lifted (Briggs et al., 2007). Maintaining a neutral spine while engaging the abdominal region has been found to be an effective protective technique for the low back (Hides et al., 2011). Coaching also included audible feedback as participants flexed their trunk past a 45° threshold, set by the researcher, based on previous literature (Santaguida et al., 2005). Verbal feedback was given after every repetition if improvements were required to be made before the next subsequent repetition. Additionally, participants were asked to adjust and modify posture during lifting techniques, particularly if audible feedback was heard from the 45° threshold. The post-feedback trials followed another rest period and involved the same order of lifting tasks while no verbal or audible feedback was provided.

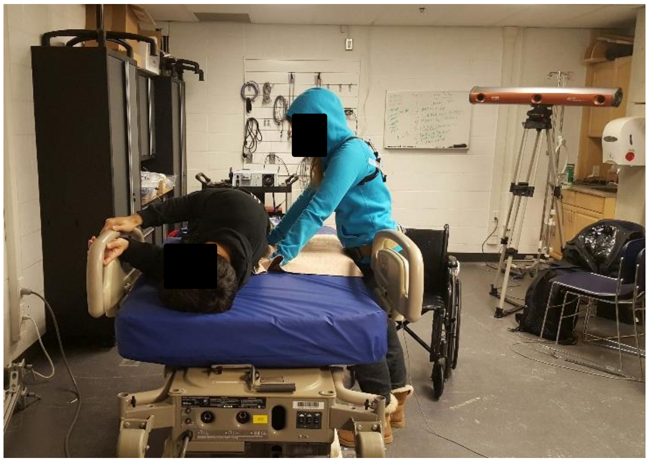


Figure 4.0 Task 1 – Sling under patient.

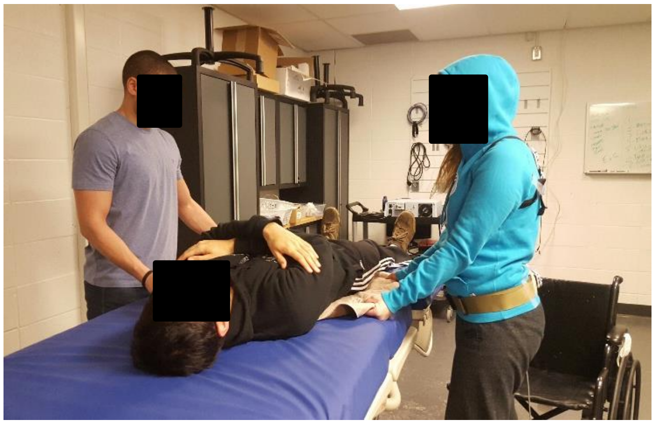


Figure 4.1 Task 2 – Repositioning a patient.

Figure 4.2 Task 3 – Transferring patient from bed to chair.

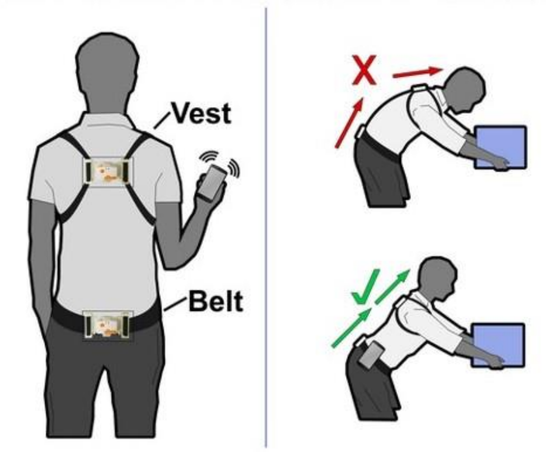


Figure 4.3 Visual feedback provided to participants during the feedback (intervention) session. Each participant was shown this picture with an explanation of the theory behind it. Each participant was coached to avoid overarching the spine and instead to keep a neutral spine posture while engaging the abdominal region. Picture provided by PostureCoach team.

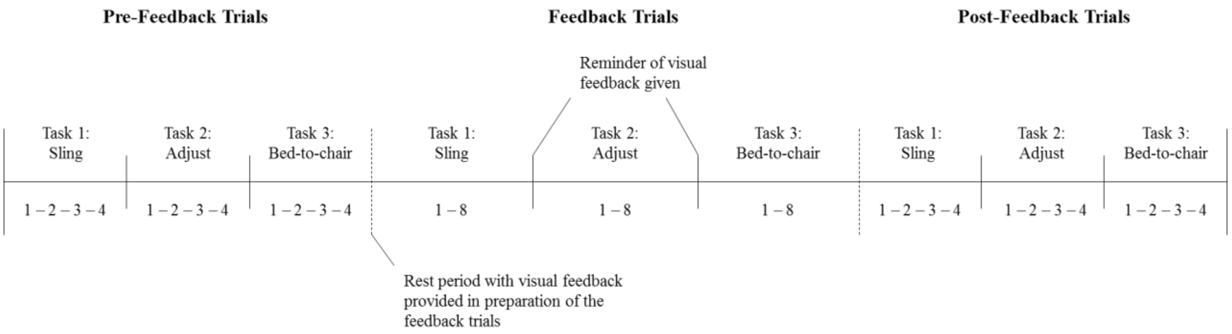


Figure 4.4 Experimental stages indicating the order for each task, pre, feedback and post sessions for each participant.

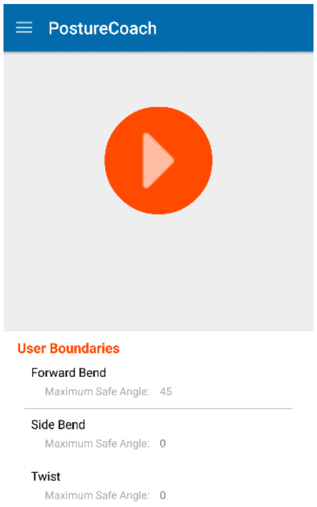
4.4.3. Trunk Kinematics

Kinematics were collected using motion capture cameras (3D Investigator, Northern Digital Inc., Waterloo, ON, Canada) sampled at 128 Hz. Custom-molded rigid bodies, containing infrared light emitting markers, were attached to each participant to determine three-dimensional kinematics. Rigid bodies were placed posteriorly on the pelvic (L5-S1) and thoracic (T3-T4) regions. Anatomical landmarks were digitized to create anatomical frames of reference for each segment with joint angles and kinematics measured for biomechanical analysis. Each landmark could be observed assuming a fixed spatial relationship with the rigid body attached to each body segment. The laboratory coordinate system was defined as flexion-extension (Y), lateral bend (X) and rotation (Z) (Figure 4.7).

4.4.4. PostureCoach

Two accelerometer-based sensors (Shimmer, Dublin, Ireland) were placed under each rigid body and connected via Bluetooth to an Android smartphone (Figure 4.5). Using a custom-made Android application, real time trunk angles could be presented to the participant via smartphone vibration (PostureCoach, Toronto, ON, Canada) sampled at 16 Hz (Figure 4.6). Note that haptic feedback was only turned on during the feedback trials and turned off during pre-and post-feedback trials. Prior to placement on the participant, each accelerometer was calibrated by rotating systematically about each axis. The accelerometers were then fastened in custom made vest-like and belt-like harnesses. Velcro was attached to the top end of the accelerometers and bottom end of the rigid bodies to keep a secure hold of the apparatuses. A rigid object was placed below the belt-like harness to secure the bottom accelerometer in a perpendicular angle to the lab. Tape was then applied to the harnesses surrounding the accelerometers and rigid bodies to avoid potential movement of the sensors while performing the lifting tasks during data collection (Figure 4.7). With the assistance of a volunteer and before every lifting repetition, both the 3D Investigator system and the PostureCoach application were started simultaneously for data collection. Any starting time discrepancy was accounted for during data analysis. Data retrieved from both 3D kinematic trackers were compared throughout the data collection for each participant in order to ensure the reliability of PostureCoach.

Figure 4.5 Accelerometer-based sensor used during data collection.



User Boundaries

Forward Bend
Maximum Safe Angle: 45

Side Bend
Maximum Safe Angle: 0

Twist
Maximum Safe Angle: 0

Figure 4.6 PostureCoach application.

Figure 4.7 Participant wearing vest and belt harnesses securing both rigid bodies and accelerometer-based sensors.

4.4.5. Data Analysis

The total duration for each task, pre-and post-feedback sessions, were calculated for each of the nine participants using Visual 3D (C-motion, V5, Germantown MD, ON) to determine start and end times of each repetition. Sagittal (flexion-extension), lateral (right-left bend) and rotational (right-left twist) trunk angles were analysed (Figure 4.8). This analysis was performed for each task, including those tasks pertaining to the intervention session. Mean and peak 3D trunk angles, velocities and accelerations were calculated for pre-and post-feedback trials as well as the percentage of time spent above the 45° forward flexion threshold. Raw kinematic data was low pass Butterworth filtered using a 6 Hz cut-off. All kinematics were analyzed using Visual 3D (C-motion, V5, Germantown MD, ON) to determine joint angles, velocities and accelerations. Spine angle was measured as thorax relative to pelvis using a Cardan Sequence of Y-X-Z (Figure 4.8). Both trunk velocity and acceleration were subsequently calculated using derivative of angle. Data from the accelerometers (PostureCoach, Toronto, ON, Canada) were analysed in a similar manner for trunk flexion-extension data only.

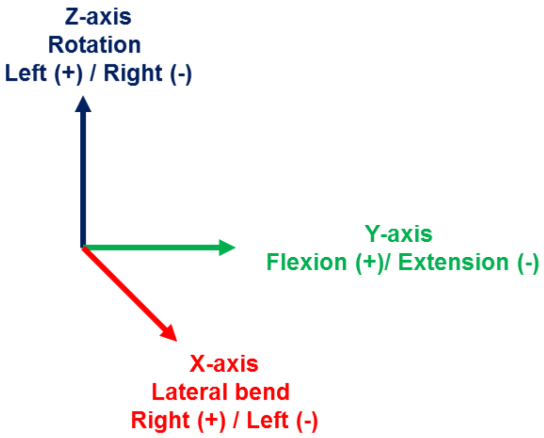


Figure 4.8 Lab coordinate system (forward bend, lateral bend and rotation) of each participant.

4.4.6. Statistical Analysis

A paired sample t-test was used to compare pre- and post-feedback trials for each task ($\alpha = 0.05$). This was performed for angle, velocity and acceleration measures using Excel (2013, Microsoft Corporation, Redmond, WA, USA) with a data analysis tool kit installed.

4.5. Results

Experimental results are shown separately for each dependent measure. Note that pre-and post-feedback trials were analyzed to determine potential differences between the two as a result of the feedback intervention session. The only instance where data from the feedback session is examined is to determine specific effects found within that session. The average experience of our participants was 2.2 ± 1.2 years.

4.5.1. Effects of Intervention on Task Completion Time

Following the feedback intervention, the post sessions demonstrated a decrease in the average time to complete each task, when compared to the pre-feedback sessions (Figure 4.9). The time to complete the repositioning or adjust task was 0.06 ± 0.04 s faster after the feedback intervention (Pre: 4.98 ± 1.20 s; Post: 4.92 ± 1.60 s). The sling-under-patient task had a 3.58 ± 2.53 s reduction (Pre: 31.01 ± 12.34 s; Post: 27.43 ± 10.32 s). There was a significant difference found in the time it took to complete the bed-to-chair task with a 6.23 ± 4.41 s reduction in the post-feedback trials ($p = 0.01$) (Pre: 27.05 ± 7.54 s; Post: 20.82 ± 5.82 s).

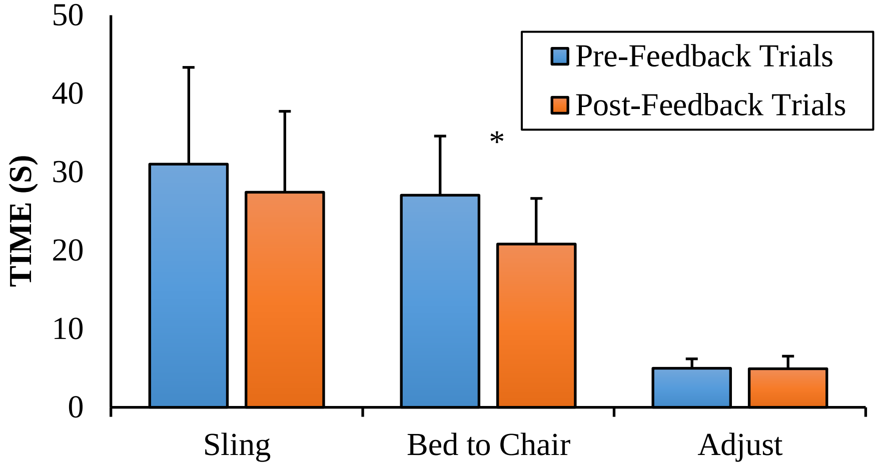


Figure 4.9 The average time (seconds) to complete each task for the pre (blue) and post (orange) feedback trials.

4.5.2. Effects of Intervention on Trunk Angle

Peak trunk flexion was reduced in each of the patient handling transfers after the feedback session (Figure 4.10). The largest reduction was found in the bed to chair condition with a 7.63 ± 0.02° reduction in trunk flexion (*p* = 0.05). The sling under condition had a 4.04 ± 1.82° reduction in trunk flexion and the patient adjustment condition had a 2.10 ± 2.79° reduction in trunk flexion, however these were not statistically different. During trunk extension, there were no differences when comparing pre to post-feedback trials for any of the tasks performed in this study. There were differences between pre and post feedback trials for trunk lateral bend and rotation (Figure 4.11 and Figure 4.12). The largest decreases were found during the transfer of the patient from the bed to the chair. There was a significant 9.43 ± 2.37° decrease in trunk rotation to the left from the pre to post trials for the bed to chair condition (*p* = 0.01) (Pre: 23.62 ± 10.47°; Post: 14.19 ± 7.12°) (Figure 4.12a). For the bed to chair condition, trunk rotation to the right was reduced by 2.65 ± 0.95° during post-feedback trials (Pre: -14.52 ± 4.80°; Post: -11.87 ± 3.45°) (Figure 4.12b). While not significant, there was also reductions in trunk lateral bend to the right of 0.66 ± 0.11° (Pre: 21.65 ± 6.67°; Post: 20.99 ± 6.83°) (Figure 4.11a) and trunk lateral bend to the left of 2.62 ± 1.46° (Pre: -11.15 ± 6.16°; Post: -8.52 ± 4.09°) (Figure 4.11b) for the bed to chair condition.

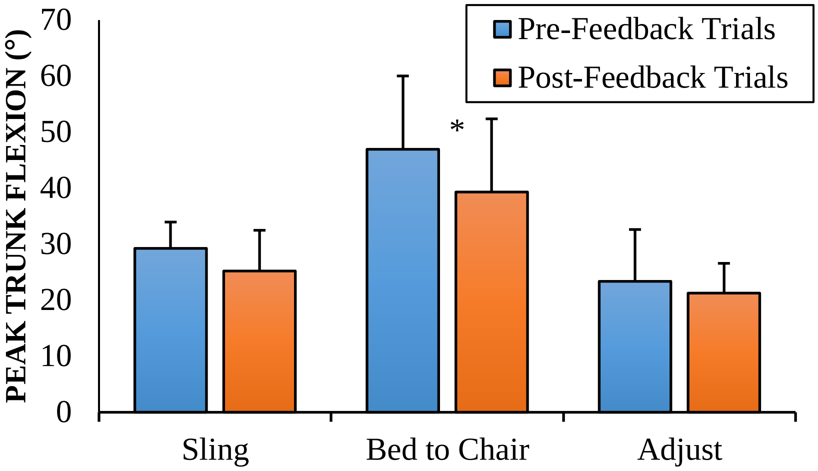


Figure 4.10 Peak trunk flexion (degrees) for the 3 patient transfers for pre (blue) and post (orange) feedback trials.

For tasks one and two, there were small reductions found between pre and post-feedback trials throughout lateral bend and trunk rotation (Figure 4.11 and Figure 4.12). For the sling task, peak trunk lateral bend to the left was significantly reduced by 2.48 ± 0.08° (Pre: -10.97 ± 4.04°; Post: -8.49 ± 3.92°) (*p* = 0.04). For trunk lateral bend to the right, there was a reduction of 1.87 ± 0.33° found in the post-feedback trials during the sling task (Pre: 10.28 ± 3.67°; Post: 8.42 ± 3.20°). Trunk lateral bend to the left decreased by 1.79 ± 0.95° (Pre: -10.50 ± 5.01°; Post: -8.71 ± 3.66°) and trunk lateral bend to the right decreased by 0.55 ± 0.07° (Pre: 4.06 ± 3.10°; Post: 3.51 ± 3.00°) during the adjustment task. Trunk rotation in both directions was also reduced for the sling task, where rotation to the left reduced by 2.03 ± 2.56° (Pre: 22.57 ± 11.77°; Post: 20.53 ± 8.14°) and rotation to the right reduced by 0.39 ± 1.59° (Pre: -19.13 ± 9.43°; Post: -18.74 ± 7.18°). For the adjustment task, trunk rotation to the left reduced by 2.21 ± 0.09° (Pre: 4.59 ± 3.22°; Post: 2.38 ± 3.09°) but remained unchanged for trunk rotation to the right.

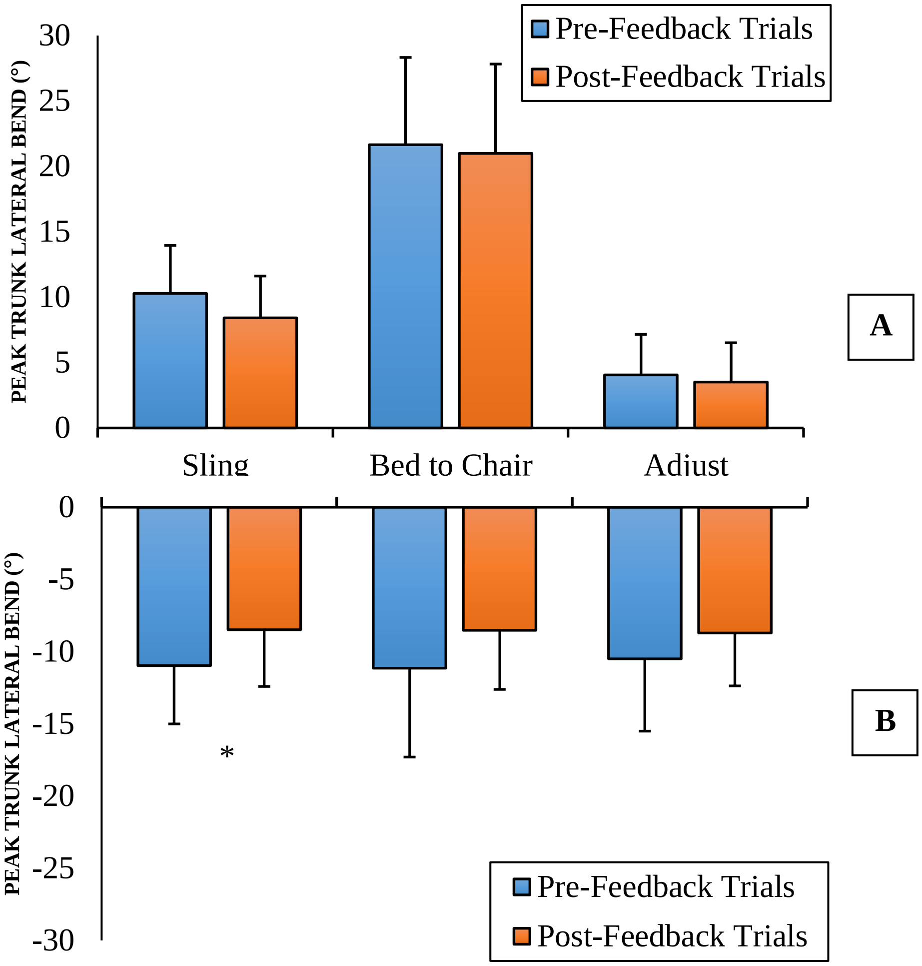


Figure 4.11 Peak trunk lateral bend for pre (blue) versus post (orange) feedback trials. A) peak trunk lateral bend (right) and B) peak trunk lateral bend (left).

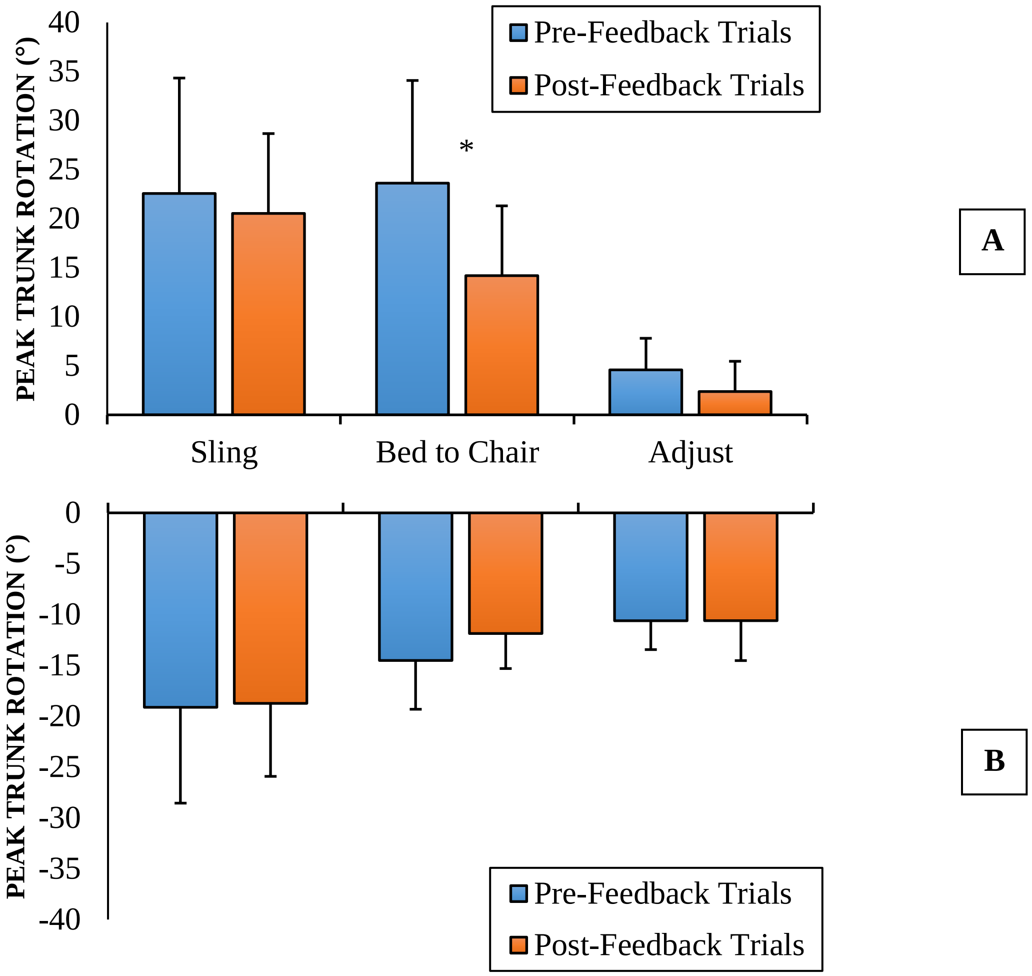


Figure 4.12 Peak trunk rotation for pre (blue) versus post (orange) feedback trials. A) peak trunk rotation (left) and B) peak trunk rotation (right).

4.5.3. Effects of Intervention on Trunk Velocity

Trunk velocity was significantly reduced for the bed-to-chair condition, for peak trunk flexion/extension (Figure 4.13), peak trunk lateral bend (Figure 4.14) and peak trunk rotation (Figure 4.15). For the bed-to-chair task, pre-feedback peak trunk flexion (61.07 ± 8.00 °/s) was significantly greater than post-feedback peak trunk flexion (51.20 ± 12.48 °/s) (p = 0.04). For the bed to chair task, peak trunk extension was significantly reduced by 18.53 ± 3.09 °/s (Pre: -69.47 ± 11.85 °/s; Post: -50.94 ± 16.22 °/s) (p = 0.003). The intervention session also reduced peak trunk lateral bend in both directions for the bed to chair task. For peak trunk lateral bend to the right, trunk velocity was significantly reduced by 11.94 ± 2.54 °/s (Pre: 58.83 ± 10.65 °/s; Post: 46.90 ± 7.07 °/s) (p = 0.003) as for peak trunk lateral bend to the left, trunk velocity was significantly reduced by 19.40 ± 13.72 °/s (Pre: -69.18 ± 15.33 °/s; Post: -49.78 ± 7.26 °/s) (p = 0.003). There was also significant reductions for peak rotation to the left by 17.04 ± 4.58 °/s (Pre: 62.52 ± 14.86 °/s; Post: 45.48 ± 8.38 °/s) (p = 0.01) and for peak rotation to the right by 12.04 ± 1.64 °/s (Pre: -63.99 ± 9.26 °/s; Post: -51.95 ± 11.59 °/s) (p = 0.05), for the bed to chair task. No significant reductions were found for tasks one and two for trunk flexion/extension, trunk lateral bend and trunk rotation velocity.

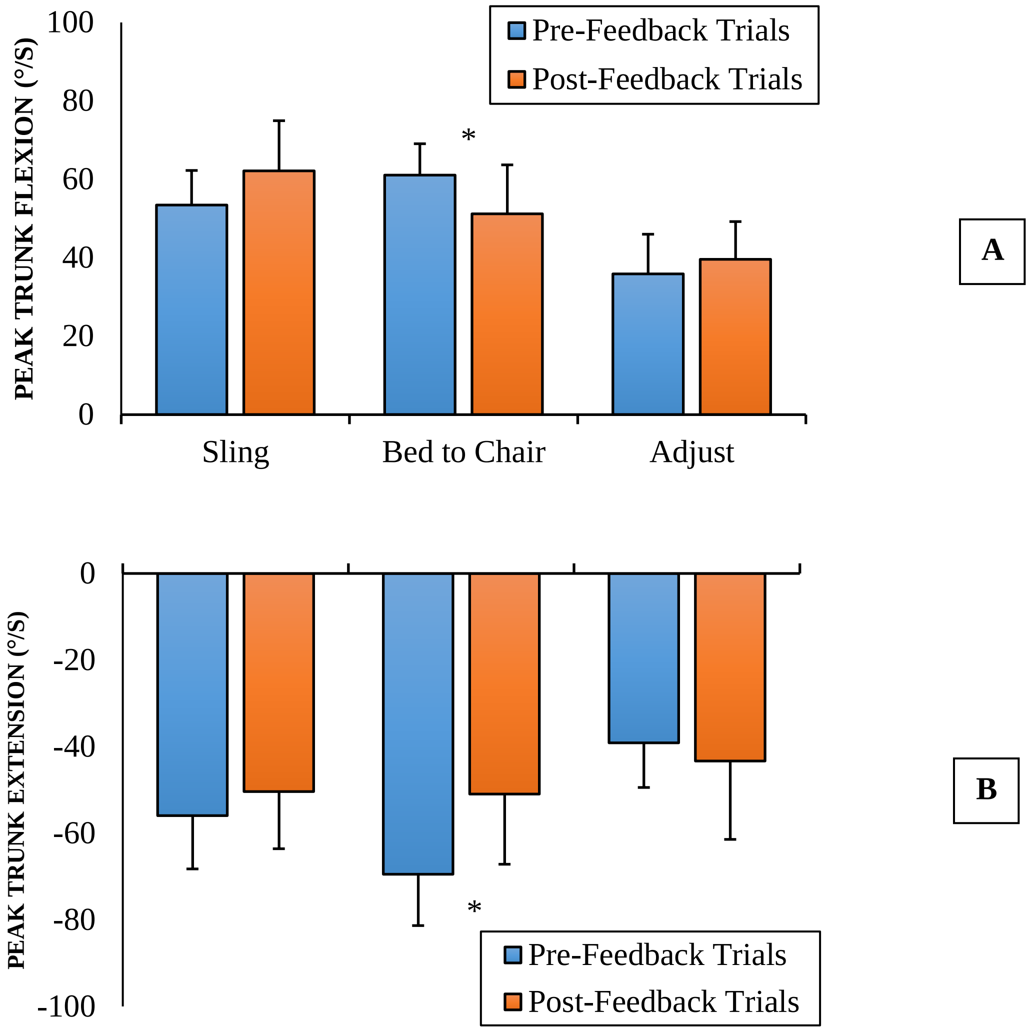


Figure 4.13 Peak trunk flexion (A) and peak trunk extension (B) for the 3 patient transfers for pre (blue) and post (orange) feedback trials.

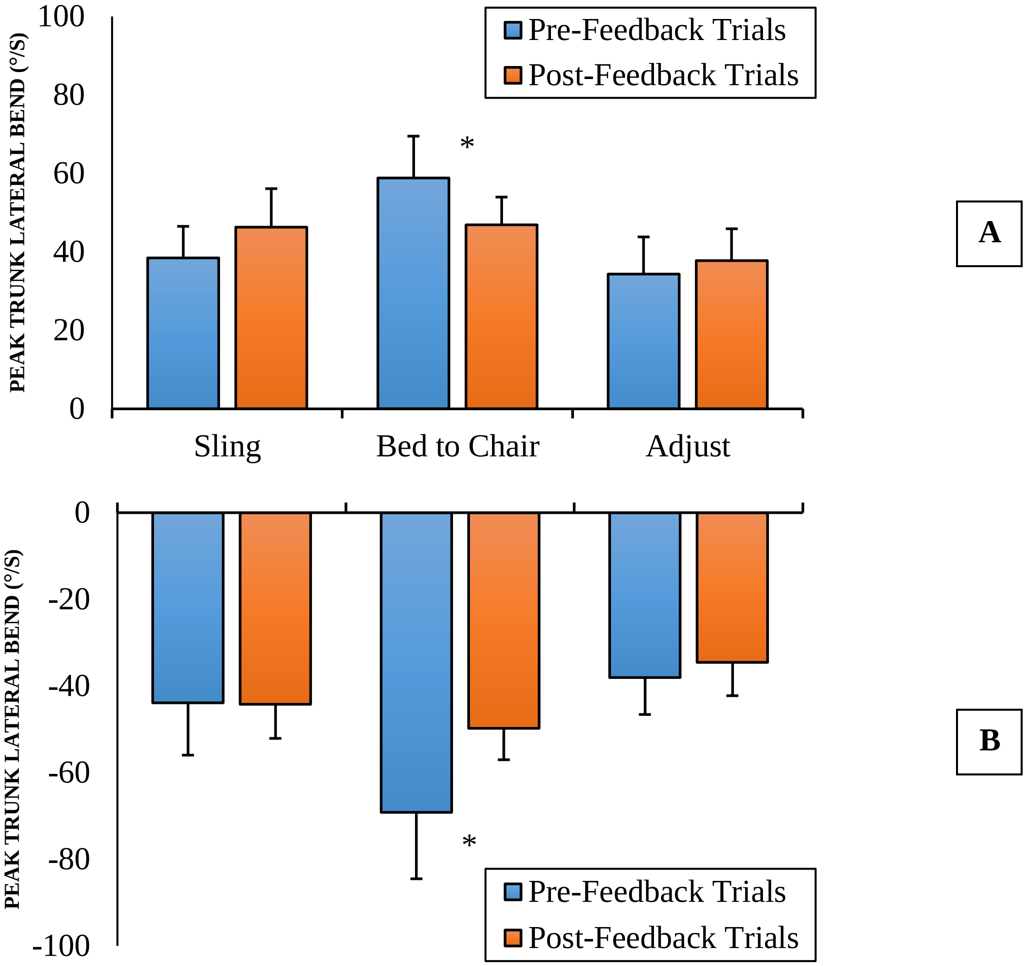


Figure 4.14 Peak trunk lateral bend for pre (blue) versus post (orange) feedback trials. A) peak trunk lateral bend (right) and B) peak trunk lateral bend (left).

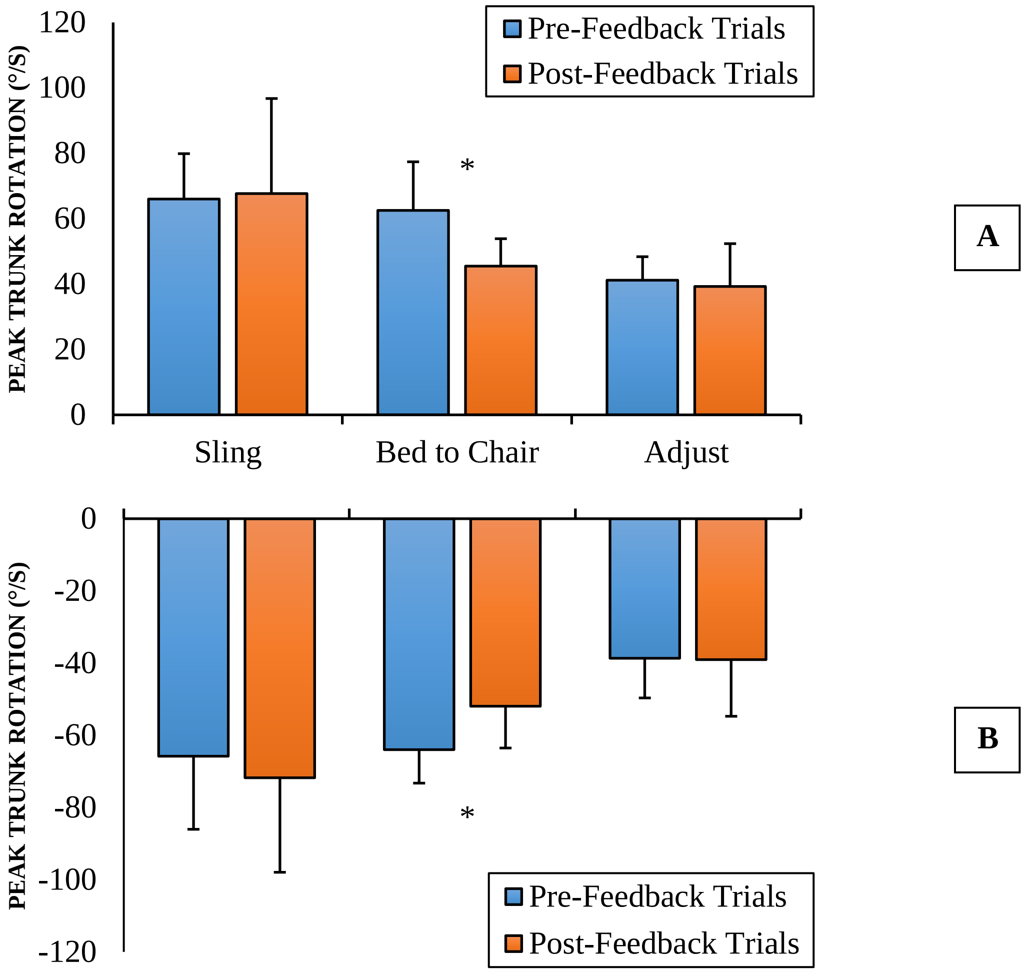


Figure 4.15 Peak trunk rotation for pre (blue) versus post (orange) feedback trials. A) peak trunk rotation (left) and B) peak trunk rotation (right).

4.5.4. Effects of Intervention on Trunk Acceleration

The bed to chair task was the only task to have significant reductions in peak trunk flexion/extension (Figure 4.16), as well as peak trunk lateral bend (Figure 4.17) and peak trunk rotation (Figure 4.18) in both directions. Non-significant reductions were found for tasks one and two throughout all dependent measures. For the bed to chair task, peak trunk flexion was significantly reduced by 1548.18 ± 38.44 $°/s^2$ (Pre: 3302.42 ± 840.76 $°/s^2$; Post: 1754.24 ± 786.40 $°/s^2$) ($p = 0.001$). Peak trunk extension was significantly reduced by 1020.26 ± 73.73 $°/s^2$ (Pre: -3129.69 ± 904.45 $°/s^2$; Post: -2109.42 ± 1008.72 $°/s^2$) ($p = 0.03$). The intervention session was found to reduce peak trunk lateral bend in both directions for the bed to chair task. Peak trunk lateral bend to the right was significantly reduced by 1189.03 ± 38.85 $°/s^2$ (Pre: 3105.64 ± 904.71 $°/s^2$; Post: 1916.61 ± 959.64 $°/s^2$) ($p = 0.01$) and peak trunk lateral bend to the left was significantly reduced by 1472.76 ± 187.48 $°/s^2$ (Pre: -3041.68 ± 925.66 $°/s^2$; Post: -1568.92 ± 660.52 $°/s^2$) ($p = 0.0007$). There were also significant reductions found for peak rotation to the left by 1188.05 ± 142.84 $°/s^2$ (Pre: 2687.31 ± 1050.90 $°/s^2$; Post: 1499.26 ± 848.90 $°/s^2$) ($p = 0.003$) and for peak rotation to the right by 1397.61 ± 1.29 $°/s^2$ (Pre: -2611.22 ± 835.47 $°/s^2$; Post: -1213.61 ± 833.64 $°/s^2$) ($p = 0.001$).

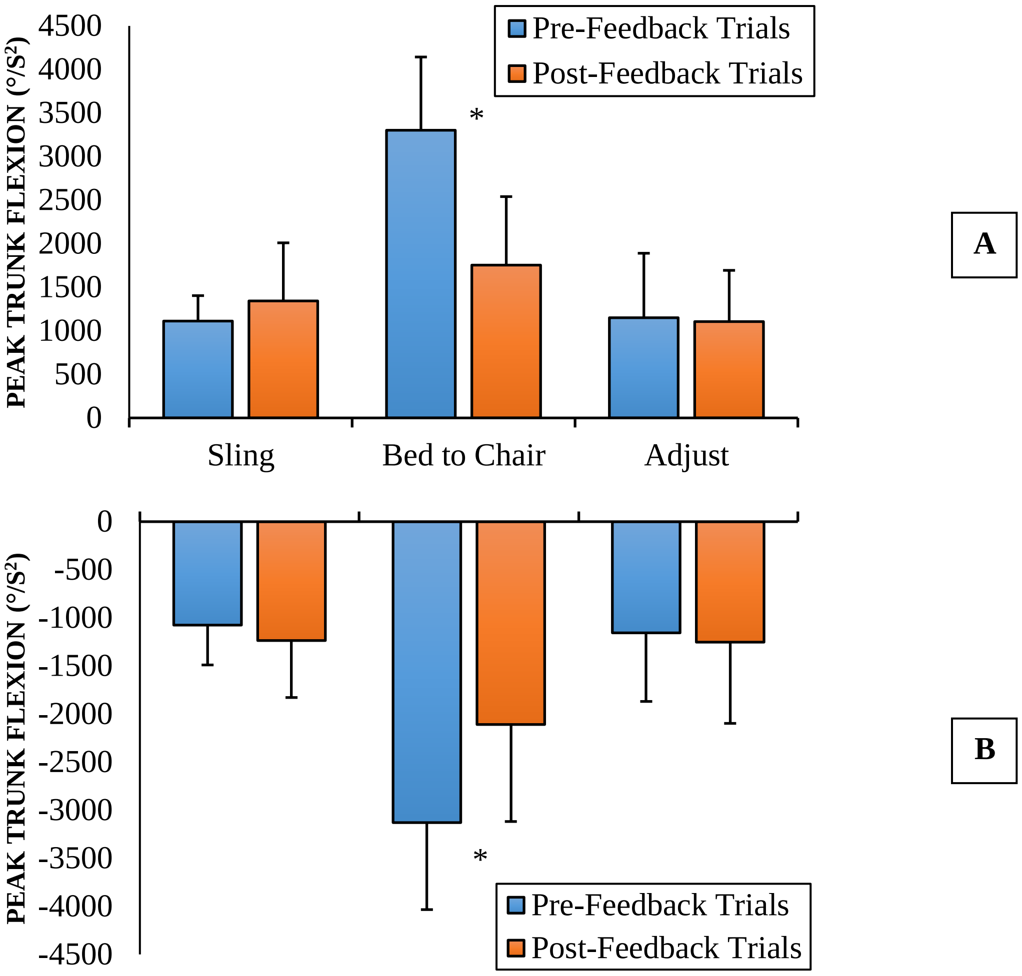


Figure 4.16 Peak trunk flexion (A) and peak trunk extension (B) for the 3 patient transfers for pre (blue) and post (orange) feedback trials.

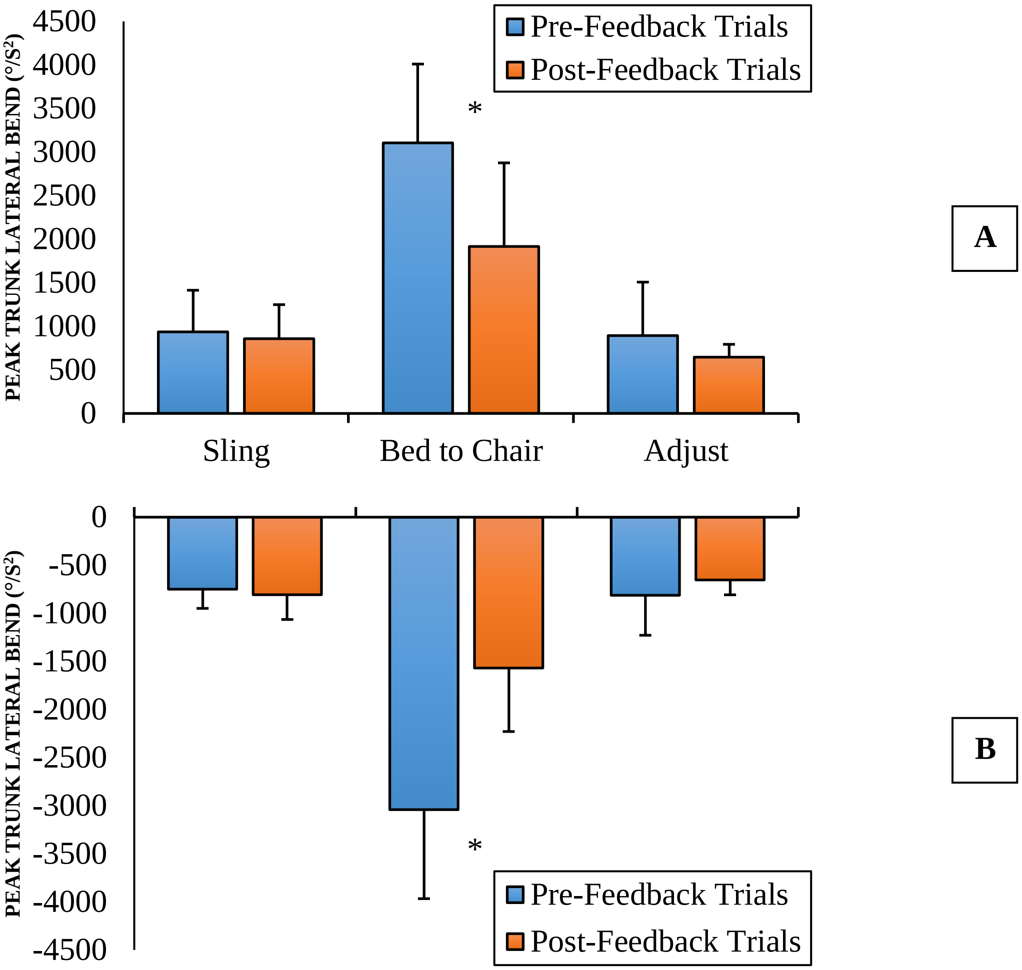


Figure 4.17 Peak trunk lateral bend for pre (blue) versus post (orange) feedback trials. A) peak trunk lateral bend (right) and B) peak trunk lateral bend (left).

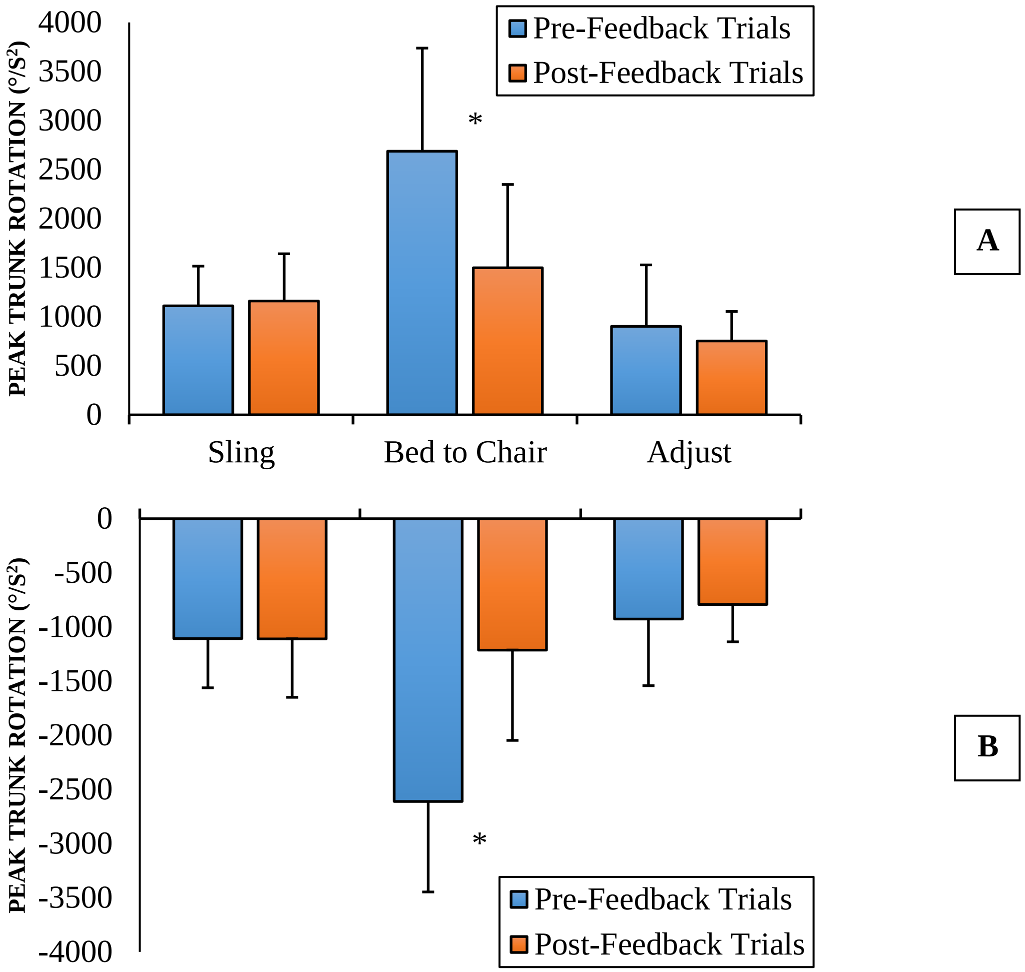


Figure 4.18 Peak trunk rotation for pre (blue) versus post (orange) feedback trials. A) peak trunk rotation (left) and B) peak trunk rotation (right).

4.5.5. Changes in PostureCoach Kinematics

For the bed to chair task, peak trunk flexion was significantly reduced by 21.73 ± 1.23° (Pre: 54.99 ± 8.05°; Post: 33.26 ± 6.31°) (*p* = 0.0002) (Figure 4.20). As for peak trunk extension, there were minor increases found for all tasks except for the sling task where there was a minor decrease of 1.19 ± 2.74° (Pre: -9.05 ± 8.13°; Post: -7.85 ± 4.25°) (Figure 4.19). Peak trunk flexion significantly decreased for the sling task by 6.36 ± 1.09° (Pre: 24.83 ± 3.07°; Post: 18.47 ± 4.60°) (*p* = 0.01). While there was no statistical difference found, there was also a decrease in peak trunk flexion for the adjust task by 2.31 ± 0.26° (Pre: 14.35 ± 2.41°; Post: 12.05 ± 2.78°).

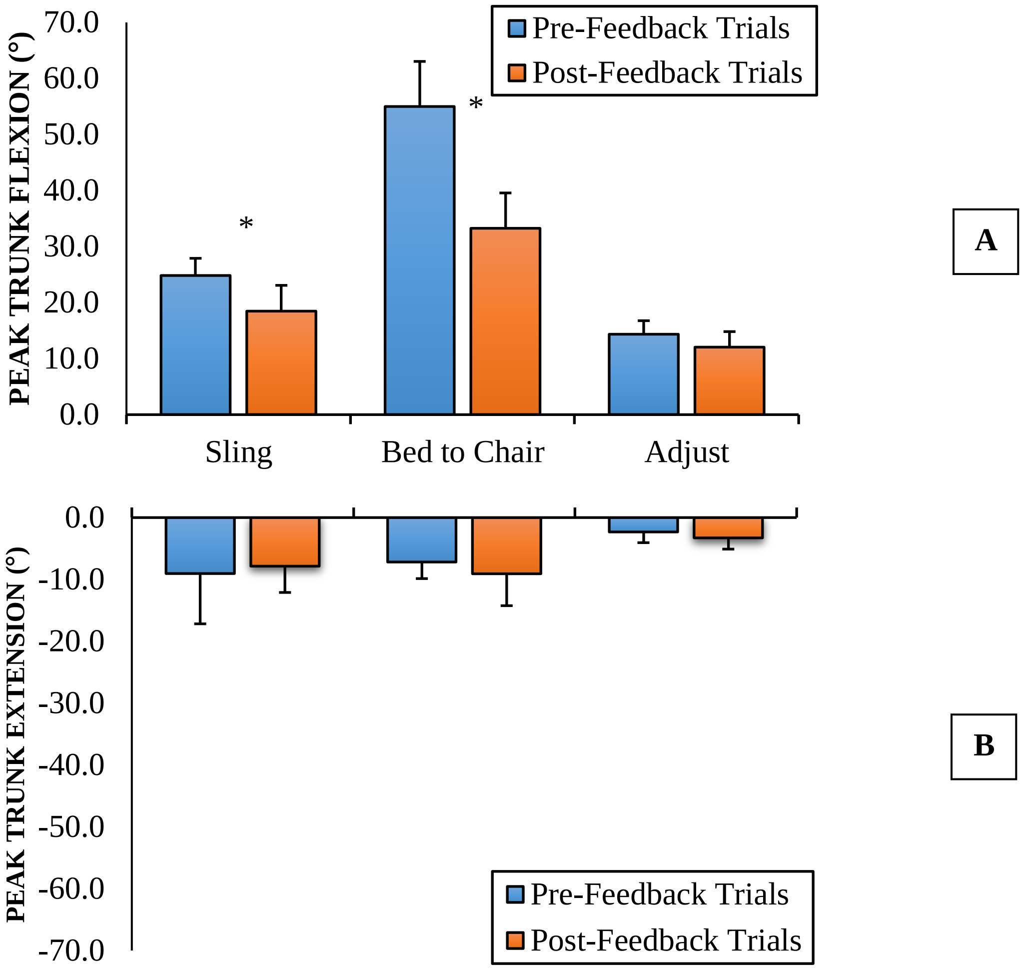


Figure 4.19 Peak trunk flexion (A) and peak trunk extension (B) for the 3 patient transfers for pre (blue) and post (orange) feedback trials.

4.6. Discussion & Conclusion

Despite worldwide attention for more than four decades (Wells, 2009), MSDs have continued to plague the nursing profession (Owen & Garg, 1991). While “no-lift” policies, banning manual lifting, have significantly reduced occupational injuries (Tullar et al., 2010; Zhuang et al., 1999), mechanical devices for patient transfers have not always been deemed effective. These lift assists take large amounts of time to use, in turn decreasing productivity (Holmes et al., 2010) and some institutions may have constraints on economic resources and physical space (Owen & Garg, 1991). Training on safe patient handling techniques has been used as a cost-effective intervention (Brown, 2003; Hinton, 2010). However, Mitchell et al. (2009) suggested that LBP remains prevalent before commencing employment and that changing procedure and motor control techniques for senior caregivers can be difficult. Therefore, our approach is that nursing students should be the target of preventative interventions to ensure the effectiveness of its implementation. This study set out to target a student nursing population with the aim of determining if biofeedback and posture coaching can improve lifting mechanics during simulated patient handing activities. The outcomes of which could be used to provide insight into long term training and retention programs embedded into student curriculum.

Feedback is an important part of motor learning for the fine-tuning of motor skills (Guadagnoli & Lee, 2004). The intervention of coaching and auditory feedback in the current study demonstrated improvements in peak trunk movements during the post-feedback trials for all dependent measures. The largest reductions were found in the most complex task, the bed-to-chair condition. For the bed-to-chair condition, peak trunk flexion angle, peak trunk rotation angle, all peak acceleration values and all peak velocity values were significantly reduced post intervention. Peak trunk flexion angle was significantly reduced by 7.63 ± 0.02° ($p = 0.05$) (Pre: 46.94 ± 13.08°; Post: 39.31 ± 13.06°). Our pre feedback trials are comparable to other studies where researchers found that trunk flexion angles were about 50° for the bed-to-chair task (Garg et al., 1991; Nussbaum & Torres, 2000). Furthermore, Hodder et al. (2010b) demonstrated a reduction in peak trunk flexion, in novice patient handlers, during the bed to chair transfer task of 1.7 ± 0.6° (Pre: 14.9 ± 9.8°; Post: 13.2 ± 9.0°). The large difference in both pre and post intervention values of this article compared to those of the present study for this particular lifting task can be attributed to the use of a transfer belt throughout the data collection. Despite this, from a biomechanical perspective, the feedback intervention session appeared to have an influence on lifting behaviours in our work.

Although there were no significant reductions for the sling and adjust tasks, trunk angles were reduced by 4.04 ± 1.82° and 2.10 ± 2.79°, respectively. Despite the emphasis on posture control, the magnitude of trunk angle changes between pre and post feedback trials were relatively small (<10°). Consistent with results from Nussbaum & Torres (2000), participants performed the investigated tasks in a more upright posture and with a squat-like lifting technique despite the small trunk angle changes. Given the magnitude of cumulative spine loading in nursing however (Daynard et al., 2001), these small trunk angle improvements, for all three tasks, could help lower the risk of back injury. Modifying lifting behaviours should reduce the risk of long-term MSDs. Given that posture greatly influences cumulative spine loading in patient handling (Holmes et al., 2010), the achieved 8-10° changes in trunk posture suggest a more upright and neutral posture that could aid in the reduction of cumulative spine loads and MSDs (Nussbaum & Torres, 2000). It can be further argued that the participants adopted relatively non-extreme postures prior to the feedback session, thus feedback could not substantially alter posture in some cases. After analyzing biomechanical measures using a static model, Nussbaum & Torres (2000) revealed reductions in estimated spinal shear and compression, along with decreases in external moments and increases in strength capability. These biomechanical changes were found even with relatively small (<10°) trunk angle differences (Nussbaum & Torres, 2000), similar to the present study.

The importance of prevention interventions, particularly for nursing students during a transferring technique from the bed, was highlighted in the study by Mitchell et al. (2009). Nursing student participants with and without LBP were compared through several bending related functional tasks and the authors found that participants with LBP modified their postures to potentially protect their spine from re-injury. This type of guarded movement may be the foundation of an appropriate and successful intervention, even for individuals without LBP (Mitchell et al., 2009). In addition, Hodder et al. (2010b) found that direct instruction on patient handling technique resulted in a more neutral spine posture and improved load location. In fact, experienced nurses performed the bed-to-chair lifting task at a peak trunk flexion angle of 10.1 ± 10.6° compared to that of the trained novice participants of 13.2 ± 9.0° (Hodder et al., 2010b), potentially indicating the protective load behaviour of the spine learned over time.

Each participant in our study was encouraged to involve the legs, by shifting weight between the legs, which has been found to promote a more neutral spine (Hodder et al., 2010b). This is further supported by the nursing participants who were found to have significantly lower erector spinae muscle activity and higher rectus femoris activity (Hodder et al., 2010b). During our intervention session, each participant was told to perform a squat-like movement, to prevent a kyphotic curve in the spine, while lowering the patient into the chair. Peak trunk angles were significantly reduced, potentially as a result of utilizing the legs, particularly during the placement of the patient in the wheelchair. Participants were also given cues that involved keeping the patient close and keeping the abdominal region engaged, which has also been shown to aid in the reduction of peak trunk flexion angle (Hodder et al., 2010b). Moreover, literature in the past has shown that trunk flexion angle is a major contributor to back loading and can be a good predictor of injury risk (Hoozemans et al., 2008), therefore peak posture should reflect the largest risk.

For the placing a sling under the patient task, feedback was found to reduce peak trunk flexion. Minor to no reductions in other trunk variables may have been attributed to its simplicity. For example, although each participant had the chance to adjust the bed to a level that was comfortable for them to perform the task before the feedback session, without the help of the researcher or research assistants, the bed height was predominately found to be in the right placement to minimize potential cumulative load on the spine. In other words, training did not substantially alter posture for the sling task because the participants adopted relatively non-extreme postures prior to the feedback session. In fact, Nussbaum & Torres (2000) found that some of their participants were generally already performing patient lifting techniques using their legs which was therefore found to restrict the magnitude of any potential changes due to the feedback session. Some of the cues given during the feedback session included but were not limited to: adjust bed height to hip height, keep abdominal region engaged and minimize a kyphotic-type of curvature in the low back. Although these cues can be helpful in maximizing spinal health and potentially minimizing the risk of MSDs, they had little to no difference in mean and peak trunk values for many of our simulated tasks. Similarly, repositioning the patient from the bottom to the top, or head of the bed, yielded little to no reductions. Again, this may be due to the simplicity of the task. During the feedback session for this particular task, participants were given simple cues including: always use assistance on opposite side of the sling, grasp the sling firmly, have a firm base of support, count to three while swinging to the direction the patient needs to be placed and use the momentum created by the legs to move the patient up the bed. Nursing students are usually instructed to minimize trunk twisting by shifting weight from one leg to the other during this transfer, and our results suggest that they were doing this before the feedback session.

Although the total times to complete each of the three tasks decreased, there was only significant reduction found for the bed-to-chair task (6.23 ± 4.41 s; Pre: 27.05 ± 7.54 s; Post: 20.82 ± 5.82 s; $p = 0.01$). It took the participants less time to complete the bed-to-chair task, while also effectively maintaining correct body mechanics. It can be argued that the participants were already comfortable with the patient handling tasks before the investigation and therefore the results are more likely a consequence of the intervention session (i.e. no learning effect). The participants were more familiar and produced appropriate lifting patterns whilst completing each task more efficiently as demonstrated through the significant reduction in peak trunk flexion particularly for the bed-to-chair task. Although there were no significant reductions for the sling and adjust tasks, total task completion time reduced by 3.58 ± 2.53 s and 0.06 ± 0.04 s, respectively. A reduction in the time component of a patient handling task can translate into lower cumulative spinal loads (Daynard et al., 2001).

Peak velocity showed significant decreases in the post-feedback session throughout all dependent measures, including peak trunk flexion/extension, lateral bend and rotation. During the bed-to-chair task, pre-feedback peak trunk flexion (61.07 ± 8.00 °/s) was significantly greater than during post-feedback trials (51.20 ± 12.48 °/s). These numbers are comparable to the study by Hodder et al. (2010a), where the authors found peak velocities for trunk flexion to be 70.3 ± 14.5°/s over the entire shift of nursing staff during a full complement of tasks. It is postulated that reduced trunk velocity may be a means to reduce the external load moment and thus the resulting forces acting on the spine (Marras & Wongsam, 1986). Marras & Wongsam (1986), found that LBP subjects were shown to exhibit less range-of-motion in the attempt to minimize static load on the spine. When comparing LBP subjects to healthy subjects, reductions in flexion velocity were found to be at least 50% as a result of a combination of trunk flexion and knee bending during certain movements. Perhaps these are the protective motor control changes that the participants utilized in the present study during the post-feedback trials, thereby improving peak trunk velocity. This protective mechanism can be used when implementing training programs on proper lifting techniques for healthy participants in the prevention of MSDs.

Marras et al. (1995) investigated various industrial lifting jobs through three-dimensional angular position, velocity and acceleration characteristics of the spine to determine low, medium and high risk values for MSDs in varying occupations. Peak trunk rotation velocity above 38.0 °/s, 48.5 °/s and 49.7 °/s are considered normative low, medium and high risk of MSDs, respectively (Marras et al., 1995). Our results are comparable to Jang et al. (2007) who found that peak trunk velocity and acceleration for flexion and rotation exceeded low and sometimes high risk groups of normative values. Nursing tasks such as bathing a patient and making the bed resulted in 53.5 °/s and 50.5 °/s peak trunk rotation, respectively, both of which exceed normative high risk group of MSDs (Jang et al., 2007). By contrast, the present study demonstrated a peak trunk rotation velocity of 62.52 ± 14.8 °/s during the pre-feedback trials for the complex bed-to-chair task, which would fall under the high-risk category (< 49.7 °/s) (Marras et al., 1995). However, during the post intervention session, peak trunk rotation velocity for the bed-to-chair task was between the low and medium risk groups (45.48 ± 8.38 °/s). Our work also demonstrated high risk accelerations for peak trunk flexion, rotation and lateral bend for the bed to chair task regardless of pre or post feedback trial. Despite significant reductions found for trunk velocity and acceleration for the bed-to-chair task, participants' movements involved a lot of quick motions, including bending and twisting postures to lift the patient, pivot them and place them in the wheelchair. Marras et al. (1995) found that rapid twisting movements could increase shear or rotational forces that may inflict LBP. However, in the study by Jang et al. (2007), the highest risk was observed for simultaneous lifting and twisting, particularly with straight knees. Therefore, suggesting the use of lower extremity musculature while transferring a patient, particularly from the bed to the wheelchair, can aid in the prevention of shear forces on the spine.

The feedback session in the current study also resulted in a global reduction of peak trunk acceleration for the bed to chair task. Peak trunk flexion and extension acceleration was reduced by 1548 ± 38.44 $°/s^2$ (Pre: 3302.42 ± 840.76 $°/s^2$; Post: 1754.24 ± 786.40 $°/s^2$; $p = 0.001$) and 1020.26 ± 73.73 $°/s^2$ (Pre: -3129.69 ± 904.45 $°/s^2$; Post: -2109.42 ± 1008.72 $°/s^2$; $p = 0.03$), respectively. Peak trunk acceleration lateral bend as well as peak trunk acceleration rotation were also significantly reduced in the post-feedback session for the bed to chair task. Reduced peak trunk acceleration has been found to arise from a change in the motor control strategy of the musculature surrounding the trunk after a feedback session on trunk stabilization (Webber & Kriellaars, 2004). It is further postulated that these changes in the motor control behaviour may be a protective strategy to minimize spine loading as a result of trunk accelerations arising from movements or from unexpected perturbations (Webber & Kriellaars, 2004). It has been found that quick movements (i.e. bending and twisting postures to reach the other side of the bed or bathing the patient) are more likely to pose higher risks in nurses for MSDs (Jang et al., 2007).

The accelerometer-based sensors were connected to a custom-made application that was set at a 45° threshold, where audible feedback was automatically provided to participants if they flexed passed this range during the investigated tasks. According to Schall, Fethke & Chen (2016), nurses are found to be between 20° and 45° for 18%-28% of their typical work day. This 45° limit was therefore set as our threshold to potentially prevent the maximal trunk flexion found in the clinical environment. The accelerometer-based sensors calculated trunk angles via the thoracic sensor relative to the pelvic sensor. Only trunk flexion and extension angles were calculated from the PostureCoach system. The data retrieved from the PostureCoach system was compared with that of the motion capture system. Results demonstrated approximately a 5-10° difference in trunk flexion between the two 3D kinematic trackers. The differences found could have been largely attributed to the movement of the belt-like harness worn by each participant. Although tape was used to ensure the stability of the harness, repetitive movement during the data collection could have shifted the harness and caused the difference in values. Because the PostureCoach system calculated trunk angles as thorax relative to pelvis, the pelvic sensor had to be stabilized by placing a rigid object behind the harness for each participant.

For the bed-to-chair task using the PostureCoach system, pre and post feedback values were found to be 54.99 ± 8.05° and 33.26 ± 6.31°, respectively. Comparatively, the kinematics data for the bed-to-chair task yielded 46.94 ± 13.08° and 39.31 ± 13.06° in peak trunk flexion for pre and post feedback session, respectively. Similar differences were found for both pre and post feedback session between the PostureCoach accelerometer-based sensors and the kinematics data for both the sling and adjust tasks. During the sling task, the PostureCoach system showed pre and post feedback values of 24.79 ± 3.13° and 18.47 ± 4.62°, respectively, while 3D Investigator demonstrated pre and post feedback values of 29.31 ± 4.72° and 25.21 ± 7.33°, respectively. During the adjust task, the PostureCoach system showed pre and post feedback values of 14.42 ± 2.37° and 12.09 ± 2.78°, respectively, while 3D Investigator demonstrated pre and post feedback values of 23.44 ± 9.32° and 21.31 ± 5.29°, respectively. However, it is important to note the relatively large reduction in peak trunk flexion found in the bed-to-chair task using the PostureCoach system (21.73 ± 1.23°; $p = 0.0002$) which was not similar to the peak flexion values of the same task through 3D Investigator. Despite this, it has been suggested that the wearable posture coach system implemented in this study is most effective for novice patient handlers. There is a high possibility that our student nurses were experienced enough in patient handling that the limited feedback may not have influenced their movement patterns to a large extent.

It has been suggested that a kyphotic-type of curve can increase load on the spine particularly while increasing moment and weight lifted (Briggs et al., 2007). Maintaining a neutral spine while engaging the abdominal region has been found to be an effective protective technique for the low back (Hides et al., 2011). Verbal feedback was given after every repetition if improvements were required before the next subsequent repetition. Some examples on training individuals to improve lifting posture and subsequently decrease load on the spine retrieved from previous research in the field included minimizing the moment arm between participant and patient during the transfer process (Briggs et al., 2007), adjust bed height to hip height (Smith et al., 2011) and using the legs while maintaining a neutral spine, particularly when lowering the patient into the chair after transferring them from the bed (Hodder et al., 2010b). Although the PostureCoach system demonstrated a significant decrease in peak trunk flexion (not extension) for the bed-to-chair task, it is difficult to differentiate whether the participants improved their postures based solely on auditory (haptic) feedback or verbal cues.

There are a few limitations that should be considered when interpreting and applying the findings. Each participant was limited to approaching the right side of the bed for each task. This may have influenced self-selected lifting techniques. However, according to Keir & MacDonnell (2003), similar muscular activity levels are produced irrespective of the side of the bed used and kinematics would likely be similar. Second, student nurses may have been more aware of their posture as a consequence of being observed in an ergonomics lab than in the clinical environment. As a result, this may have changed their lumbar motion, and even change their muscular activity, which can potentially be non-representative of occupational settings. Third, although there was only one patient used for all tasks, he was partially-weight bearing which could have helped to decrease loading on the spine. Fourth, the peak values retrieved from the PostureCoach system were not similar to those of the 3D Investigator, therefore indicating that the auditory feedback from the accelerometer-based sensors had minimal effect towards the reductions found post feedback session. Fifth, it is unknown whether the participants retained the knowledge of correct lifting tasks past the investigation day. Future work should include investigating retention levels of the equipment in question and determining learning retention during a follow-up period. With that being said, the sixth point involves the eight repetitions used during the feedback session. Although the results suggest that feedback can modify lifting techniques in an intended manner, it is unknown whether the eight repetitions completed yielded retainment of motor control strategies during the lifting tasks.

In summary, this study suggests that feedback given during lifting tasks can have an effect on some lifting behaviors and is shown to be a very important part of learning and fine-tuning motor skills. It provided assistance in improving the lifting and transferring techniques of the student nurses in turn protecting the spine from injury. The feedback intervention session reduced trunk angle, velocity and acceleration, thus likely helping reduce the load on the spine and future injury risk in these student nurses. Due to scheduling constraints, some nurses perform patient tasks, such as bathing and lifting the patient, quickly which consequently poses a risk on the low back (Jang et al., 2007). These rapid types of movements can cause stress and fatigue (Garg, Owen & Carlson, 1992), disc prolapse (Kelsey et al., 1984) and generate and increase shear or rotational forces (Marras et al., 1995) which can each increase the risk of developing MSDs. We found that a combination of auditory feedback and coaching lead to improved spine postures (closer to neutral). There is a continuing need to ensure that caregivers are properly trained to protect themselves and their patients during patient handling tasks when assistive devices are not available such as in transferring a patient from the bed to the wheelchair. Issues such as assessing long-term retention levels of feedback, performing a comparison analysis between novice (1st year) and experienced (4th year) nursing students, onsite evaluation focusing on the percentage of time spent above/below the feedback threshold of trunk angle, and evaluating other susceptible joints such as the shoulder should be further evaluated.

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Chapter 5: Conclusion and Limitations

The purpose of this work was to investigate the effectiveness of feedback and posture coaching to improve patient handling techniques (trunk posture) in a student nurse population. The prevalence of injury in nurses remains high despite the vast research done on this topic. Most recommendations to reduce injury risk during patient handling has focused on mechanical lifts (Tullar et al., 2010; Dawson et al., 2007). However, the poor ratio of nurses per patient in many hospitals appears to have a negative influence on mechanical loading device use. A recent article suggested that lifting devices take significantly more time than manual patient transfers (Koppelaar et al., 2012); an important factor towards the disuse of assistive lifts. Therefore, this study encapsulated the essence of where the problem arose in the first place.

In order to effectively implement proper lifting techniques before the incidence of LBP, Mitchell et al. (2009) suggested that because this MSD remains prevalent before commencing employment, nursing students should be the target of preventative interventions. Moreover, as it is suggested that experienced nurses develop proper lifting techniques over time (Holmes et al., 2010), it was proposed that feedback and training as an ergonomic aid would assist in the prevention of MSDs in student nurses. In order to effectively demonstrate the appropriate lifting techniques, student nurses were the primary target for this study so that as a result, these techniques would be instilled in the clinical environment.

A pilot study (Chapter 3) was conducted in order to determine feasibility, time, cost, and effect size. It involved looking at various patient handling tasks and the musculature demands associated with each. This was done to establish a framework of not only the most physically demanding tasks, but the tasks that may best be suited to feedback training. It allowed the researchers to gain a better understanding of the most common patient handling activities and how they are typically performed in the workplace. This pilot study was used to determine muscle recruitment strategies and demands for each task such that the researchers could be more knowledgeable when providing guidance for the feedback provided in the full-scale research project (Chapter 4).

Overall, the main study (Chapter 4) suggested that feedback given during lifting tasks can have an effect on some lifting behaviors. Despite the lack of a control group or retention assessment, the eight repetitions given during the feedback intervention session reduced trunk angle, acceleration and velocity, thus likely helping reduce the load on the back and injury risk in nursing students. The largest reductions were found in the most complex task, the bed-to-chair condition. Nursing student participants performed the investigated tasks in a more upright posture and with a squat-like lifting technique despite the small trunk angle changes (<10°). Even with these small trunk angle improvements, for all of the investigated tasks, the modification of lifting behaviours should reduce the risk of long-term MSDs (Nussbaum & Torres, 2000). During the sling and adjust tasks, training did not substantially alter posture because the participants adopted relatively non-extreme postures prior to the feedback session. Although there were no significant reductions for the sling and adjust tasks, total task completion time reduced, which can translate into lower cumulative spinal loads (Daynard et al., 2001).

The accelerometer-based sensors were set at a 45° threshold, to prevent the maximal trunk flexion found in the clinical environment based on previous literature (Schall et al., 2016). Data retrieved from these sensors were not similar to the results from the three-dimensional motion capture system. Therefore, despite the significant reduction in trunk flexion angle for the bed-to-chair task, the auditory feedback from the accelerometer-based sensors may have had minimal effect towards the reductions found.

Student nurses appeared to have retained the training as their kinematics were improved. Because LBP remains prevalent before commencing employment (Mitchell et al., 2009), nursing students should continue to be the target of preventative methods to ensure the effectiveness of implementing the intervention. There is a continuing need to ensure that caregivers are properly trained to protect themselves and their patients during patient handling tasks when assistive devices are not available such as in transferring a patient from the bed to the wheelchair.

Chapter 6: Future Directions

In summary, the current study suggests that feedback on modifying lifting behaviours can have an effect on improving patient handling tasks. The pilot study (Chapter 3), while preliminary in nature, provided important additions towards determining the level of complexity of each task and the different aspects of coaching/feedback that should be identified. This small-scale research study also helped, through the use of EMG, to determine the musculature that should be targeted when coaching participants for the main study (Chapter 4). Despite the lack of a control group or retention assessment, the eight repetitions given during the feedback intervention session reduced peak trunk angle, acceleration and velocity, thus likely helping reduce the load on the back and injury risk in nursing students.

Future work should include investigating a wide range of experienced nurses, from first year students to fourth year students in varying institutions to determine the effectiveness of the equipment. It is important to not only assess kinematics but also EMG in a controlled laboratory environment. By analyzing mean, peak and cumulative EMG of certain muscle groups (i.e. erector spinae, rectus femoris, rectus abdominis, latissimus dorsi, trapezius and deltoids) during specific patient handling tasks, differences in experience level can be found. In fact, after comparing experienced to novice patient handlers, Keir & MacDonnell (2003) found that experienced handlers had higher mean and peak latissimus dorsi and trapezius activity. In addition, analyzing EMG activity can also help in determining certain protective strategies that are already used by experienced patient handlers. This type of information can be useful in providing a more successful intervention for novice patient handlers in order to prevent long-term MSDs. Modifying lifting behaviours through the use of EMG can potentially reduce compressive forces on the spine and decrease erector spinae activation while increasing the activation of other muscle groups as a protective strategy. Analyzing more than eight repetitions during a feedback intervention session can further emphasize change in EMG and calculated spine loads. More repetitions and a second training day could also provide valuable information into the possible retention of the ergonomic intervention.

It is also important to investigate these dependent measures in a clinical setting during a typical work-shift or practicum work. Assessing motor control strategies and lifting patterns of caregivers during the normal workday in varying health care facilities is required in order to improve and define a concrete intervention, particularly for nursing students. This will not only improve the type of feedback given to nursing students during their lifting tasks but also help determine the risks, which may not even pertain to lifting tasks, which need to be avoided or improved in the clinical environment. A follow-up period is crucial to determine long-term retention levels of each participant post-intervention session. Modifying lifting behaviours should reduce the risk of long-term MSDs. Ideally, these tasks will be perfected, nursing students will acquire a set of developed motor skills through various types of patient handling tasks and more importantly, occupational MSD injury risk will be widely reduced.

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