# USING BIOMECHANICAL, PHYSICAL ACTIVITY, AND PHYSICAL FITNESS MEASURES TO EVALUATE RISK OF DEVELOPING A LOW BACK INJURY IN A NURSING STUDENT POPULATION

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# Abstract

Recent research has suggested that physical fitness, physical activity, and biomechanical factors relate to low back injury development. However, these works used established workers (including practicing nurses), making it difficult to identify potential predisposing characteristics that could be targeted in preventative efforts. Likewise, fourteen female nursing students were assessed using six biomechanical, two physical activity, and three physical fitness variables. Participants were grouped based on transient pain development, an established predictor of increased low back injury risk, during the 60 minute data collection. Transient pain developers (n=6) had reductions in some physical fitness and biomechanical variables (muscular strength, endurance, postural stability, and lumbopelvic control) but had no differences in any of the physical activity variables. These findings suggest improvements in physical fitness and/or the biomechanical variables have potential in nursing students to reduce their transient pain development, which may reduce their risk of developing a future low back injury.

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## List of Acronyms and Abbreviations

| | |
|---|---|
| AHAbd: | Active Hip Abduction Test |
| ASLR: | Active Straight Leg Raise Test |
| BL: | Bottom-left Corner (Wii Balance Board™) |
| BR: | Bottom-right Corner (Wii Balance Board™) |
| COP: | Centre of Pressure |
| ICC: | Intra-class Correlation Coefficient |
| IPAQ: | International Physical Activity Questionnaire |
| LBP: | Low Back Pain |
| MET: | Metabolic Equivalent of Task |
| MPH: | Manual Patient Handling |
| NSQ: | Nursing Student Questionnaire |
| ODI: | Modified Oswestry Low Back Pain Disability Index Screening Tool |
| PA: | Physical Activity |
| PD: | Transient Pain Developer |
| PF: | Physical Fitness |
| ROM: | Range of Motion |
| TL: | Top-left Corner (Wii Balance Board™) |
| TR: | Top-right Corner (Wii Balance Board™) |
| VAS: | Visual Analog Scale |
| WBB: | Wii Balance Board™ |

## **1.0. Introduction**

Low back pain (LBP) was identified by the World Health Organization as the most prevalent cause of disability worldwide (Driscoll et al., 2014). Occupationally, LBP affected the mental and physical health of employees (Marras & Karwowski, 2006) and created a social and economic burden. LBP affected the nursing workforce more than any other occupation in Canada (Shields & Wilkins, 2006), with Canadian female nurses experiencing LBP at an incidence rate significantly higher than male nurses, as well as of either sex in any other occupation. The high incidence of LBP caused absenteeism and reduced productivity by nurses who failed to report LBP (Callison & Nussbaum, 2012), both of which potentially reduced patient quality of care. Likewise, it is important to continue to investigate LBP in the nursing occupation, in efforts to reduce the impact on the workers and patients.

The high prevalence of LBP in nurses was attributed to the high physical demands of common work tasks observed in the nursing occupation (Jang et al., 2007). Despite numerous successful ergonomic improvement that have reduced the work related demands (especially relating to manual patient handling or MPH detailed below), nurses continued reporting more strenuous, activity-limiting job situations than any other occupation in Canada (College of Nurses of Ontario, 2015). MPH tasks have been associated with LBP (Yassi & Lockhart, 2013), as they sometimes require heavy, sudden, and/or unpredictable spine loading, often while in deviated spine postures (such as flexed combined with axially rotation). These type of exposures are very difficult to improve using only changes to work design (i.e. ergonomic approaches), and often are unavoidable. Aside from MPH tasks, nursing also involves prolonged standing (Omokhodion et al., 2000) which has been associated with the development of LBP (Chung et al., 2013; Nelson-Wong & Callaghan, 2010; Nelson-Wong et al., 2009). Again, controlling this exposure (duration and frequency) has proven difficult across the various nursing environments (and related work requirements). Recent research with physical activity (PA), physical fitness (PF), and biomechanical measures had some success in distinguishing working nurses with and without recent low back injuries (Babiolakis et al., 2015). Given the consistently high demands associated with nursing and the limitations ergonomic approaches face in reducing these demands, investigating whether these PA, PF, and biomechanical measures are related to the risk of developing a low back injury before injuries occur has significant merit.

Support for examining PA, comes from research showing both a lack and excess of PA were associated with the development of LBP through disuse and overuse mechanisms, respectively (Auvinen et al., 2008). This association between PA and LBP has also been observed using self-report questionnaires (Craig et al., 2003) and tri-axial accelerometer (Van Weering et al., 2009) data, but further investigation is still required amid contradicting evidence (Lela & Frantz, 2012). Babiolakis et al. (2015) observed that recently-injured nurses were less active per work shift than unaffected nurses. However, these results were interpreted with caution, and investigators questioned whether the data had been impacted by a potential "survivor effect" and or side-effect of nurses avoiding absenteeism despite their impaired capacity.

While some research has related PA to LBP, other evidence has suggested that improvements in PA protect against occupational LBP only when the improvement yielded simultaneous improvements in PF (Heneweer et al., 2012). This observation, as well as other PF research (Taanila et al., 2012), suggested that PF improvements might protect against occupational LBP. Previous studies have down that LBP has been associated with muscular strength (Besler & Can, 2003), muscular endurance (Mitchell et al., 2009), and muscular flexibility (Halbertsma et al., 2001). In a comparison of PF variables between recently-injured working nurses and unaffected controls, Babiolakis et al. (2015) observed no differences in muscular strength, endurance, or in flexibility. However this may be due to the use of working nurses as participants, where work experience and variable work-related exposures may have impacted the potential role of PF to reduce LBP. Again, further research is required given the mixed evidence of a relationship between LBP and PF.

Other than analyses of MPH tasks and other work-related variables, biomechanical variables were rarely examined in working nurses. In a field study, Jang and colleagues (2007) observed that the main nursing work-related risk factors for developing a low back injury included trunk moment and trunk axial rotation during MPH tasks as well as the weight of the patient being assisted. Assistive lifting devices and a two-person lifting strategy were mandated to reduce the incidence of occupational low back injury (D'Arcy et al., 2012), but were both unsuccessful due to time constraints and a lack of device accessibility (College of Nurses of Ontario, 2015). While there is plenty of evidence that MPH tasks directly caused low back injuries in working nurses, many other risk factors were identified in regular nursing work tasks (Jang et al., 2007). Trunk range of motion (ROM) (Biering-Sørensen, 1984), lumbopelvic control (Hodges & Moseley, 2003), and postural control (Panjabi, 2003) have all been associated with LBP in non-occupational populations. Differences in lumbopelvic control were observed between recently-injured and unaffected working nurses (Babiolakis et al., 2015), which suggested that biomechanical factors are worthy of further investigation as potential risk factors for occupational LBP. Therefore, it would likely be beneficial to assess functional biomechanical factors of nurses to examine potential risk of future occupational low back injury.

To determine which PA, PF, and biomechanical measures may related to reducing the risk of developing a low back injury before injuries occur, a method to identify an individual's risk is required. Nelson-Wong et al. (2009) developed a method to assess the risk of developing a low back injury in asymptomatic individuals using self-reported discomfort and a variety of biomechanical measures throughout the duration of a relatively low demand 2hr prolonged exposure. These researchers showed that between 40 – 65% of asymptomatic male and female participants ranging between 18 and 50 years of age developed clinically relevant increases in self-reported pain and had neuromuscular and musculoskeletal responses that posed a greater risk of developing a future low back injury (Nelson-Wong, et al., 2008; Nelson-Wong et al., 2009; Nelson-Wong & Callaghan, 2014). However, the pain developed over the testing protocol could be dissipated in the participants with rest. Hence, the method of using asymptomatic participants, low (to moderate) demand prolonged exposures, and self-reported pain to identify relative risk of developing a low back injury is called the transient pain developer model or approach. Briefly, for this identification method participants indicate their low back pain by making a vertical mark on a 100 mm Visual Analog Scale (VAS) before testing and after every 15 minute interval of the prolonged exposure. Participants were identified as transient pain developers (PD) and to have a relatively higher risk of developing an injury if they had a greater than 10mm change from baseline over the exposure; whereas low risk was associated with less than 10mm of change in self-reported pain in the non-pain developers (non-PD) (Nelson-Wong et al., 2009). Therefore, the use of asymptomatic upper year nursing students would enable examination of the PA, PF, and biomechanical factors relation to the risk of developing a low back injury without the confounding factors associated with working or previously injured nurses previously described.

### *1.1. Objectives*

The objective of this thesis was to evaluate PA, PF, and biomechanical factors in relation to the risk of developing a low back injury. Fourteen asymptomatic female nursing students completed questionnaires, tracked their activity for a seven day period, and completed low to moderate demand tasks during a 60 minute testing session. Participants were categorized as either PD or non-PD based on their self-reported low back pain during the 60 minute testing using the 10mm change relative to baseline criterion. Self-reported pain, PA, PF, and biomechanical measures have not been studied concurrently in an asymptomatic student nursing population. Likewise, this thesis aims at improving our understanding of the relationship of these measures prior to the occurrence of low back injury, with the future goal of identifying factors that may inhibit or facilitate the development of injury in nurses.

### *1.2. Hypotheses*

In terms of PA measures,

- Hypothesis #1: PD will have lower self-reported and accelerometer-based PA.

In terms of PF measures,

- Hypothesis #2: PD will display less muscular strength (quantified using handgrip strength as the surrogate measure for total muscular strength).
- Hypothesis #3: PD will display less muscular endurance, with lower time scores in the oblique trunk hold, back extension test, and lower repetition counts in the partial curl-ups test.
- Hypothesis #4: PD will display less muscular flexibility, with lower scores in the Active Straight Leg Raise (ASLR) test.

In terms of biomechanical measures,

- Hypothesis #5: PD will perform the postural control task with greater anteroposterior and mediolateral sway distance and will have greater total COP path distance.
- Hypothesis #6: PD will perform a side-lying leg raise with less frontal plane lumbopelvic control resulting in higher scores in the Active Hip Abduction (AHAbd) test.
- Hypothesis #7: PD will perform the simulated patient transfer task with greater peak lumbar (L4/L5) joint shear and compression forces and with a greater percentage of the lifting cycle in non-neutral trunk and shoulder postures.

## 2.0. Literature Review

### *2.1. LBP Prevalence and Cost in Nursing*

The Global Burden of Disease 2010 study, published by the World Health Organization, examined trends of major diseases and injuries across the world and concluded that LBP caused more disability since 1990 than any other condition (Hoy et al., 2014). About the same time, Driscoll et al. (2014) suggested future research was needed to better understand workplace exposures and risks that cause occupational LBP. In Canada, occupational LBP injuries accounted for 16% of all occupational injuries (Statistics Canada, 2003) and were worth $1.4 billion dollars in annual injury claims in the province of Ontario alone (Workplace Safety and Insurance Board, 2014).The nursing occupation was affected more by occupational LBP in 2005 than any other occupation in Canada (Shields & Wilkins, 2006). This statistic was concerning, especially amidst evidence that working nurses often failed to report occupational LBP (Callison & Nussbaum, 2012). The 2005 data also suggested that the relative incidence of LBP in the nursing occupation was even more pronounced when considering only female nurses. The gravity of this statistic cannot be overlooked, given that approximately 95% of Canadian nurses are female (Shields & Wilkins, 2006; College of Nurses of Ontario, 2015). Regardless of why female nurses were at greater risk than male nurses of developing an occupational LBP injury, the high incidence of occupational LBP and the associated economic and social costs are worthy of further investigation.

Occupational LBP was a major source of absenteeism in the nursing workforce (Knibbe & Friele, 1996), and 75% of affected nurses who reported LBP also reported that the LBP directly limited the ability to carry out routine nursing duties (Shields & Wilkins, 2006). The same 2005 data suggested that the top occupational exposures for pain were repetitive movements, MPH tasks, as well as flexed and axially rotated postures, reported in 62%, 62%, and 58% of all occupational LBP scenarios, respectively (Shields & Wilkins, 2006). Despite evidence of a high prevalence of occupational LBP in the nursing workforce, the under-reporting of LBP within the occupation has likely limited the implementation of prevention strategies and may have led to a questionable definition of a 'healthy' nurse (Callison & Nussbaum, 2012). Nonetheless, there is an 'injury cycle' present in the nursing occupation (Van Wyk et al., 2015), and it needs to be addressed so that working nurses can be better protected from occupational LBP.

### *2.2. Transient Pain Developer Approach*

The early identification of 'pre-clinical' individuals who had an increased risk of developing a future low back injury was established using a 2hr prolonged standing protocol and a transient pain developer paradigm (Nelson-Wong & Callaghan, 2010). This approach was used to classify each participant as either PD (high-risk) or non-PD (low-risk). The paradigm of transient pain allowed investigators to characterize neuromuscular differences between PD and non-PD, in search of LBP risk factors that could be used to guide preventative and rehabilitative strategies. Self-reported transient pain was recorded every 15 minutes of the data collection using a 100mm VAS, a pain measurement instrument that was proven to be both valid and reliable (Summers, 2001; Revill et al., 1976). The two anchors on the end of the scale were set as "no pain" and "worst pain imaginable", keeping the phrases general to avoid pain-focusing. The amount of transient pain developed during the data collection determined whether the participant was considered low- or high-risk: If the participant surpassed the threshold, determined a priori, for the changes in self-reported transient pain, the participant was labeled as PD.

Nelson-Wong et al. (2009) demonstrated that a 10mm threshold for change in self-reported transient pain in asymmetric participants was best for identifying PD and non-PD individuals during a relatively low-demand experimental protocol. The 10mm threshold was selected based on an 8mm minimal clinically important difference for the worsening of LBP symptoms in patients with chronic LBP (Hagg et al., 2003), and a minimal detectable change of 5.94mm for the VAS tool itself (Nelson-Wong et al., 2009; Kovacs et al., 2008).

The development of clinically significant transient pain (>10mm change on VAS), was reported by 40% of young, asymptomatic individuals in response to a 2hr prolonged standing data collection protocol (Nelson-Wong & Callaghan, 2010). During a three-year follow-up period of the same participants, PD participants were observed to develop low back injuries at a significantly higher rate than the non-PD participants (Nelson-Wong & Callaghan, 2014). This supports the classification of PD as high-risk and non-PD as low risk for the development of a low back injury.  Accuracy statistics of the follow-up period further suggested that the development of transient pain was a positive predictor for future clinical LBP as well as the risk of developing recurrent or chronic LBP.

### *2.3. Rationale for Investigating Biomechanical, PF, PA Factors Concurrently*

The heightened risk of occupational LBP in the nursing workforce was explained by the high workload, the frequent lifting, pushing and pulling, the awkward working postures, and the rapid peak loads placed on the spine that were all commonly observed (Schenk et al., 2007). However, because of the complexity of LBP (Sherehiy et al., 2004), the exact influence of each protective and risky workplace exposures remained unknown. As previously described, some MPH tasks involve sudden and unpredictable loading, which can add mental stress to the high workload demands in the nursing profession (Engels et al., 1996).

While a lot of research has investigated work-related exposures of the nursing occupation as LBP risk factors, similar research efforts have not yet been applied to understanding the limitations of the workforce. The shift in focus was suggested previously by Babiolakis et al. (2015) who compared biomechanical, PA, and PF factors between recently-injured working nurses and unaffected controls. These investigators observed that recently-injured working nurses displayed less frontal plane lumbopelvic control and were less active per work shift, but concluded that further research was needed regarding the biomechanical, PA, and PF factors of the nursing occupation (Babiolakis et al., 2015).

### *2.4. LBP Risk Factors - Biomechanical*

Biomechanical evaluations of the workplace have identified risk factors for occupational LBP, including the handling of physical loads, flexed and axially rotated postures, and whole-body vibrations (Hoogendoorn et al., 1999). While it was understood that LBP has a multifactorial etiology, the direct measurement of biomechanical demands in the workplace was advocated to develop strategies for the primary prevention of occupational LBP (Kerr et al., 2001). A field study that targeted working nurses (Jang et al., 2007) observed that the trunk moment and axial rotation, the prolonged exposures to static and awkward postures, as well as the mass of the patient in MPH tasks, were major risk factors for occupational LBP in nurses. While MPH tasks seemed to present the most risk for occupational LBP, exposure to nursing duties in general was also observed to confer great risk of occupational LBP (Jang et al., 2007).

A causal relationship was suggested between nurse exposure to occupational tasks and LBP, with MPH tasks presenting the most risk (Yassi & Lockhart, 2013). However, some of the exposures related to occupational LBP in nurses are neither completely predictable nor preventable (Engels et al., 1996), as patients' needs and function can be highly variable. As such, it was suggested by Babiolakis et al. (2015) to instead assess biomechanical factors of the workforce to examine risk of future occupational LBP. Using non-occupational populations, LBP was previously associated with trunk ROM (Biering-Sørensen, 1984), lumbopelvic control (Hodges & Moseley, 2003), and postural control (Panjabi, 2003).

### *2.4.1. Trunk Range of Motion*

Research has produced mixed evidence for whether trunk ROM was a risk factor for LBP, but generally have all suggested that further research is necessary to properly understand how spine flexibility and/or ROM influence future LBP (McGill, 2016). The spine is capable of movement in three different axes: Flexion and extension in the sagittal plane, left/right lateral flexion (lateral bend) in the frontal plane, and axial rotation (twist) to the left and right in the transverse plane. A prospective study of 403 healthcare workers observed that reduced frontal plane ROM was a consistent predictor of LBP during a 36-month follow-up period (Adams et al., 1999). These researchers was suggested that individuals who have reduced spine ROM move with increased trunk flexion movements, which in turn increased the risk of LBP injury (Adams et al., 1999). Differences in ROM have also been observed in participants with LBP relative to healthy controls. From a prospective study of 928 participants (Biering-Sørensen, 1984), reduced sagittal trunk ROM was observed as a residual sign in participants who developed LBP during the one-year follow-up, suggesting that participants with LBP used reduced motion of the spine to adapt to the pain. Reduced trunk ROM in participants with LBP was also observed in the transverse plane (Pope et al., 1985). Despite some evidence of an association between trunk ROM and LBP, ROM in all three axes has also been reported to have no correlation with LBP or with the ability to perform occupational work (Parks et al., 2003). Considering the mixed evidence, further research on LBP and trunk ROM is necessary. By combining the asymptomatic transient pain development paradigm, non-PD (low-risk) and PD (high-risk) participants can be compared to potentially better understand if or how differences in ROM possibly precede the development of a low back injury.

### *2.4.2. Postural Control*

Postural control, defined as the precise, coordinated motor output required to maintain whole-body balance (Radebold et al., 2001), can be tested by measuring the movement of the body's centre of pressure (COP). The body's COP has been described as the transverse location of total pressure of the body if it were concentrated into one point, and is measured using a force platform to assess postural sway (Winter, 2009). The body's control of the COP represents the neuromuscular response to changes in centre of mass (Winter, 2009).

Impaired postural control was previously observed in patients with LBP (Radebold et al., 2001; Luoto et al., 1996). Stability of the lumbar spine, achieved through antagonistic trunk flexor-extensor muscle coactivation, was shown to function as a postural control recovery strategy when balance was impaired or temporarily lost (Benvenuti et al., 1999). Therefore, the increased postural sway used to indicate impaired postural control in LBP patients was explained as inadequate motor control of the trunk musculature and poor stabilization of the spine (Panjabi, 2003). Research explored decreased postural control in LBP using acute presence of pain (Ruhe et al., 2011), delayed abdominal muscle activation (Hodges & Richardson, 1998), and impairment in proprioception and hip motor control strategy (Mok et al., 2004). To investigate a cause-effect relationship, Hodges and colleagues (2003) used experimentally induced pain and unaffected controls to compare the feedforward postural activity of the trunk muscles. While a lot of variability was reported in motor control changes within the experimental group, consistent impairment of the transversus abdominis muscle was observed (Hodges et al., 2003).

Despite the associations between increased postural sway and poor balance, research on the rehabilitation of stroke patients has observed increases in postural sway as patients improve balance control (Cho et al., 2014). Postural control is a dynamic task, and body movements are used to control posture and keep the centre of mass within the base of support. Observations in stroke rehabilitation suggested that individuals with poor postural control might actually display reduced postural sway as a preventative mechanism reflective of an inability to perform the required body adjustments. Together, the observations of LBP patients and of stroke patients suggested that both an increase and a decrease in postural sway can indicate poor balance, and thus further research was required to better understand the connection between changes in postural sway and poor balance.

Postural control was compared between unaffected and recently-injured working nurses (Babiolakis et al., 2015), and although no differences were observed between groups sway distances and total COP path distance were not quantified. Slips, trips, and falls were established as one of the main causes of occupational injury in Ontario (Ontario Ministry of Labour, 2015) and specifically identified as an important factor in the nursing occupation (Bell et al., 2013). Given that a contributing factor to slips, trips, and falls relate to loss of balance, additional measures of postural control should be further investigated in the nursing occupation.

### *2.4.3. Lumbopelvic Control*

An inability to stabilize the lumbopelvic region in the frontal plane was investigated as a potential risk factor for LBP development. Increased muscle activation of the gluteus medius, trunk flexors, and trunk extensor muscles were observed in participants who developed transient pain during a prolonged standing exposure (Nelson-Wong & Callaghan, 2010; Nelson-Wong et al., 2008). To further test this observation of increased muscle activation, a clinical movement assessment known as the AHAbd test was developed to categorize asymptomatic participants as PD or non-PD and associated risk level of developing a future low back injury (Nelson-Wong et al., 2009). The AHAbd test evaluated frontal plane lumbopelvic control during a side-lying leg raise movement, and was shown elsewhere to have good intra-rater ($ICC_{3,1}$=0.74) and inter-rater ($ICC_{2,1}$=0.70) reliability (Davis et al., 2011). The AHAbd test was shown to be the best clinical predictor of standing-induced transient LBP, with asymptomatic participants who failed the test observed to be 3.85 times more likely to develop clinical levels of transient pain during the prolonged standing task. Similar findings were found in an investigation of nurses, specifically that working nurses that had a low back injury in the preceding 12 months were observed to display less frontal plane lumbopelvic control than working nurses who had not had a recent low back injury (Babiolakis et al., 2015). Likewise, these observations suggested poor movement strategies in these individuals may have been linked to the underlying mechanism of LBP (Nelson-Wong et al., 2016).

Nelson-Wong et al. (2013) compared movement strategies during the AHAbd test between participants with LBP and unaffected controls. Participants with LBP were more variable in movement strategy, while unaffected controls executed the test consistently with a ‘proximal-to-distal’ activation pattern that has also been commonly observed in unaffected populations in other studies (Hodges et al., 1999). The strategy consistently observed in unaffected individuals was considered anticipatory, in that the stabilizing musculature is activated prior to lower extremity movement to achieve lumbopelvic stability. Participants with LBP, while variable, generally demonstrated a 'distal-to-proximal' activation pattern, which was considered to be a strategy reactive to limb movement rather than anticipatory (Nelson-Wong et al., 2013).

### *2.4.4. Manual Patient Handling Kinetics and Kinematics*

Nurses are commonly subjected to physically demanding tasks during their routine work duties, with MPH tasks often being the most demanding (Marras et al., 1999). MPH can be defined as the care giver transporting, pushing, pulling, carrying, holding, and supporting a patient by hand (Health and Safety Executive, 2016). Nurses were observed to lift 1.8 tonnes per shift through MPH, and the physical demands required by these heavy and awkward loads were recognized as risk factors for occupational LBP (Jones, 2012; Yassi & Lockhart, 2013; Tuohy-Main, 1997). Lumbar spine compression and shear forces were shown to exceed acceptable limits during MPH, and this excess force placed the workforce at an increased risk of LBP injury (Marras et al., 1999). When compared to other MPH tasks, Vieira & Kumar (2009) reported that patient transfers to or from a wheelchair caused the higher peak compression and shear forces in working nurses. When shear and compression forces acting simultaneously the increase in risk of injury increases non-linearly (Norman et al., 1998).

There is no one value that can be used to evaluate whether any task is always safe or unsafe to perform. However, the Action Limit established by the National Institute for Occupational Safety and Health is often used as the threshold to identify when a task poses an unacceptable risk for most workers: peak shear and compression force at 500N and 3,400N, respectively (Waters et al., 1993). Loads less than these values tend to be considered safe for all workers. When either of the Action Limits was exceeded, engineering or administrative controls would be considered to make the task less burdening for the worker. A Recommended Weight Limit of 15.88kg (35 lbs) (Waters, 2007) was established specifically for manual materials handling tasks to account for the repetition and duration of the task. For MPH this limit really only applies to scenarios in which the patient was entirely cooperative and still during the task. The American Nurses Association identified engineering controls, specifically addition of assistive MPH devices, as the best means of musculoskeletal disorder prevention (American Nurses Association, 2003). When the assistive devices are able to be used properly, they partially alleviated the physical requirements of MPH tasks, thereby reducing the risk associated with MPH tasks (Edlich et al., 2004). Laboratory and field studies have both shown that the assistive devices decrease perceived physical stress and the peak forces placed on the spine (Evanoff et al., 2003). The main limitation of the assistive devices was poor compliance, caused by a lack of time, space, or personnel to properly use the device, insufficient training and ability, and a lack of perceived need for the mechanical assistive device (Evanoff et al., 2003). Additionally, while the assistive devices reduced peak compression and shear forces, investigators observed increases in cumulative forces and awkward postures (McGill, 2016), resulting in a “trade” in the type of risks versus a reduction of risk.

### *2.5. LBP Risk Factors - Physical Activity*

The World Health Organization defined PA as any bodily movement produced that required energy expenditure (World Health Organization, 2016). Campello and colleagues (1996) described a U-shaped theoretical model of PA and risk of LBP, acknowledging that both an excess and a lack of PA were risk factors for LBP development, whereas sufficient PA appeared to protect against LBP development (Figure 2.1). This theoretical model was supported elsewhere by research that observed that insufficient and excessive PA were associated with a 1.44 and 1.36 times greater risk of developing LBP in female participants, respectively (Heneweer et al., 2009). While both studies observed the U-shaped theoretical model in both sexes, the relationship between PA and LBP risk appeared to be even stronger when considering only female participants (Campello et al., 1996; Heneweer et al., 2009).

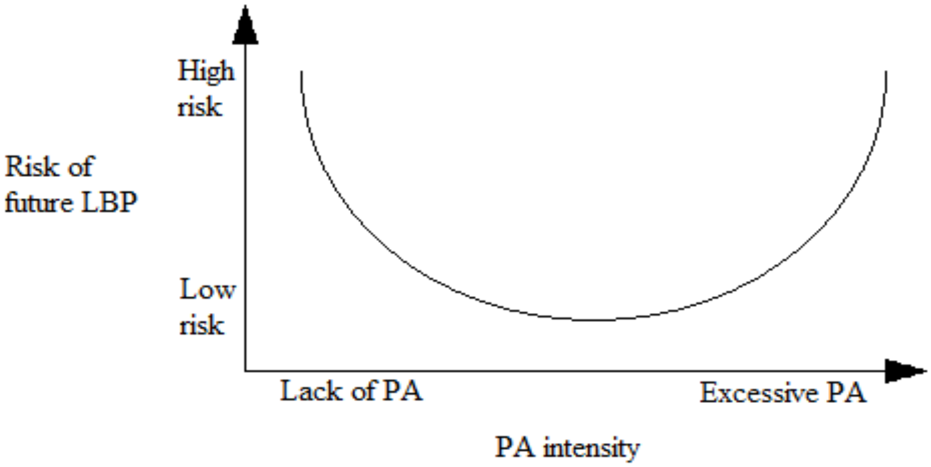


Figure 2.1. The association between physical activity and risk of developing a low back injury can be explained in this U-shaped theoretical model (Campello et al., 1996). Through disuse and overuse mechanisms, a lack and excess of PA have both been identified as risk factors. (Approval to reproduce copyrighted image was granted by John Wiley and Sons.)

While the relationship between PA and risk of LBP was repeatedly observed, the underlying mechanisms of the relationship are still not well understood. The difficulty in understanding this relationship exists due to the lack of understanding regarding frequency, intensity, type, and duration variables that are used to describe PA. Despite the U-shaped relationship (Campello et al., 1996) no association between PA frequency, intensity, type, or duration were observed. Different domains of PA might have unique, independent relationships with LBP development and protection (Heneweer et al., 2009), and individual factors such as PF and health perceptions add to the complexity of the relationships. Research that considered PA levels globally have not associated PA and LBP (Picavet & Schuit, 2003), whereas research that separated type of PA has identified PA as a risk factor for LBP development (Kujala et al., 1996). Likewise, the mechanisms of each domain of PA that explain the U-shaped relationship require further investigation.

Occupational and non-occupational PA were previously considered separately to better understand the relationship between PA and risk of LBP development. Heneweer et al. (2011) explained the dichotomy in the measurement of occupational and non-occupational PA measurement in terms of LBP risk: Non-occupational PA is observed from the perspective of insufficiency and not complying with the minimal recommendations, whereas occupational PA is observed from the perspective of excessive PA and overexertion. Previous research by Hoogendoorn et al. (1999) found no associations between leisure PA and LBP risk, but reported that occupationally heavy physical labour was a risk factor. Inconsistent results regarding leisure time PA, sport, and physical exercise were reported, and studies that targeted only daily habitual PA were lacking (Heneweer et al., 2011).

Of the research conducted on occupational PA as a risk factor for LBP development, few studies have examined occupational PA in the nursing occupation. Babiolakis et al., (2015) observed that recently-injured working nurses displayed less moderate-intensity PA than their not-recently-injured counterparts. However, the use of working nurses could not determine whether the reduced PA was a contributing factor to the recent injury ("causal) or if it was a result of the recent injury ("adaptive"). The use of the transient pain developer paradigm in asymptomatic nursing students, may provide insight regarding PA behaviours that may precede the development of a low back injury.

### *2.6. LBP Risk Factors – Physical Fitness*

Physical fitness was defined as the ability to complete regular daily tasks with ease and vigour, and with sufficient energy remaining to enjoy leisure-time activities and to meet unforeseen emergencies (Centers for Disease Control and Prevention, 2015). Examining PA and PF simultaneously, high levels of PF at a high intensity were associated with 46% less low back injury prevalence in working police officers, when compared to the officers with lower PF levels (Heneweer et al., 2012). This observation suggested that PA at an intensity that yields improvements in muscular capacity may be important for LBP preventative strategies. Specific to the nursing occupation, an investigation of the gap between occupational demands and physical capacity in the nursing occupation suggested that nurses should improve muscular strength, endurance, and flexibility to help ease the burden of the heavy workload (Blue, 1996). Although separate mechanisms were proposed to explain how the PF variables muscular strength and endurance protect against LBP, the two variables have been shown to be related to low back injuries (Naclerio et al., 2009).

Muscular strength, defined as the ability of a muscle or muscle group to exert external maximal force (American College of Sports Medicine, 2013), was related to LBP through differences in functional capacity (Besler & Can, 2003). Some research has suggested that insufficient muscular strength was related to the development of low back injuries (Bayramoglu et al., 2001), while other research suggested that the insufficiency was only related when matched to specific job requirements (Marras, 2000). Previously, grip strength was shown to be a simple, fast, and accurate indicator for overall muscular strength (Bohannon et al., 2012), and so is often used as a surrogate measure. Ropponen et al. (2011) normalized hand grip strength by body mass in young adulthood and found that low grip strength was a risk factor of musculoskeletal disorders (presumably including LBP) later in life. However, other research (Timpka et al., 2013) studied overall isometric muscle strength in adolescent men, and concluded that low muscle strength was not identified as a risk factor of LBP.

Muscular endurance, defined as the ability of a muscle or muscle group to repeatedly exert a submaximal force (American College of Sports Medicine, 2013), was shown to be a risk factor for the first occurrence of LBP (Taanila et al., 2012; Mitchell et al., 2009; Strøyer & Jensen, 2008). Biering-Sørensen (1984**)** conducted a physical examination on 928 participants, with a follow-up on the participants one year later. Those with poor trunk extensor muscle endurance had an increased risk of first-time LBP. Similarly, Luoto et al. (1995) reported that poor static back endurance were 3.4 times more likely for a new low-back pain injury. The Heneweer et al. (2012) study that concluded that a lack and excess of PA are both risk factors for LBP development also observed that higher levels of muscular endurance reduced the risk of LBP development by 46%, and again concluded that perhaps differences in PA protect against LBP development through changes in the PF variable of muscular endurance.

One of the main limitations in the research aiming to understand how PF associates with occupational LBP was the unfair exposure of workers with high PF relative to workers with low PF (McGill, 2016). Workers with higher PF were shown to take on more physically demanding occupational tasks, which in turn increased the risk of developing LBP (McGill, 2016). This exposure imbalance may explain why some recently-injured workers display similar PF to uninjured workers. A comparison of occupational behaviours between recently-injured and not-recently injured working nurses found that recently-injured nurses performed less patient lifts alone and spent a larger portion of the working shift in a seated position, but both groups displayed similar levels of PF (Babiolakis et al., 2015). The relative occupational exposure in the recently-injured nurses prior to injury was unknown, and may be that these nurses actually had higher PF pre-injury but were injured due to an exposure imbalance not PF capacity.

## **3.0. Methods**

### ***3.1. Overview***

The data collection protocol (form included in Appendix A) was based on previous research conducted on working nurses (Babiolakis et al., 2015). The data collection consisted of two visits, seven days apart, in a York University Health and Fitness Behaviours laboratory. In visit one, each participant recorded a baseline measurement of self-reported pain, completed three questionnaires, and anthropometric measurements were recorded. At the end of visit one, each participant was given an accelerometer to wear on their right hip for the seven days between visits. In visit two, a second baseline self-reported pain measurement was recorded and biomechanical, PA, and PF variables were collected, as listed in Table 3.1, with changes in self-reported pain recorded at 0, 15, 30, 45, and 60 minute time increments. Briefly, biomechanical variables were collected using a Wii Balance Board™ (WBB), a modified deep squat test, the AHAbd test, a ROM task, a nursing student questionnaire (NSQ), and one repetition of a simulated patient transfer task, PA variables were collected using the International Physical Activity Questionnaire (IPAQ) (International Physical Activity Questionnaire, 2002) and a tri-axial accelerometer, and PF variables were collected using a handgrip dynamometer, the partial curl-ups test, oblique trunk hold test, back extension tests, and the ASLR test. The collection protocol was approved prior to the collection by York University's Office of Research Ethics (Ethics Certificate # E2014-304).

Table 3.1. Summary of the variables of interest, task or tool used, and outcome measures for each of the biomechanics, PA, and PF factors.

| Factor | Variable of Interest | Task or Tool | Outcome Measure |
|---|---|---|---|
| i. Biomechanical | Postural Control | Wii Balance Board | Sway distance in the mediolateral and anteroposterior axes, and total COP path distance (mm) |
| | Movement Control | Modified Squat | Score, based on heels raising from the ground (rated 0-3) |
| | Frontal Plane Lumbopelvic Control | Active Hip Abduction Test | Score, based on loss of frontal plane lumbopelvic alignment (rated 0-3) |
| | Trunk Range of Motion | Protractor Overlay | Angles from end-start range of motion positions (degrees) |
| | Nursing Student Behaviours | Nursing Student Questionnaire | Questions regarding sitting and standing behaviours (minutes), footwear and patient transfer technique (score) |
| | Patient Transfer Kinetics and Kinematics | 3DMatch | Peak moments (N•m), peak forces (N), and time in neutral and non-neutral trunk and shoulder postures for the one repetition (% of cycle) |
| ii. PA | Self-reported PA | International Physical Activity Questionnaire | Energy expenditure in walking, moderate, and vigorous intensities (MET-minutes) |
| | Accelerometer-based PA | Accelerometer | Time in sedentary, light, moderate, and vigorous intensities (minutes), total energy expenditure (MET), sitting and standing time (minutes) |
| iii. PF | Muscular Strength | Handgrip Dynamometer | Resistance (kg) |
| | Muscular Endurance | Partial Curl-ups Test, Oblique Trunk Hold Test, Back Extension Test | Repetitions (#), hold time (s) |
| | Muscular Flexibility | Active Straight Leg Raise Test | Score (rated 0-3) |

### *3.2. Participants*

Fourteen participants were recruited from the York University nursing program. Inclusion criteria were: to be female, currently registered in the third- or fourth-year of the nursing program, and be asymptomatic ("healthy") at the time of the data collection. Male nursing students were excluded from participation given that the occupation is predominantly female (College of Nurses of Ontario, 2015), as is the population of the nursing program at York University. The upper-year nursing student population was targeted for the relative homogeneity regarding nursing work experience and work-related exposures, as well as the quantity and quality of nursing-specific training. Nursing students specialize into different types of care and employment settings after graduation, so it was ideal to assess the nursing students prior to graduation from the same university program. The required completion of two years in the nursing program ensured that MPH techniques, which are taught in year two of the program, had been learned and practiced. Additional inclusion criteria were that each participant was required to score less than 30% ("moderate") disability on the Modified Oswestry Low Back Pain Disability Index screening tool (ODI) (Fritz & Irrgang, 2001), and not to have had a recent low back injury. Specifically, the participant was excluded if any low back injury required medical attention or absence from either school or work within the previous 12 months. This exclusion was necessary to ensure that each participant was asymptomatic at the time of the data collection. These criteria required for participation in this study ensured a relatively homogenous sample of participants.

### *3.3. Instrumentation/Equipment*

A massage table was used for tests requiring supine, prone, or side-lying positions. Two standard video cameras recorded approximately perpendicular views of the protocol at a frequency of 30 frames per second. Thirty pieces of masking tape (1cm x 1cm) were placed over anatomical landmarks (Table 3.2 and Figure 3.1) to assist with the kinematic data processing (to track body segments and joint angles when measuring trunk range of motion, when processing the simulated patient transfer task data, and when scoring the Active Straight Leg Raise test.).

Table 3.2. Placements of the 30 pieces of masking tape over 17 anatomical landmarks used to assist with the processing of kinematic data.

| **Body Region** | **Anatomical Landmarks** |
|---|---|
| Head | • Tragus of Ear (Left & Right) |
| Spine | • C7 Vertebral Process<br>• T9 Vertebral Process<br>• L1 Vertebral Process<br>• L5 Vertebral Process |
| Hips | • Anterior Superior Iliac Spine (Left & Right)<br>• Posterior Superior Iliac Spine (Left & Right)<br>• Greater Trochanter (Left & Right) |
| Arms | • Head of 5th Metacarpal (Left & Right)<br>• Head of Ulna (Left & Right)<br>• Medial Epicondyle of Humerus (Left & Right)<br>• Lateral Epicondyle of Humerus (Left & Right) |
| Legs | • Lateral Epicondyle of Femur (Left & Right)<br>• Lateral Tibial Plateau of Femur (Left & Right)<br>• Lateral Malleolus of Ankle (Left & Right)<br>• Posterior Calcaneus (Left & Right)<br>• Head of 5th Metatarsal (Left & Right) |

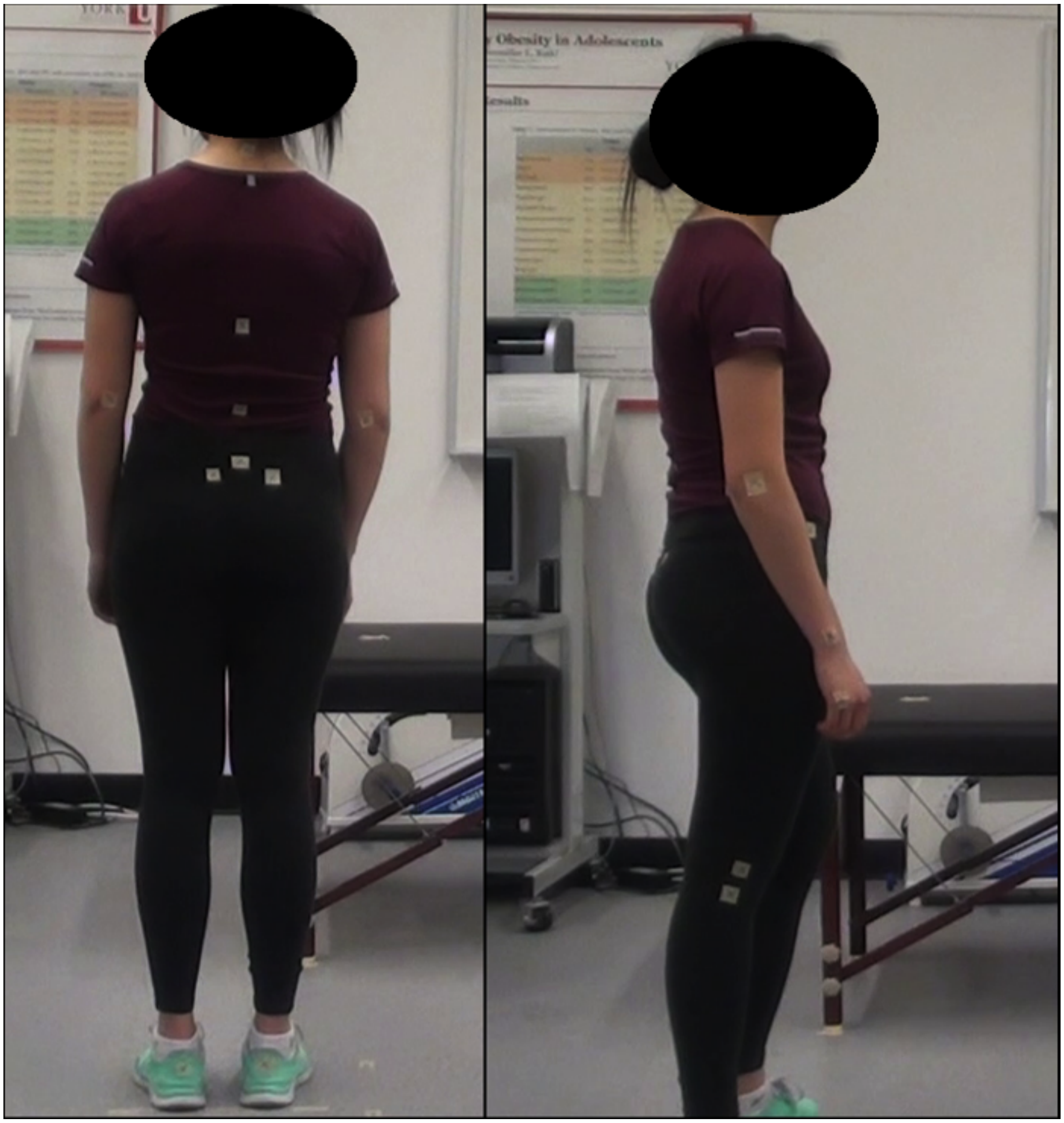


Figure 3.1. Seventeen anatomical landmarks were marked on either the clothing or directly on the skin of each participant with 1cm x 1cm pieces of masking tape. The masking tape acted as a passive marker, which assisted with the tracking of body segments and joint angles through the video frames.

### *3.3.1. Anthropometry*

During the first visit, a mechanical column scale (Seca 700 Medical Beam Scale, © Seca Corporation, California, USA) was used to measure the participant's height and weight, respectively. Body fat percentage was measured using a hand-to-hand bio-electrical impedance analysis tool (Omron HBF-306CAN Fat Loss Monitor, © Omron Healthcare, Inc., China). During the measurement of body fat percentage, the participant was instructed to hold the hand-to-hand bio-electrical impedance analysis tool with arms held straight at shoulder height. A retractable body tape measure (MyoTape™, AccuFitness LLC., Colorado, USA) was used to quantify circumferences of the upper arm, waist, hip, and thigh regions (Table 3.3). During the circumference measurements, the participant was instructed to inhale, exhale, and then relax before the measurement was recorded. Upper arm circumference was measured at the midpoint of the right humerus while the participant's arm was relaxed and at their side. Waist circumference was measured at the most superior point of the iliac crest. Hip circumference was measured at the level of the maximal posterior extension of the buttocks, with the participant's feet together. Finally, thigh circumference was measured distal to the gluteal fold of the right femur, while the participant was instructed to distribute weight evenly between both legs.

Table 3.3. Anthropometric data of the nursing students (n=13), reported as a mean (±SD). The statistical difference is shaded.

| **Characteristics** | **Range** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|---|
| Age (years) | 20-34 | 23.9 (4.7) | 23.2 (4.1) | 0.781 |
| Height (cm) | 151-169 | 161.5 (4.7) | 156.7 (3.4) | 0.056 |
| Mass (kg) | 44-75 | 60.7 (9.2) | 49.7 (3.0) | 0.032 |
| BMI (kg/m$^2$) | 18-30 | 22.9 (3.7) | 20.3 (1.4) | 0.124 |
| Body fat (%) | 16-34 | 24.1 (5.9) | 22.1 (5.3) | 0.536 |
| Waist circumference (cm) | 65-89 | 76.3 (7.1) | 74.0 (8.5) | 0.616 |
| Thigh circumference (cm) | 48-67 | 58.2 (5.6) | 53.2 (3.5) | 0.079 |
| Hips circumference (cm) | 85-106 | 97.9 (6.6) | 92.4 (4.6) | 0.103 |
| Upper Arm circumference (cm) | 23-31 | 27.4 (2.3) | 25.7 (2.1) | 0.182 |

### *3.3.2. Questionnaires*

Three questionnaires were completed by each participant during the first visit: The ODI, IPAQ, and NSQ. The IPAQ (Appendix B) was shown to be a valid and reliable instrument for self-reported PA (Craig et al., 2003), designed specifically for adults (15-69 years old). The IPAQ examines four domains of self-report PA and leisure time (specifically, job-related PA, transportation PA, house and family work PA, recreation and leisure PA, and sitting time) and assesses the cumulative time per day spent in walking, moderate, and vigorous intensities within each domain. As per the IPAQ scoring guide, outcomes for each intensity and type of PA were reported as MET-minutes per week and reported as a median and interquartile range due to the non-normal distribution typically observed in this data (International Physical Activity Questionnaire, 2005). Similarly, the ODI (Appendix C) was also shown to be valid and reliable in screening for LBP disability (Fritz & Irrgang, 2001). The NSQ (Appendix D) was a modified questionnaire designed specifically for nursing students to gain insight about the participants, and was developed from the custom questionnaire designed for working nurses (Babiolakis et al., 2015). The NSQ included questions pertaining to self-reported PA, lifting technique, footwear, and work-related exposures.

### *3.3.3. Accelerometry*

Tri-axial ActiGraph™ GT3X+ accelerometers (ActiGraph™ LLC, Penascola, USA) were distributed at the end of the first visit and worn on the right hip (Peeters et al., 2013) to objectively quantify participant PA. Participants were instructed to wear the accelerometer at all times during the 7 days between the two visits, with the only exceptions of bathing to prevent damage to the accelerometers. To assist with the identification of non-wear time, participants were asked to record on a log sheet the dates and times that the accelerometer was removed. The data was processed using the associated device software (Actilife™ version 6.13.2, ActiGraph™ LLC, Penascola, USA).

### *3.3.4. Wii Balance Board*

A Wii Balance Board™ was used in conjunction with WiiMote Physics (Open source software, http://wiimotephysics.codeplex.com/) to quantify COP displacement during quiet standing, forward bend (90° trunk flexion), as well as left and right single stance. The WBB software collects four time-varying signals at 100 Hz, one from each corner of the platform. As explained by Bartlett et al. (2014), each corner contains a uni-axial strain gauge that functions as a vertical force transducer, converting the force applied to the rigid platform into a voltage that was digitized and transmitted wirelessly to a computer where the data was recorded.

### *3.3.5. Visual Analog Scale*

A 100mm VAS was used to quantify the participants' self-reported low back pain in visit one (first baseline) and visit two (second baseline and then at 15 minute intervals to the end of the 60 minute testing). A comparison between the two baselines were performed, and the second baseline used to normalize the visit two testing VAS values. The VAS was previously shown to be both valid and reliable as an instrument for self-reported pain (Summers, 2001; Revill et al., 1976). During a low demand, 2hr prolonged standing exposure protocol, a pre-determined threshold of a 10mm change in self-reported pain was used successfully to identify PD within a sample of asymptomatic university-aged participants (Nelson-Wong et al., 2009; Nelson-Wong & Callaghan, 2010). The tasks included in this thesis' data collection protocol were considered non-strenuous and predominantly low-demand, and the participants were asymptomatic and university-aged. Likewise, the threshold of 10mm was used to classify participants as non-PD and PD from <10mm and >10mm respectively of self-reported transient pain developing during visit two.

The biomechanical, PA, and PF tasks were presented in a random order for each participant, so VAS measurements were recorded after different tasks for each participant but at the same relative time (every 15 minutes). Blank VAS were presented to participants for each interval, so that previous markings were not available to participants. This was done to help focus the participant to consider each interval separately (i.e. on their current perceived pain).

## ***3.4. Procedure***

### *3.4.1. Visit One*

Visit one consisted of the completion of an informed consent, screening regarding their LBP history, anthropometric measurements, a baseline VAS measurement, and completion of the three questionnaires (ODI, IPAQ, and NSQ). To begin the first visit, the participant was introduced to the study with a brief overview. An informed consent that pertained to both visits one and two was read out loud to the participant, and was reviewed and completed by the participant. Afterward, the participant was screened for LBP history in the previous 12 months as detailed above, and a baseline VAS measurement was recorded. The VAS tool was explained to the participant as a pain scale, with “a score of 0 represents no pain at all in the low back region, and a score of 10 represents the worst pain imaginable in the low back region”. The participant was instructed to draw a vertical line with a pen across the 100mm horizontal VAS line that corresponded to their current level of perceived LBP. Next, and in a random order determined a priori, the three questionnaires (ODI, IPAQ, and NSQ; Appendices B, C, and D) were distributed to the participants, and then anthropometric measurements were taken and recorded. Again, the anthropometric measurements included height, weight, body fat percentage, and circumference measurements of the waist, hip, thigh, and upper arm. Height and weight were measured while the participant stood barefoot in as narrow of a stance as possible, with the upper back region making contact with the vertical tape, and with their arms hanging at the sides. At the end of visit one, each participant was given instructions on the use of the accelerometer that they were to wear on their right hip for the seven days between visits. Also, verbal and written instructions regarding clothing and footwear necessary for visit two were given to each participant.

### *3.4.2. Visit Two*

Visit two began with a second baseline measurement of self-reported pain using the VAS. Then five PF and five biomechanical measures were completed in a random, pre-determined order, with self-reported pain recorded every 15 minutes using VAS. The 15 minute intervals were tracked using a digital timer and confirmed by recording the time of each measurement beside the vertical line. Each test was explained with standardized verbal instructions and demonstrated by an investigator prior to the testing.

The five PF measures included three endurance tests, a flexibility test, and bilateral grip strength tasks (Reiman & Manske, 2009). To ensure that each observation was reflective of a complete effort to the best of the participant’s ability, verbal encouragement was given by one investigator during each measure. The three endurance tests of the trunk muscles included a partial curl-ups test, an oblique trunk hold test, and a back extension test. The partial curl-ups test used two white pieces of tape, 10cm apart, labelled “start” and finish” that were marked on the massage table. The procedure began with the participant laying supine on the massage table, arms fully extended at the sides and hands flat against the table with fingertips able to reach no further than the “start” line. With knees bent to a 90° angle and feet flat on the massage table separated at hip-width, the participant was instructed to curl the upper spine enough so that the finger tips reached the “finish” line (first metronome click), and then returned to the “start” line with the head and shoulder blades rested on the massage table (second metronome click).The partial curl-ups test ended when the participant stopped due to pain or fatigue, once an investigator observed the participant moving with jerky, uncontrolled movements, or when the participant could not keep pace with the metronome. The test was completed one time and scored as number of completed repetitions in 60 seconds to the pace of a metronome (with a cadence of 50 beats per minute). The oblique trunk hold test began with the participant relaxing in a side lying position, with their elbow propped up against the massage table at a 90° angle. The participant extended both legs, with the top foot resting against the bottom foot, and an investigator lifted the hips up to straighten the participants’ body alignment (“side bridge” position). The stopwatch was started once the body was aligned in the “side bridge” position and the participant released by the investigator, and was stopped once alignment was lost. Specifically, the stopwatch was stopped once the knee, hip, or thigh of the participant made contact with the table. The test was completed twice on both sides (left-right-left-right), and was scored by adding together the highest scores from both sides. During the back extension test, the participant was instructed to lay prone and cantilever their trunk off the edge of the massage table, with their iliac crests aligned to the table edge, and hold their trunk parallel to the floor. An investigator supported the participant by the ankles to ensure that the participant did not fall during the test. The participant was instructed to maintain contraction of abdominal muscles to support the lower spine, and the timer was started once the participant lifted their hands off the floor and crossed both hands across their chest. Each participant was given one warning for loss of form (movement of their trunk to a higher or lower position than parallel, or flexing their trunk), and a chance to reposition appropriately. The stopwatch was stopped upon the second loss of form or at the maximum time of 180s. The ASLR test was used to assess flexibility of the hip and lower extremity while also testing sagittal plane lumbopelvic control. For this test, the participant was laying supine on the massage table, arms resting at their sides, with a metre stick extended underneath the knees. The participant was instructed to lift the testing leg as high as they could while keeping the knee extended and the toes dorsiflexed. During the movement, an investigator ensured that the opposing knee was not raised above the metre stick and that the head and shoulders did not elevate. The ASLR test was completed twice on both sides (left-right-left-right), and was scored as either a 0 if the participant reported pain during the movement or on a 1-3 scale based on the horizontal displacement of the ankle malleolus when the test leg stopped at the end of the movement: 1, if below the mid-patella; 2, if between mid-thigh and mid-patella, and; 3, if between mid-thigh and ASIS. Grip strength was tested twice on each hand in an alternating order (left-right-left-right). Participants were instructed to hold the dynamometer (Takei Grip Dynamometer 5001, Takei Scientific Instruments Co., Ltd., Japan) in the start position of elbows fully extended and arms abducted to 90°. The participants were instructed to squeeze the dynamometer with a complete effort while lowering their arms in a slow, controlled manner until the dynamometer was resting against the side of the thigh. The grip strength task was scored by adding together the higher scores from both sides.

The five biomechanical measures included a postural control task, a modified deep squat test, the AHAbd test, a ROM task, and a simulated patient transfer task. Recall, NSQ was completed in visit one. The postural control task, completed to analyze COP distance using a WBB, consisted of four static standing postures: Quiet standing, forward bend (trunk flexion), and bilateral single stance postures. Once the correct posture was stabilized, the participant was instructed to remain as still and quiet as possible during 30s of recording. An investigator told the participant the time points: at 0s (start), 15s (midpoint), and 30s (end) of completion. The modified deep squat test (Reiman & Manske, 2009) was completed twice with participants standing with feet shoulder-width apart and instructed to extend arms out in front and keep them at a shoulder height during the movement. This test was used to evaluate the coordinated mobility of the upper and lower extremity as well as the stability of the trunk and hips. Maximum displacement of the heels from the ground at the bottom of the squat movement were measured by an investigator using a ruler. The AHAbd test was used to assess the participant's ability to maintain frontal plane lumbopelvic control, by rating trunk and pelvic alignment during hip abduction (Nelson-Wong et al., 2009). The participant was assisted into a side-lying position on the massage table. The top hand of the participant was placed on the abdomen, and the bottom hand was placed underneath the head for support. The participant was instructed to raise the top leg while keeping both knees extended and maintaining pelvic alignment in the frontal plane. Participants completed two trials on each side (left-right-left-right). To quantify trunk ROM, five standing trunk movements were completed by each participant with the end position maintained for five seconds: Trunk flexion, bilateral lateral flexion (lateral bend), and bilateral axial rotation (twist). For the trunk flexion movement, the participant was instructed to stand upright, look forward, have feet shoulder-width apart, and arms crossing the chest, and then to "Go as far as you can go without discomfort and hold the position for five seconds". For the axial rotation movement, the participant was instructed to stand upright, look forward, have feet shoulder-width apart, arms extended at height of the shoulders, and keeping their head and neck locked with their shoulders, and then to "Rotate as far as you can go without discomfort and hold the position for five seconds". For the lateral flexion movement, the participant was instructed to stand upright, look forward, have feet shoulder-width apart, and arms hanging at sides, and then "Without moving your trunk forward backward, slide your arm as far down the side of your thigh as you can go without discomfort and hold the position for five seconds". For all five movements, still images were captured before the movement began and during the end position. Still images were captured in the frontal plane for the axial rotation and lateral flexion movements, and in the sagittal plane for the trunk flexion movement. Trunk flexion and bilateral lateral flexion ROM was measured using a protractor overlaying the image projected on a flat screen television, and bilateral axial rotation ROM was estimated using 3DMatch software (3DMatch Cumulative Models version 5.10, University of Waterloo, Waterloo, Canada) (Callaghan et al., 2003). This software enables a user to assign the angle from the image to one of three angle ranges or bins (i.e. 0°-15°, 15°-25°, >25°). To more accurately quantify axial rotation ROM, still images would be necessary from a ceiling-mounted camera to capture movement in the transverse plane. However, recording images from this perspective was not feasible, so an estimation of trunk axial rotation ROM was made using the 3DMatch software. The simulated patient transfer task required participants to move a 27.22kg (60lbs) fire prevention weighted manikin from a seated position in a chair to a seated position on the massage table (Figure 3.2). The chair was located 30cm from the massage table, and the top of the table was 14cm higher than the seat pan of the chair. The participant was instructed to complete the task as per their nursing training, as if it was a real hospital scenario, and to treat the manikin as if it were a living patient. The task was designed to represent a wheelchair-to-bed transfer, one of the most common types of patient transfer tasks that working nurses complete. Participants completed one repeat of this transfer task. The kinetics and kinematics of this task were estimated using the video-based posture-matching tool, 3DMatch.

Figure 3.2. In the simulated patient transfer task, the participant moved the manikin from a seated position in the chair to a seated position on the massage table.

### *3.5. Data Processing*

Accelerometer data was downloaded into 10s epochs and processed using Actilife™ software (Actilife™ version 6.13.2, ActiGraph™ LLC, Penascola, U.S.A.). In this process, Actilife™ filtered the raw data within each epoch to create "counts", which reflected the frequency and intensity of the raw acceleration. An established algorithm (Choi et al., 2011) used the counts to identify periods of non-wear time during the seven days between visits. After the non-wear time was identified, a complete 24 hour time window (midnight to midnight) was clipped and separated from the remaining accelerometer data. An established Metabolic

Equivalent of Task (MET) algorithm (Crouter et al., 2010) used the counts to determine the mean MET of the 24-hour time window. Additionally, the cumulative time spent at a sedentary, light, moderate, and vigorous level was determined with the of cut points. The cut points, measured in counts per minute, that were chosen for the sedentary (0-149 counts/minute), light (150-2689 counts/minute), moderate (2690-6166 counts/minute), and vigorous (6167+ counts/minute) levels of PA were previously established (Kozey-Keadle et al., 2011; Peeters et al., 2013). These cut points had been previously used in comparable research that was conducted on working nurses (Babiolakis et al., 2015). Finally, Actilife™ used the counts to quantify cumulative and maximum single bout times in the seated and standing postures.

To ensure valid and reliable AHAbd results, three raters (all 2nd year MSc graduate students in Biomechanics) were trained to ensure that the appropriate scoring method was applied to evaluate the trials. The training video created by Davis et al. (2011) was reviewed, and the raters practiced assessing AHAbd videos from a previous study and discussing any discrepancies in scores recorded. Once the training was completed, each rater evaluated the trials of each participant three times in a predetermined random order, on two separate occasions with a three-week washout period between rating dates (rated each participant a total of 6 times). This approach was in accordance with previously research on the inter- and intrarater reliability of the AhAbd test (Davis et al., 2011). Each left and right AHAbd trial was scored a total of 18 times by the three raters combined, and the score most commonly chosen was the score reported for the participant.

The AHAbd test was scored from 0-3, and each score was reflective of the degree to which the participant was unable to maintain lumbopelvic alignment in the frontal plane during the side-lying leg raise movement (Nelson-Wong et al., 2009) (Table 3.4). The scores were transformed into ‘pass’ (test score ≤1) and ‘fail’ (test score > 1) scores, and the higher score of the two trials was reported as the test score for each side.

Table 3.4. The Active Hip Abduction test was scored 0-3 based on the degree to which frontal plane alignment of the lumbopelvic region was lost during the performance of a side-lying leg raise movement (Nelson-Wong et al., 2009). (Approval to reproduce copyrighted table was granted by the Journal of Orthopaedic & Sports Physical Therapy.)

| AHAbd Test Score | Loss of Frontal Plane Position | Test Cues |
|---|---|---|
| 0 | None | • Participant smoothly and easily performs the movement.<br>• Lower extremities, pelvis, trunk and shoulders remain aligned in the frontal plane. |
| 1 | Minimal | • Participant may demonstrate a slight wobble at initiation of the movement, but quickly regains control.<br>• Movement may be performed with noticeable effort or with a slight ratcheting of the moving limb. |
| 2 | Moderate | • Participant has a noticeable wobble, tipping of the pelvis, rotation of the shoulders or trunk, hip flexion, and/or internal rotation of the abducting limb.<br>• Movement may be performed too rapidly, and participant may or may not be able to regain control of the movement once it has been lost. |
| 3 | Severe | • Participant demonstrates the same patterns as in a test score of 2, with greater severity.<br>• Participant is unable to regain control of the movement and may have to use a hand or arm on the table to maintain balance. |

The WBB data from WiiMote Physics was filtered to remove high frequency noise and then used to calculate the time-varying x-y COP coordinate location ($COP_x$, $COP_y$). These COP coordinates were used to determine the COP path distance and the anteroposterior and mediolateral sway distances. The output of WiiMote Physics, a 100Hz uni-axial force transducer signal from each of the four corners of the WBB, was saved into comma-separated values file.

The uni-axial force transducer signals were previously shown to have a low signal-to-noise ratio with high frequency electronic noise (Leach et al., 2014), and so the signal was low-pass filtered using Visual 3D (Visual3D Biomechanics Analysis Software, version 6.01.3, C-Motion, Inc., Kingston, Canada). The comma-separated values file was converted to an American Standard Code for Information Interchange-formatted file format using Microsoft Excel (Microsoft Excel version 15.27, Microsoft Co., Redmond, U.S.A.), so that Visual3D could read the time-varying force measurements as a force signal. The force signal was filtered using a fourth-order, zero-lag Butterworth filter with a cut-off frequency of 5Hz, as per the recommendations of previous research (Leach et al., 2014). The filtered force signals were then exported from Visual3D to a comma-separated values file.

The time-dependent ($COP_x$, $COP_y$) location was calculated in Microsoft Excel, using two Equation 3.1 and Equation 3.2, respectively. These equations were established specifically for the WBB by Bartlett et al. (2014) (Approval to reproduce copyrighted equations was granted by Elsevier). The equations incorporated the time-varying signal from each corner, the top-left (TL), top-right (TR), bottom-left (BL), and bottom-right (BR) corners, as well as the length (433mm) and width (228mm) dimensions of the WBB. Using the equations, a positive $COP_x$ value was defined as to the right direction, and a positive $COP_y$ value was defined as to the forward direction (toward the toes) of the WBB.

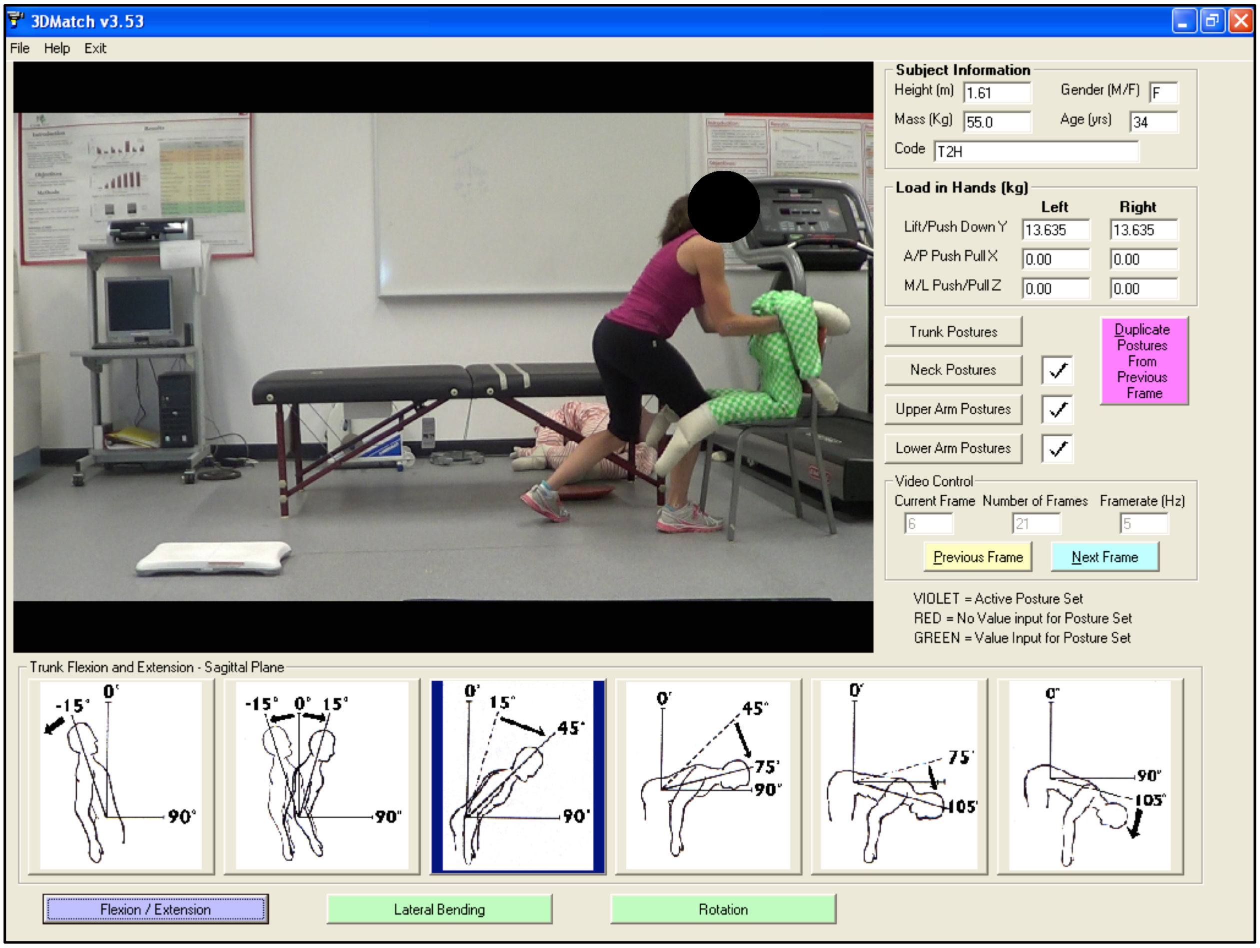
$$Equation\ 3.1. \qquad COPx = \frac{length}{2} \times \frac{(TR + BR) - (TL + BL)}{TR + BR + TL + BL}$$

$$Equation\ 3.2. \qquad COPy = \frac{width}{2} \times \frac{(TR + TL) - (BR + BL)}{TR + BR + TL + BL}$$

Once the time-varying ($COP_x$, $COP_y$) location was established, COP path distance as well as the anteroposterior and mediolateral sway distances were calculated using Microsoft Excel. The hypotenuse distance between each successive ($COP_x$, $COP_y$) location was calculated using the Pythagorean Theorem, and the COP path distance was then calculated as the summation of the hypotenuse distances. The COP sway distance was calculated in the mediolateral axis by subtracting the minimum $COP_x$ value from the maximum $COP_x$ value, capturing the range of left-to-right COP sway. Similarly, the anteroposterior COP sway distance was calculated by subtracting the minimum $COP_y$ value from the maximum $COP_y$ value, capturing the range of backward-to-forward COP sway.

The kinematic data from the one repetition of the simulated patient transfer task was processed using 3DMatch to estimate peak L4/L5 joint compression and shear forces and to estimate the amount of time in the patient transfer that required non-neutral trunk and shoulder posture ranges. Briefly, 3DMatch is a video-based posture-matching tool created by Dr. Jack Callaghan (University of Waterloo, ON, Canada) that estimates L4/L5 joint forces and moments of occupational tasks by incorporating basic anthropometry and hand forces into a quasi-static top-down inverse dynamic model. The model was considered quasi-static as it is able to account for changes in hand forces throughout the movement, but does not account for segment inertia (Parkinson et al., 2011). Furthermore, the model was considered top-down approach as the calculations start at the hands of the participant (including external forces acting on the hands) and move segment-by-segment to the L4/L5 joint to estimate the internal spine loading. The program permits the analysis of three-dimensional movements through two-dimensional video capture, which allows the program to assess asymmetrical multi-planar loading and axial rotation. The inter- and intra-rater reliability of 3DMatch has been established (Sutherland et al., 2007, Cann et al., 2008), and its validity has been proven through testing against electromagnetic based motion tracking (Sutherland et al., 2008). The 3DMatch training module (included with the software) was completed before the investigator began the processing. To pass this training, the investigator was required to correctly assess the postures in two consecutive trials from 25 randomly presented stock image sets.

Kinematic data of the one repetition of the simulated patient transfer task, captured with approximately perpendicular video angles, was down sampled from 30Hz to 5Hz, and was transformed into a series of still images in Audio Video Interleaved format. The still images were uploaded into the 3DMatch program, and the participant's sex, height, body mass, and hand forces relating to the lift were entered before the segment postures in each image were identified (Figure 3.3). The user matches the trunk, neck, upper arm, and lower arm segment postures in the image, to the appropriate range of established segment posture angles. This binning approach groups the occurrence of similar angles together from all of the task image series to efficiently calculate appropriately weighted L4/L5 joint forces and moments. Eleven binned ranges were matched for each image of the task image series. To determine hand forces, the distribution of the manikin's mass was visually assessed and assigned a load dispersion ratio. The manikin had a mass of 27.22kg, and while most participants lifted the manikin with what appeared as an approximately 50%-50% (13.61kg-13.61kg) load dispersion between the two hands (e.g. two-arm front hook technique shown in Figure 3.3), others lifted at what appeared as an approximately 70%-30% (19.05kg-8.166kg) load dispersion (e.g. asymmetric techniques like the arm-bottom scoop technique).



Subject Information
Height (m) 1.61
Gender (M/F) F
Mass (Kg) 55.0
Age (yrs) 34
Code T2H

Load in Hands (kg)

| | Left | Right |
|---|---|---|
| Lift/Push Down Y | 13.635 | 13.635 |
| A/P Push Pull X | 0.00 | 0.00 |
| M/L Push/Pull Z | 0.00 | 0.00 |

Neck Postures ✓
Upper Arm Postures ✓
Lower Arm Postures ✓

Video Control

| Current Frame | Number of Frames | Framerate (Hz) |
|---|---|---|
| 6 | 21 | 5 |

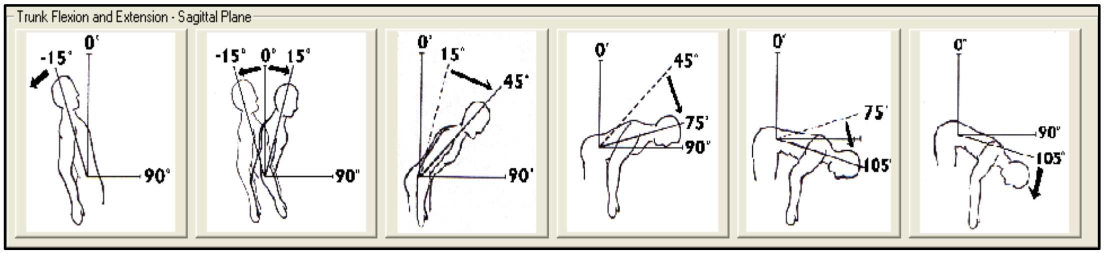
VIOLET = Active Posture Set
RED = No Value input for Posture Set
GREEN = Value Input for Posture Set

Figure 3.3. Example of the 3DMatch processing interface for sagittal plane trunk posture. The participant's trunk posture in the image was matched to the 15°-45° posture bin. (Approval to reproduce copyrighted image was granted by Dr. Jack Callaghan, University of Waterloo, ON, Canada.)

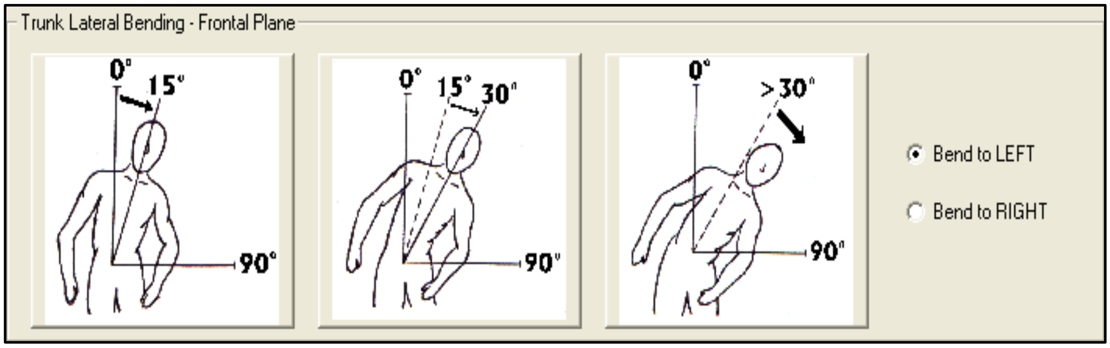
For each image in series that the one repetition of the simulated patient transfer task video was broken into, the postures of the trunk, neck, upper arm, and lower arm were estimated by matching the flexion, extension, abduction, lateral flexion, and axial rotation when appropriate (Figures 3.4, 3.5, and 3.6). The size and ranges of the posture bins were previously established in attempt to minimize both the size of errors made by the observer and the likelihood of making an error (Andrews et al., 2016). The program translated the selected bin into a value, usually near the midpoint of the bin's range, which was then used as inputs for the rigid link quasi-static inverse dynamic model to determine L4/L5 peak shear and compression forces and the associated moments (Seaman et al., 2010).

To compare the kinematics of occupational tasks, 3DMatch also quantified the total number of frames within each neutral and non-neutral posture range bin (Figures 3.4, 3.5, and 3.6). The program normalizes the number of frames within each posture bin by the total number of frames required for the occupational task cycle. In doing so, the program provided normalized time (as a percentage of the cycle) that required neutral, mild non-neutral, and severe non-neutral trunk and shoulder postures.

**A.** Trunk Flexion and Extension



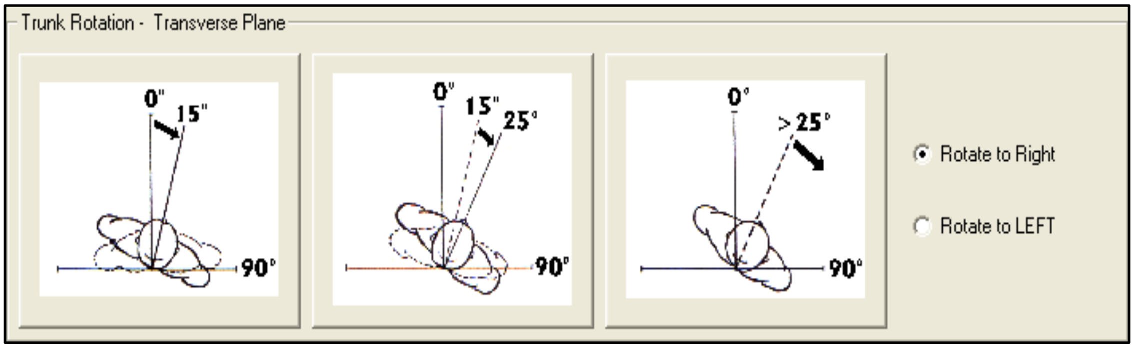
**B.** Trunk Lateral Flexion



● Bend to LEFT

○ Bend to RIGHT

**C.** Trunk Axial Rotation

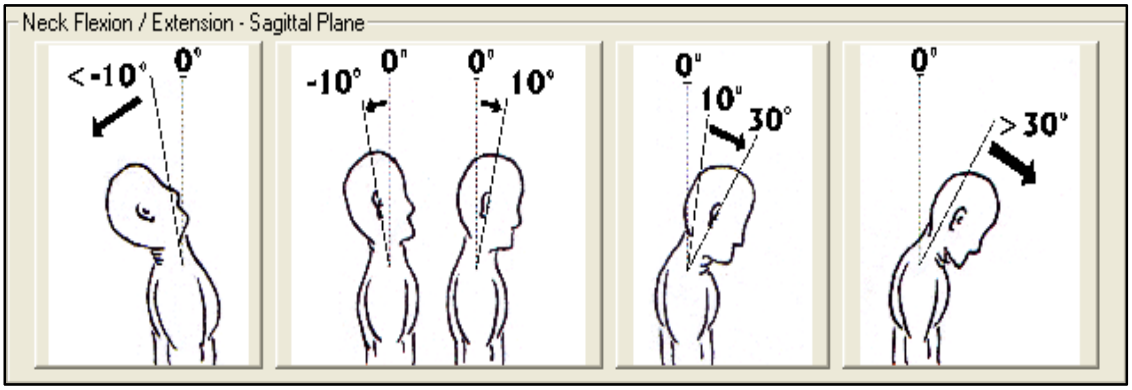


● Rotate to Right

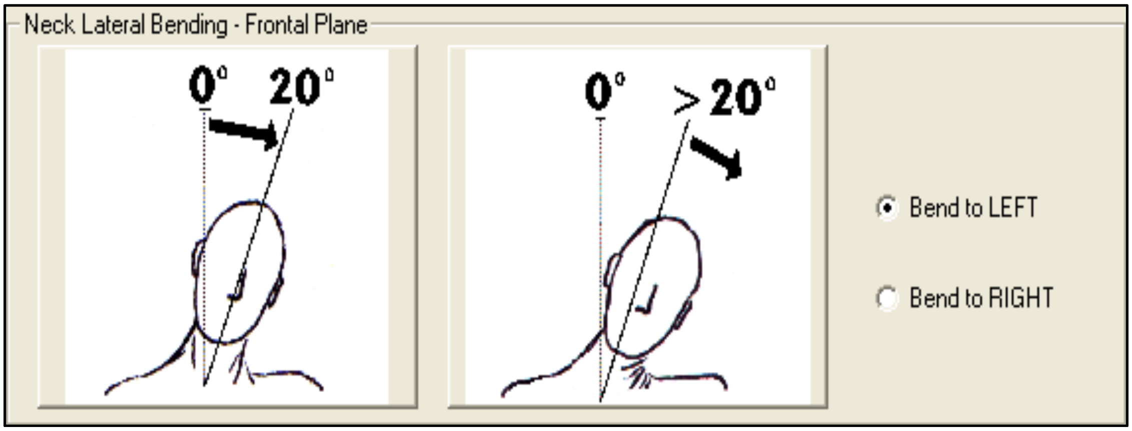
○ Rotate to LEFT

Figure 3.4. The trunk posture ranges in 3DMatch for: A. Trunk Flexion and Extension; B. Trunk Lateral Flexion; and C. Trunk Axial Rotation. (Approval to reproduce copyrighted images was granted by Dr. Jack Callaghan, University of Waterloo, ON, Canada.)

A. Neck Flexion and Extension



B. Neck Lateral Flexion

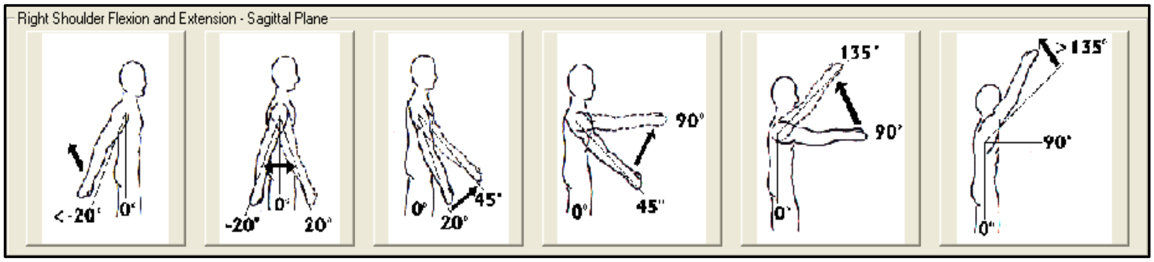


● Bend to LEFT

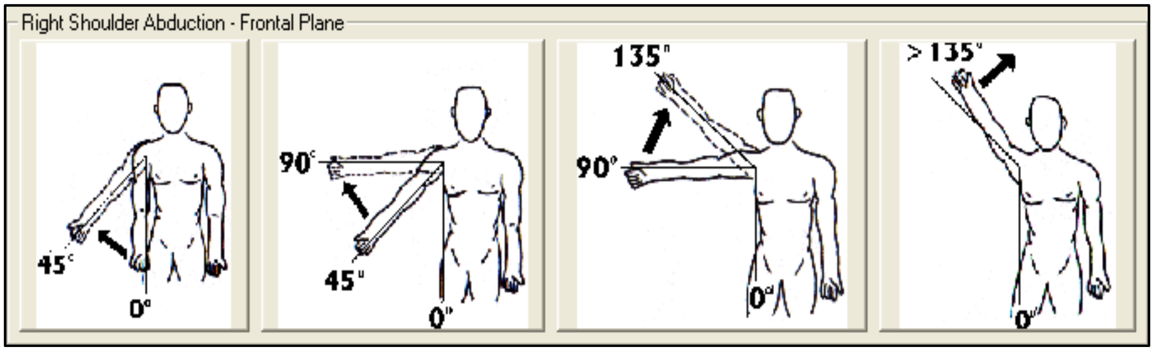
○ Bend to RIGHT

Figure 3.5. The neck posture ranges in 3DMatch for: A. Neck Flexion and Extension; and B. Neck Lateral Flexion. (Approval to reproduce copyrighted images was granted by Dr. Jack Callaghan, University of Waterloo, ON, Canada.)

A. Shoulder Flexion and Extension



B. Shoulder Abduction



C.  Elbow Flexion and Extension

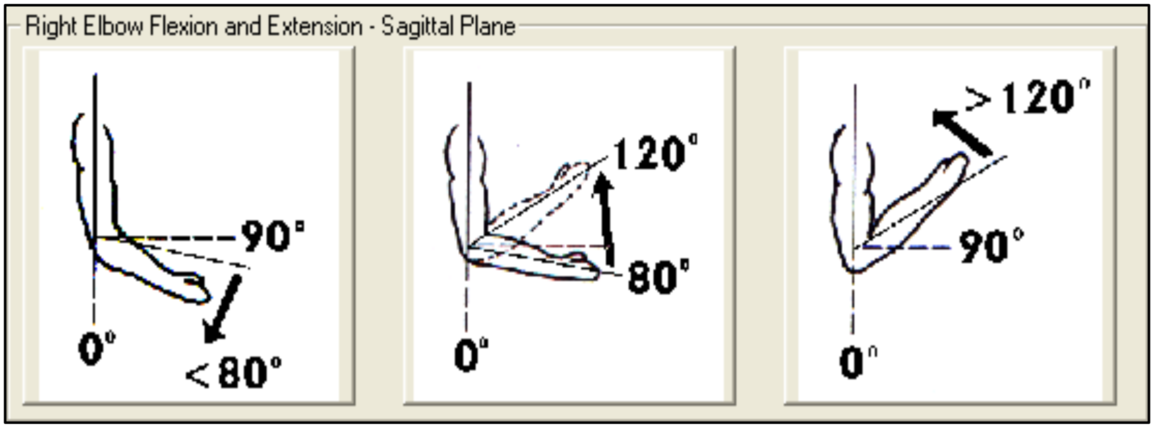


Figure 3.6. The shoulder and elbow posture ranges in 3DMatch for: A. Shoulder Flexion and Extension; B. Shoulder Abduction; and C. Elbow Flexion and Extension. These posture ranges were used for the left and right shoulders and elbows. (Approval to reproduce copyrighted images was granted by Dr. Jack Callaghan, University of Waterloo, ON, Canada.)

### *3.6. Statistical Analysis*

All statistical analyses performed in this thesis were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC) with an allowable Type I error rate of 0.05 to test for statistical differences (unless modified as listed below). The results of each comparison were reported as mean (± standard deviation (SD)), unless stated otherwise.

A two-factor, repeated measures mixed model Analysis of Variance was used to test whether the changes in self-reported transient pain developed during the data collection was different between non-PD and PD nursing students. Within- and between-group post-hoc comparisons were tested using the Tukey-Kramer method. The mixed model design of the Analysis of Variance and the Tukey-Kramer method were both chosen since both are powerful and conservative with unbalanced sample sizes.

The two-sample t-test, Wilcoxon-Mann-Whitney test, and Fisher's exact test were used to compare the six biomechanical, two PA, and three PF outcome measures between non-PD and PD nursing students when appropriate (Table 3.5). Specifically, the two-sample t-test was used to compare the mean and SD of parametric outcome measures between groups. For non-parametric outcome measures, the Wilcoxon-Mann-Whitney test was used to compare medians and interquartile ranges, while the Fisher's exact test was used to test the distribution of scores of categorical data between groups. Many comparisons were tested in each of the biomechanical, PA, and PF factors of this thesis, and so the Bonferroni correction to reduce the familywise error rate when appropriate. Specifically, the Bonferroni correction was applied when multiple comparisons were tested within one outcome measure to reduce the likelihood of incorrectly rejecting a null hypothesis (Type I error).

To ensure the reliability of the AHAbd scores within each scorer and between scorers, inter-rater and intra-rater reliability were calculated using an Intra-class Correlation Coefficient (ICC): Specifically, $ICC_{2,1}$ tested for intra-rater reliability, and $ICC_{3,1}$ tested for inter-rater reliability (Davis et al., 2011).

Table 3.5. Summary of the statistical analyses used for factor's variable of interest used to compare between non-PD (low risk) and PD (high risk) groups of nursing students.

| Factor | Variable of Interest | Statistical Analysis |
|---|---|---|
| i. Biomechanical | Postural Control | Two-tailed t-test |
| | Movement Control | Fisher's exact test |
| | Frontal Plane Lumbopelvic Control | Fisher's exact test |
| | Trunk Range of Motion | Two-tailed t-test (flexion, lateral flexion), Fisher's exact test (axial rotation) |
| | Nursing Student Behaviours | Two-tailed t-test (continuous responses), Fisher's exact test (discrete responses) |
| | Patient Transfer Kinetics and Kinematics | Two-tailed t-test (kinetics), Fisher's exact test (kinematics) |
| ii. PA | Self-reported PA | Wilcoxon-Mann-Whitney test, Fisher's exact test |
| | Accelerometer-based PA | Two-tailed t-test |
| iii. PF | Muscular Strength | Two-tailed t-test |
| | Muscular Endurance | Two-tailed t-test |
| | Muscular Flexibility | Fisher's exact test |

## 4.0. Results

Six biomechanical, two PA, and three PF measures were assessed in 14 asymptomatic nursing students. Each participant was classified as either PD (high-risk) or non-PD (low-risk) based on the amount of transient pain that developed during the 60 minute testing session (PD had >10mm change relative to baseline). The only anthropometric difference found between the groups was mass, with non-PD being 22% heavier than PD (p=0.032; Table 3.3). All other measures (age, height, BMI, body fat, and segment circumferences) were similar. A two-tailed t-test and a two-factor, repeated measures mixed model ANOVA was conducted to test if PD and non-PD groups were statistically different in terms of self-reported transient pain developed during the protocol. To identify statistical differences in the biomechanical, PA, and PF measures between the PD and non-PD groups, a two-tailed t-test, a Fisher's exact test, and a Wilcoxon-Mann-Whitney test was conducted where appropriate.

### *4.1. Transient Pain Development Results*

To compare the self-reported transient pain developed during the 60 minute testing of visit two, it was first necessary to record a baseline measurement of self-reported pain to normalize the responses. The data collection in this study consisted of two visits, and so baseline measurements of self-reported pain from visits one and two recorded, compared and tested using a two-tailed t-test (Figure 4.1). During visit one, baseline self-reported pain scores ranged for all participants from 0mm to 25.2mm, and were not different between non-PD, who averaged 7.86mm (±10.83), and PD, who averaged 3.62mm (±5.28) ($t_{11}$=-0.871, p=0.383). Visit two baseline scores ranged from 0mm to 39.5mm for all participants and were also not different between non-PD and PD, who averaged 11.74mm (±13.67) and 13.93mm (±16.86) respectively ($t_{11}$=-0.259, p=0.805). No differences were observed when comparing the second baseline measurements to the first baseline measurements ($t_{11}$=0.566; $p_{non\text{-}PD}$=0.567; $t_{11}$=-1.43; $p_{PD}$=0.203). Baseline self-reported pain scores were not different between- within-groups, which suggested that the participants were asymptomatic as low- and high-risk nursing students reported a similar amount of pain prior to the 60 minute visit two testing, and that the baseline values were stable. Note, the baseline score taken at the beginning of visit two was subtracted from all subsequent self-reported pain measurements to normalize the data.

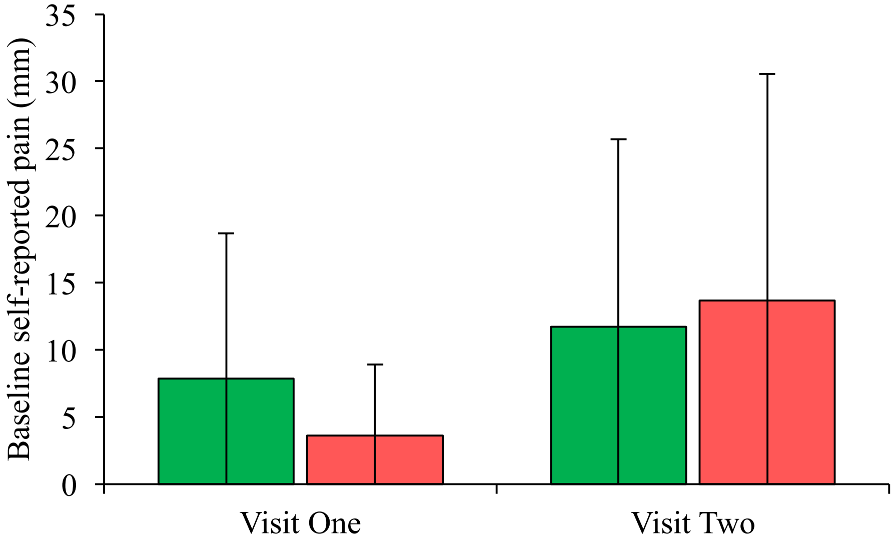


Figure 4.1. No differences in baseline scores of self-reported pain (mm), reported as a mean (±SD), were observed between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.203).

To compare self-reported transient pain developed during the data collection, two-tailed t-tests were conducted on the minimum, maximum, and average changes in self-reported pain. Differences were observed between groups in minimum, maximum, and average change of the self-reported transient pain scores ($p<0.004$) (Table 4.1). Again, a 10mm increase of self-reported transient pain from baseline developed at any of the 15min intervals during the data collection was used to classify each participant as a PD. The maximum changes in self-reported transient pain during the collection protocol was the criterion used to classify each participant as non-PD or PD, and was significantly larger in PD than non-PD ($t_{11}=-4.488$, $p=0.004$) (Figure 4.2). These results suggested that the PD group experienced more pain than the non-PD during visit two.

Table 4.1. The minimum, maximum, and average changes in self-reported transient pain (mm), reported as a mean (±SD), from the non-PD (n=7) and PD (n=6) during the 60 minute testing.

| | **Minimum (mm)** | **Maximum (mm)** | **Average (mm)** |
|---|---|---|---|
| **Non-PD** | -4.51 (±4.73) | 0.94 (±5.57) | -1.64 (±3.91) |
| **PD** | 5.90 (±4.72) | 24.18 (±12.39) | 15.48 (±8.79) |
| **p-Value** | 0.002 | 0.004 | 0.004 |

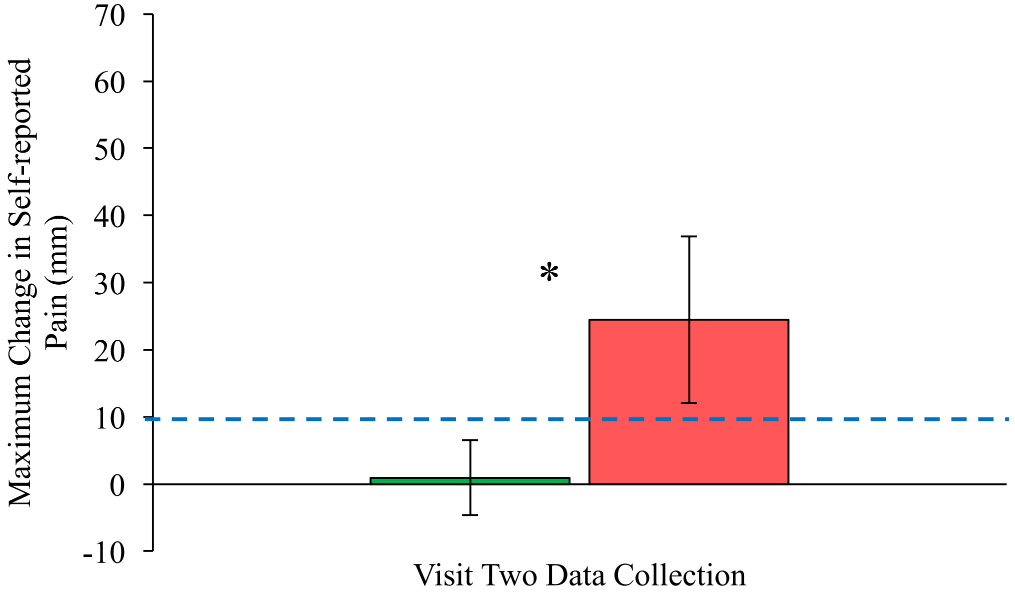


Figure 4.2. The maximum change in self-reported transient pain (mm) during visit two, reported as a mean (±SD), was lower in non-PD (n=7; 🟩) than in PD (n=6; 🟥) (p=0.004, significance indicated with an asterisk, *). The horizontal dashed blue line indicates the 10mm threshold used to classify participant as either a PD or non-PD.

To investigate the self-reported pain levels at each of the four intervals (15min, 30min, 45min, and 60min), a two-factor, repeated measures mixed model was used. Findings indicated a significant group effect ($F_1$=21.77, p=0.0007) and a significant interaction between group and time on the changes in self-reported transient pain ($F_4$=3.45, p=0.014) (Figure 4.3). To further investigate the interaction, a Tukey-Kramer method was used as a post-hoc test for between- and within-groups comparisons. Between-groups differences in self-reported pain changes were observed at each of the four time points (p<0.021). For the within-group comparisons, significant differences were observed in PD when comparing the baseline score to the change in self-reported transient pain at the 15-minutes (p=0.007), 30-minutes (p=0.027), 45-minutes (p=0.017), and 60-minutes (p=0.0003) time points. However, no differences were observed in non-PD when comparing the baseline VAS score to the change in VAS score at any of the four time points (p>0.999), and only at the 0-15 minute interval for PD. Changes in VAS score were also compared between successive time points (15-30 minutes, 30-45 minutes, 45-60 minutes), and no differences were observed in either non-PD (p=1.000) or PD (p>0.943). These results suggested that non-PD remained at baseline levels throughout testing, and that PD had higher self-reported pain at the first 15-minutes time point but no further increase thereafter.  Therefore, the division of participants based on the transient development of pain was used as a factor for all subsequent analyses.

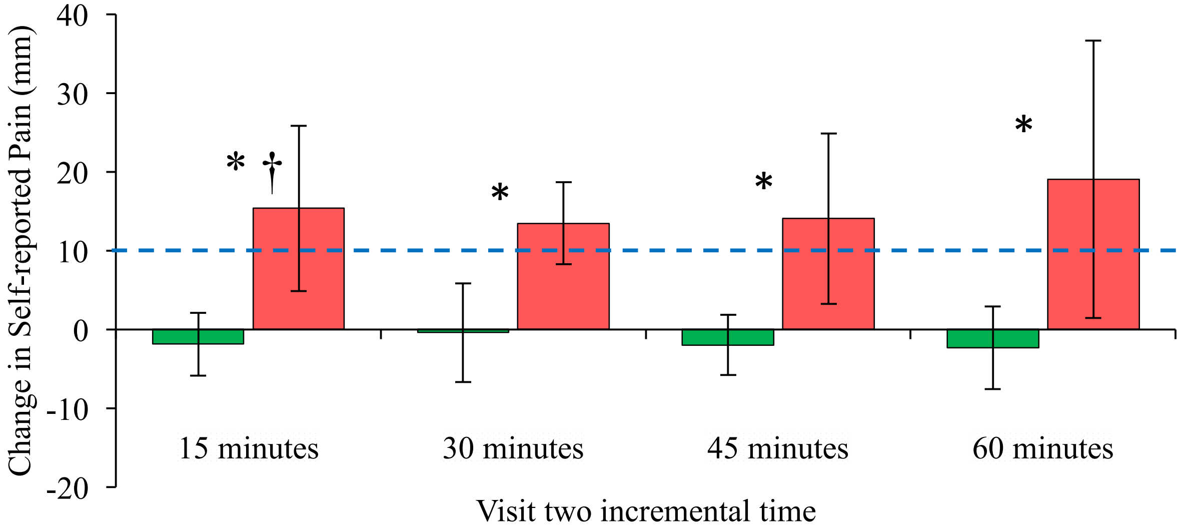


Figure 4.3. Changes in self-reported transient pain (mm), reported as a mean (±SD), were lower for non-PD (n=7; 🟩) than for PD (n=6; 🟥) at each increment (p<0.027, significance indicted with an asterisk, *). Only one within-group difference was observed, between 0-15 minutes in the PD group (p=0.007, significance indicated with a dagger, †). The horizontal dashed blue line depicts the clinically-relevant 10mm threshold used to classify each participant as either non-PD or PD.

## *4.2. Biomechanical Results*

Biomechanical measures were compared between non-PD and PD to test for a potential association between the development of clinically-relevant transient pain and differences in postural control, movement patterns, and a simulated patient transfer task.

### *4.2.1. Postural Control*

Recall, a WBB was used to assess the postural control in non-PD and PD nursing student participants. Four 30-second static posture trials were used for the comparison: Quiet standing, forward bend (held trunk flexion), as well as left and right single stance. Three outcome measures were necessary to assess COP distance in the frontal and sagittal planes (mediolateral and anteroposterior sway distance, respectively), and to assess total COP distance in both planes (path distance). All postural control comparisons were tested using a two-tailed t-test. Due to a technical error with the WBB Bluetooth signal, the data for one non-PD participant was unable to be analyzed. Twelve outcome measures were compared in total, and so an adjusted critical p-value of $p=0.00417$ was used.

To quantify postural control in the frontal plane, mediolateral COP sway distance (mm) was compared between PD and non-PD (Figure 4.4). No differences were observed between groups in any of the four trials ($p>0.006$). Specifically, for the quiet standing trial, mediolateral sway distance ranged from 3.66mm to 15.26mm, and non-PD had a smaller sway distance at 7.15mm (±3.17) than PD at 12.75mm (±2.13) ($t_{10}=-3.59$, $p=0.006$). For the forward bend (held trunk flexion) trial, sway distance ranged from 10.21mm to 26.36mm, and non-PD and PD displayed a sway distance of 18.11mm (±4.45) and 17.44mm (±5.02) respectively ($t_{10}=0.24$, $p=0.813$). For the left single stance trial, sway distance ranged from 23.05mm to 50.61mm, and non-PD and PD displayed 34.37mm (±10.82) and 30.23mm (±3.05) of sway distance, respectively ($t_{10}$=0.91, p=0.403). Lastly, for the right single stance trial, mediolateral sway distance ranged from 21.85mm to 77.58mm, and non-PD and PD displayed 38.71mm (±19.29) and 29.80mm (±4.81), respectively ($t_{10}$=1.22, p=0.271). These data suggested that non-PD displayed a more tightly-controlled posture in the frontal plane than did PD, but only during the quiet standing trial.

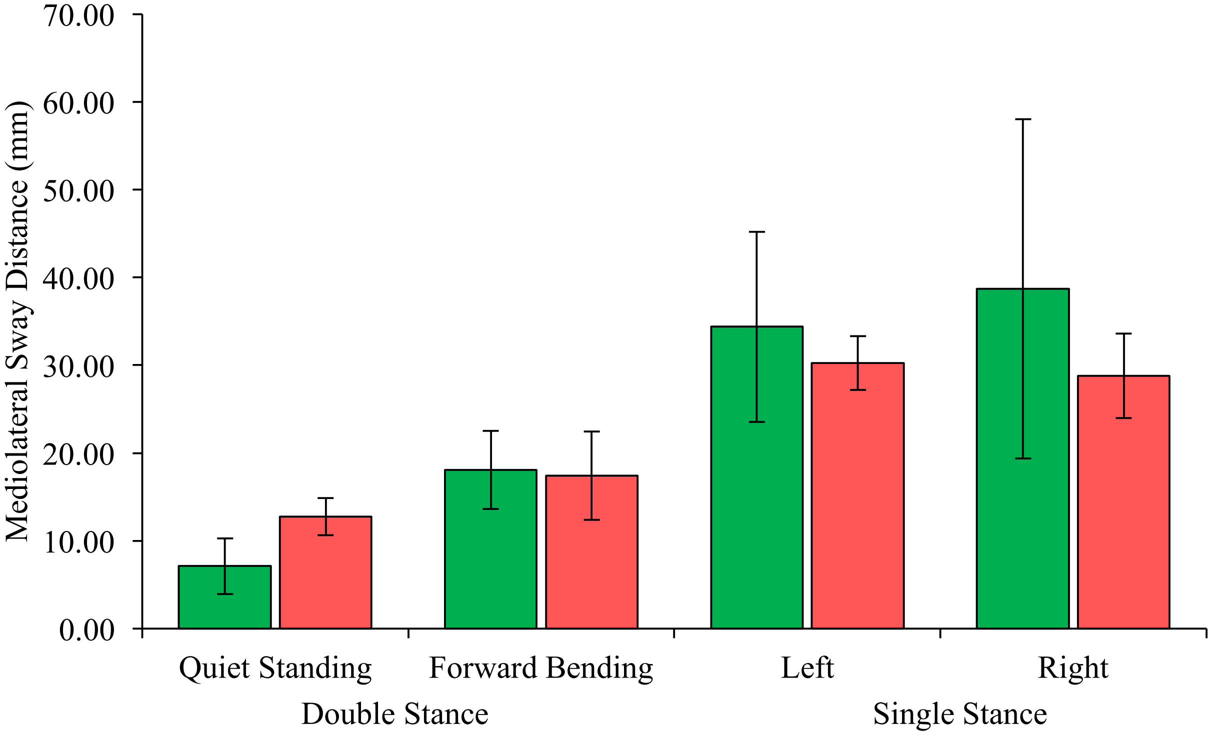


Figure 4.4. Mediolateral sway distance (mm), reported as a mean (±SD), of non-PD (n=6; 🟩) and PD (n=6; 🟥). No differences were observed between groups (p>0.006 using adjusted critical p-value of p=0.00417), which suggested that the two groups displayed a similar amount of postural sway in the mediolateral axis.

Postural control was also compared between non-PD and PD in the sagittal plane by quantifying anteroposterior COP sway distance (mm) (Figure 4.5). No differences in anteroposterior sway distance were observed between groups ($p>0.372$). Specifically, for the forward bend (held trunk flexion) trial, anteroposterior sway distance ranged from 12.50mm to 41.59mm, and non-PD and PD displayed 23.68mm (±8.86) and 26.95mm (±8.72), respectively ($t_{10}=-0.65$, $p=0.530$). For the quiet standing trial, sway distance ranged from 10.13mm to 30.21mm, and non-PD and PD displayed 17.83mm (±6.92) and 17.92mm (±5.93), respectively ($t_{10}=-0.02$, $p=0.982$). For the left single stance trial, sway distance ranged from 30.81mm to 59.41mm, and non-PD and PD displayed 40.82mm (±8.20) and 45.81mm (±10.18), respectively ($t_{10}=-0.94$, $p=0.372$). Finally, for the right single stance trial, sway distance ranged from 23.39mm to 49.25mm, and non-PD and PD displayed 37.74mm (±5.71) and 37.57mm (±8.94), respectively ($t_{10}=0.04$, $p=0.971$). These data indicated that, in contrast to the frontal plane, non-PD and PD were not different in terms of postural stability in the sagittal plane.

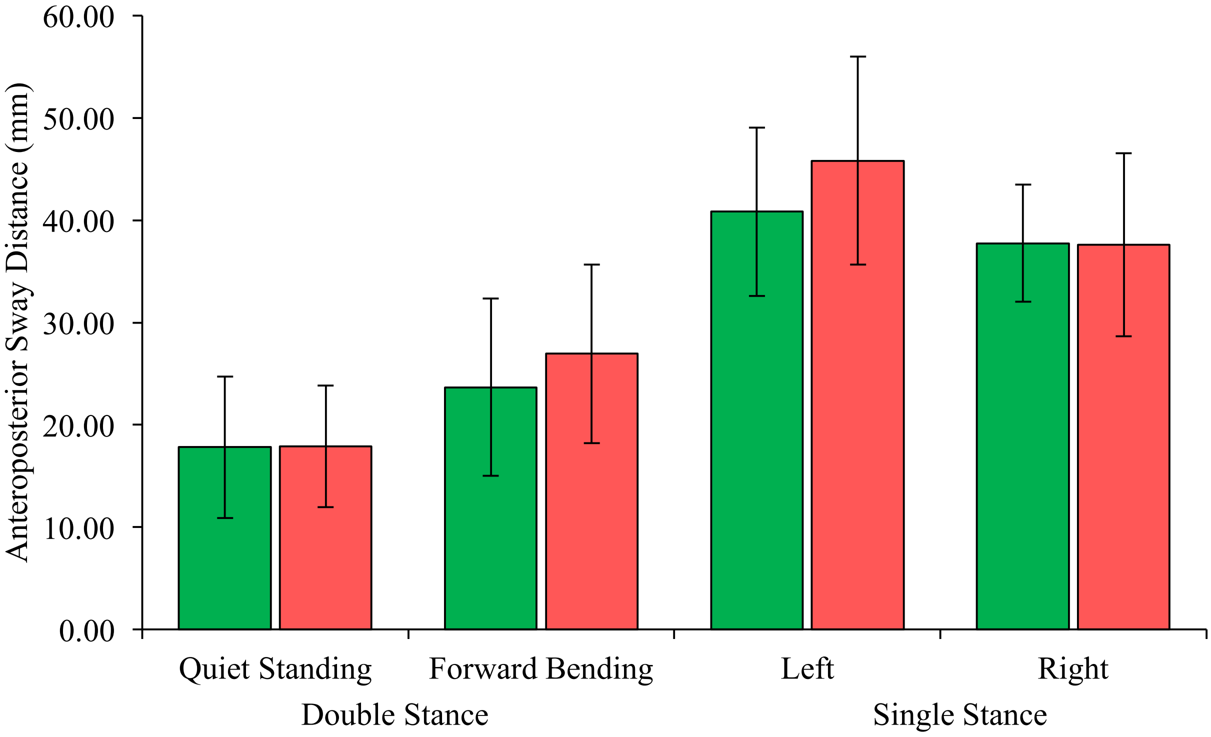


Figure 4.5. No differences were observed in the anteroposterior sway distance (mm), reported as a mean (±SD), between non-PD (n=6; 🟩) and PD (n=6; 🟥) (p>0.370). These observations suggested that the two groups displayed a similar amount of anteroposterior postural sway.

The mediolateral and anteroposterior COP sway distance data gave insight to planar range of COP movement, but provided no detail of the quantity of movement that occurred within the range boundaries. To quantify the cumulative distance that the COP travelled on the WBB during each trial, COP path distance (mm) was used (Figure 4.6). No differences were observed between non-PD and PD in terms of COP path distance in any of the four trials (p>0.339). Specifically, for the forward bend (held trunk flexion) trial, COP path distance ranged from 219.31mm to 532.10mm, and non-PD and PD displayed 386.43mm (±120.12) and 408.97mm (±69.67), respectively ($t_{10}$=-0.4, p=0.701). For the quiet standing trial, path distance ranged from 131.04mm to 408.61mm, and non-PD and PD displayed 205.20mm (±66.66) and 250.05mm (±86.37), respectively ($t_{10}$=-1.01, p=0.339). For the left single stance trial, path distance ranged from 583.04mm to 1316.98mm, and non-PD and PD displayed 939.73mm (±267.49) and 909.80mm (±166.56), respectively ($t_{10}=0.23$, $p=0.822$). Finally, for the right single stance trial, COP path distance ranged from 681.29mm to 1269.73mm, and non-PD and PD displayed 889.37mm (±238.07) and 896.14mm (±155.27), respectively ($t_{10}=-0.06$, $p=0.955$). These data indicated that, similar to the anteroposterior COP sway distance, non-PD and PD were not different in terms of COP path distance.

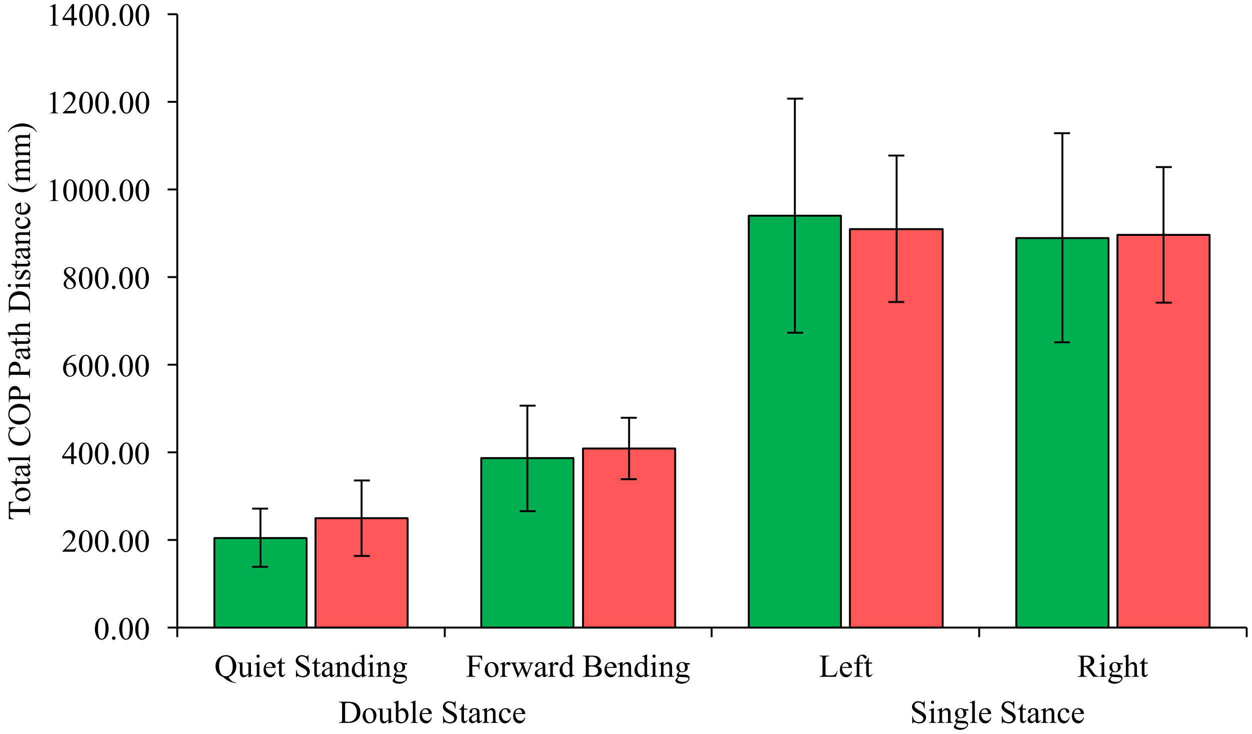


Figure 4.6. No differences were observed in total COP path length (mm), reported as a mean (±SD), between non-PD (n=6; 🟩) and PD (n=6; 🟥) ($p>0.339$). These observations suggested that the two groups displayed a similar quantity of postural sway.

*4.2.2. Movement Control*

The modified deep squat test was used to compare general movement control between low- and high-risk nursing students. Specifically, the modified deep squat tested the coordinated mobility of the upper and lower extremities, as well as the stability of the trunk and hips. A Fisher's exact test was used to compare the distribution of scores between the two groups, and no differences were observed (p=0.559) (Table 4.2). Specifically, 85.7% (6 of 7) of non-PD scored a 2, while the remaining 14.3% (1 of 7) scored a 3. For the PD, 66.7% (4 of 6) scored a 2 while the remaining 33.3% (2 of 6) scored a 3. These data suggested that non-PD and PD may not be different in terms of performing unaided controlled movements.

Table 4.2. No differences were observed in the distribution of scores of the modified deep squat test (scored 0-3), reported as a distribution of frequency, between non-PD (n=7) and PD (n=6) (p=0.559).

| **Movement Control** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Modified deep squat test score (rated: 0-3) | | | 0.559 |
| 2: Heels off ground (< 5.1cm) | 6 (85.7%) | 4 (66.7%) | |
| 3: Heels off ground (> 5.1cm) | 1 (14.3%) | 2 (33.3%) | |

*4.2.3. Frontal Plane Lumbopelvic Control*

The AHAbd test was used to compare frontal plane lumbopelvic control between the non-PD and PD groups. Briefly, the test was scored on a 0-3 scale for both the left and right sides by three separate raters. The consensus scores of the three raters were then dichotomized into "positive" (≥2) and "negative" (<2) scores, and the distribution of scores were compared between non-PD and PD on the left and right sides using a Fisher's Exact Test. Due to a technical error with the AHAbd test recording in one non-PD participant, this participant was scored only during the collection protocol and was excluded from intra- and inter-rater reliability analyses. The observed data was determined to be reliable ($ICC_{2,1}$=0.860, $ICC_{3,1}$=0.855).

No differences were observed in AHAbd scores on either of the two sides between non-PD and PD (p>0.103) (Table 4.3). For the left side, 85.7% (6 of 7) of non-PD and 50.0% (3 of 6) of PD passed the AHAbd test (p=0.266). For the right side, however, 85.7% (6 of 7) of non-PD and 33.3% (2 of 6) of PD passed the AHAbd test (p=0.103). These data suggested that low- and high-risk nursing students displayed a similar ability to maintain frontal plane lumbopelvic control during a side-lying leg raise movement, however the interpretation may have been limited due to a low sample size.

Table 4.3. No differences were observed in the distribution of Active Hip Abduction test negative and positive scores on either the left or right sides, reported as distributions of frequency, between non-PD (n=7) and PD (n=6) (p>0.103).

| **Frontal Plane Lumbopelvic Control** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| AHAbd Test - Left (rated: 0-3) | | | 0.266 |
| 1: Minimal (negative test) | 6 (85.7%) | 3 (50%) | |
| 2: Moderate (positive test) | 1 (14.3%) | 3 (50%) | |
| AHAbd Test - Right (rated: 0-3) | | | 0.103 |
| 1: Minimal (negative test) | 6 (85.7%) | 2 (33.3%) | |
| 2: Moderate (positive test) | 1 (14.3%) | 4 (66.7%) | |

### *4.2.4. Trunk Range of Motion*

To compare trunk ROM (measured in degrees, °) between non-PD and PD groups, the ROM of five standing to end point angles were measured: Flexion, lateral flexion, and axial rotation (Figure 4.7). Briefly, ROM was measured using still images that were captured before the movement began and again at the end position reached by each participant. Trunk flexion (captured in the sagittal plane) and left/right lateral flexion or bend (captured in the frontal plane) ROM were measured using a protractor overlay of the two still images, and left/right axial rotation (frontal plane image) ROM was estimated using 3DMatch software. The estimation based on the 3DMatch axial rotation posture bins was necessary since images in the transverse plane could not be collected. Comparisons between groups were tested using a two-tailed t-test.

No differences in trunk ROM were observed between non-PD and PD in any of the five angles ($p>0.112$). Specifically, the trunk flexion angles ranged from 35.0° to 77.0°, and non-PD and PD averaged 60.86° (±10.93) and 49.8° (±11.8) °, respectively ($t_{11}=1.75$, $p=0.112$). The trunk lateral flexion angles ranged from 26.0° to 44.0°, and non-PD and PD averaged 36.7° (±4.8) and 35.3° (±4.9) for the right side ($t_{11}=0.51$, $p=0.619$) and 31.3° (±4.7) and 31.8° (±1.7) for the left side, respectively ($t_{11}=-0.27$, $p=0.783$). The axial rotation angles ranged from 20.0° to 35.0°, and non-PD and PD averaged 32° (±6) and 30° (±8) for the right side ($t_{11}=0.77$, $p=0.474$) and 33° (±6) and 30° (±8) for the left side ($t_{11}=0.77$, $p=0.474$), respectively. These data suggested that non-PD and PD displayed a similar amount of maximal trunk ROM in terms of flexion, lateral flexion, and axial rotation.

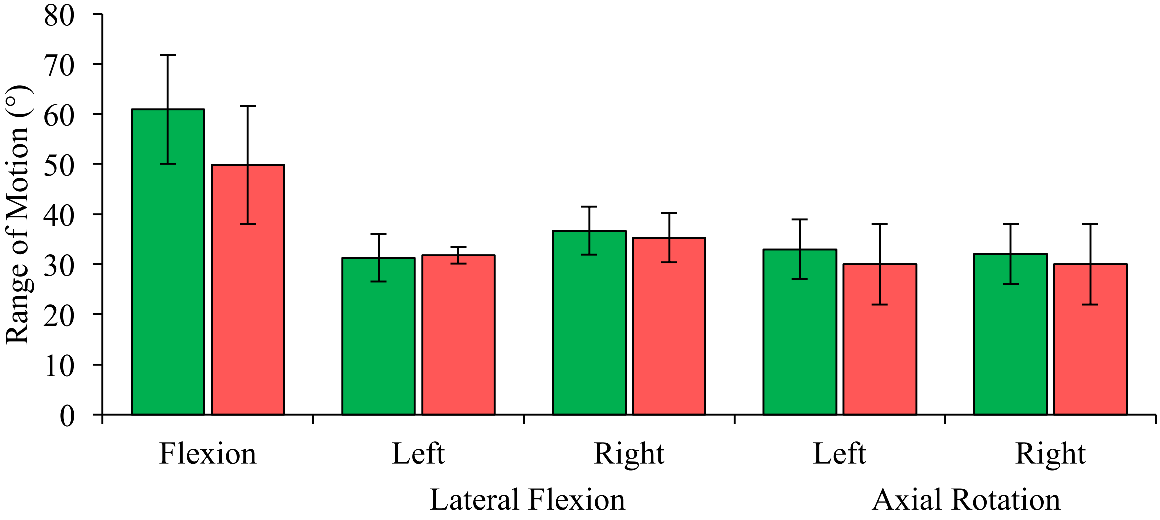


Figure 4.7. No differences were observed in the trunk range of motion (°), reported as a mean (±SD), between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.112).

### *4.2.5. Nursing Student Behaviours – Sitting, Standing, Footwear, and Lifting Technique*

The sitting and standing behaviours, as well as footwear and lifting technique characteristics, of nursing students were assessed using a custom designed NSQ. Again, the NSQ was based off a questionnaire previously used on working nurses (Babiolakis et al., 2015) and was adjusted to specifically target nursing students. For comparisons between low- and high-risk nursing students, a two-tailed t-test was used to compare the continuous data of the NSQ, while a Fisher's exact test was used to compare the discrete data of the NSQ.

No differences were observed between non-PD and PD in terms of sitting behaviours (p>0.143) (Table 4.4). On an average school day, the longest self-reported duration of a sitting bout at a desk or computer ranged from 1 to 4 hours between non-PD and PD and averaged 2.27 hours ($t_{11}$=-0.72, p=0.501). The total self-reported duration of sitting at a desk or computer on an average school day ranged from 3 to 14 hours between non-PD and PD and averaged 9.23 hours

($t_{11}$=-1.69, p=0.143). No differences were observed regarding frequency of chair adjustments between groups. These observations suggested that non-PD and PD did not differ in the sitting behaviours of an average school day.

Table 4.4. No differences were observed in sitting duration on an average school day or in frequency of chair adjustment between non-PD (n=7) and PD (n=6) (p>0.143).

| **Sitting Behaviours** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Sitting at a desk/computer (average school day) | | | |
| Maximum bout duration (hours) | 2.07 (0.93) | 2.50 (1.22) | 0.501 |
| Total duration (hours) | 7.86 (2.34) | 10.83 (3.92) | 0.143 |
| "Do you adjust the chair's height, seat angle, backrest angle, and/or arm rests?" | | | 0.386 |
| "Never" | 1 (14.3%) | 1 (16.7%) | |
| "Rarely" | 1 (14.3%) | 2 (33.3%) | |
| "Sometimes" | 3 (42.9%) | 0 (0.0%) | |
| "Most of the time" | 2 (28.6%) | 1 (16.7%) | |
| "Always" | 0 (0.0%) | 2 (33.3%) | |

No differences were observed between non-PD and PD in terms of standing behaviours (p>0.421) (Table 4.5). On an average school day, the longest self-reported duration of a standing bout ranged from 1 to 5 hours between non-PD and PD and averaged 1.29 hours ($t_{11}$=0.57, p=0.592). The total self-reported duration of standing on an average school day ranged from 1 to 8 hours between non-PD and PD and averaged 2.27 hours ($t_{11}$=0.81, p=0.421). These findings suggested that non-PD and PD did not differ in terms of standing behaviours on a typical school day.

Table 4.5. No differences were observed in standing duration on an average school day, in frequency of bending at a seated desk, or in frequency of standing desk use between non-PD (n=7) and PD (n=6) (p>0.421).

| **Standing Behaviours** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Standing still (average school day) | | | |
| Maximum bout duration (hours) | 1.54 (1.40) | 1.00 (1.97) | 0.592 |
| Total duration (hours) | 2.71 (2.63) | 1.75 (1.41) | 0.421 |
| "Do you bend over to complete desk/computer work while standing at a seated desk?" | | | 0.837 |
| "Never" | 0 (0.0%) | 0 (0.0%) | |
| "Rarely" | 1 (14.3%) | 1 (16.7%) | |
| "Sometimes" | 5 (71.4%) | 3 (50.0%) | |
| "Most of the time" | 1 (14.3%) | 1 (16.7%) | |
| "Always" | 0 (0.0%) | 1 (16.7%) | |
| "Do you complete desk/computer work while standing at a standing desk?" | | | 0.662 |
| "Never" | 2 (28.6%) | 1 (16.7%) | |
| "Rarely" | 3 (42.9%) | 4 (66.7%) | |
| "Sometimes" | 1 (14.3%) | 1 (16.7%) | |
| "Most of the time" | 1 (14.3%) | 0 (0.0%) | |
| "Always" | 0 (0.0%) | 0 (0.0%) | |

No differences in footwear were observed between non-PD and PD (p>0.493) (Table 4.6). The use of insoles was reported by one non-PD and none of the PD (p=1.000), and comfort was the reason reported for use of the insoles. Similarly, the use of orthotics was reported by one non-PD and none of the PD (p=1.000), and plantar fasciitis was the reason reported for use of the orthotics. These results suggested that non-PD and PD did not differ in terms of most commonly worn footwear.

Table 4.6. No differences were observed in type of shoes most commonly worn, in wear time of shoes, or in use of insoles or orthotics between non-PD (n=7) and PD (n=6) (p>0.493).

| **Footwear Characteristics** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Type of shoes most commonly worn | | | 1.000 |
| “Running shoes” | 4 (57.1%) | 3 (50.0%) | |
| “Boots” | 1 (14.3%) | 1 (16.7%) | |
| “Sandals” | 1 (14.3%) | 1 (16.7%) | |
| “Flats” | 1 (14.3%) | 1 (16.7%) | |
| “How old are your shoes?” | | | 0.493 |
| “<6 months” | 3 (42.9%) | 1 (16.7%) | |
| “6-12 months” | 2 (28.6%) | 1 (16.7%) | |
| “>12 months” | 2 (28.6%) | 4 (66.7%) | |
| Use of insoles or orthotics | | | |
| Insoles | 1 of 7 (14.3%) | 0 of 6 (0.0%) | 1.000 |
| Orthotics | 1 of 7 (14.3%) | 0 of 6 (0.0%) | 1.000 |

In terms of lifting technique, all participants reported that proper lifting techniques were learned in first and second year courses “NURS 110” and “NURS 1900”. The most commonly reported key characteristics of a “good” lift included, in descending order, “Lifting with the legs (at the knees) with a squat technique”, “Maintaining a neutral spine during the lift”, and “Avoiding flexed (leaned) postures”. No differences were observed between non-PD and PD in any of the three responses (p>0.069). Specifically, “Lifting with the legs (at the knees) with a squat technique” was reported by 100% of non-PD and 83.3% of PD (p=0.462). “Maintaining a neutral spine during the lift” was reported by 100% of non-PD and 50.0% of PD (p=0.069). Finally, “Avoiding flexed (leaned) postures” was reported by 57.1% of non-PD and 33.3% of PD (p=0.592). These results suggested that non-PD and PD had undergone similar MPH training in the nursing program and had a similar understanding of the elements that define a “good” lift.

Table 4.7. No differences were observed in the listed components of a proper lifting technique between non-PD (n=7) and PD (n=6) (p>0.069).

| **Lifting Technique Characteristics** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Proper lifting technique components | | | |
| "Lifting with the legs (at the knees), with a squat technique" | 7 of 7 (100%) | 5 of 6 (83.3%) | 0.462 |
| "Maintaining a neutral spine during the lift" | 7 of 7 (100%) | 3 of 6 (50.0%) | 0.069 |
| "Avoiding flexed (leaned) postures" | 4 of 7 (57.1%) | 2 of 6 (33.3%) | 0.592 |

### *4.2.6. Simulated Patient Transfer Task Kinetics and Kinematics*

A simulated patient transfer task consisting of a transfer from a chair to a massage table (similar to a hospital bed) was performed by each nursing student using a 27.3kg (60lbs) fire prevention practice manikin. Recall, the transfer was quantified from video analysis using 3DMatch software, a posture-matching tool that estimated L4/L5 joint forces and moments using a rigid link quasi-static model. Briefly, this tool quanified three-dimensional movements during the simulated patient transfer task through two-dimensional video capture and a selection of three-dimensional segment angle (trunk, neck, upper arm, and lower arm) bins. The peak L4/L5 joint moments, peak L4/L5 joint compression and shear forces, as well as kinematics of the trunk and shoulders were output form the program and compared between non-PD and PD.

The cycle time for the simulated patient transfer task was compared between groups using a two-tailed t-test. No difference was observed between groups ($t_{11}$=1.05, p=0.315), as non-PD performed the task in 7.7s (±3.0) and PD performed the task in 6.2s (±1.8.

To compare peak L4/L5 moments (N•m) of the simulated patient transfer task between non-PD and PD, as calculated by the 3DMatch spine model, peak extension, flexion, left and right lateral flexion, as well as left and right axial rotation moments were quantified (Figure 4.8) and compared using a two-tailed t-test. No significant differences were observed between non-

PD and PD in any of the six peak L4/L5 moments (p>0.063). Specifically, for the peak extension moment, ranging from 0 N•m to 40.91 N•m, non-PD and PD scored 6.76 N•m (±15.25) and 5.19 N•m (±12.72), respectively ($t_{11}$=0.21, p=0.843). For the peak flexion moment, ranging from 91.05N•m to 139.11N•m, non-PD and PD scored 113.10 N•m (±12.53) and 119.30 N•m (±14.95), respectively ($t_{11}$=0.81, p=0.438). For the peak left and right lateral flexion moments, ranging from 0N•m to 57.25N•m, non-PD and PD scored 26.70 N•m (±18.62) and 11.46 N•m (±12.17) for the left side ($t_{11}$=-1.71, p=0.106) and 9.60 N•m (±15.17) and 17.76 N•m (±20.43) for the right side ($t_{11}$=-0.83, p=0.441), respectively. For the peak left and right axial rotation moments, ranging from 0N•m to 83.26N•m, non-PD and PD scored 16.23 N•m (±17.85) and 22.79N•m (±12.58) for the left side ($t_{11}$=-0.75, p=0.456) and 46.46 N•m (±30.57) and 18.61 N•m (±15.48) for the right side ($t_{11}$=-2.01, p=0.063), respectively. These results suggested that non-PD and PD performed the task with similar peak L4/L5 moments.

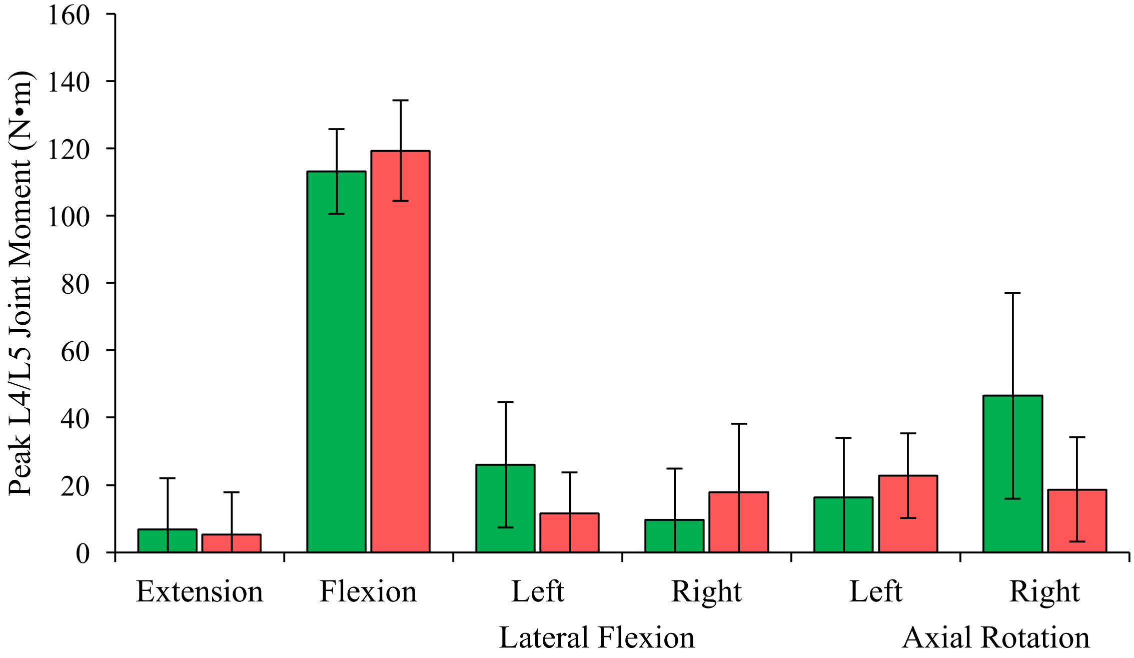


Figure 4.8. No differences were observed in any of the six peak L4/L5 joint moments (N•m) during the simulated patient transfer task, reported as a mean (±SD), between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.063).

To compare peak L4/L5 shear and compression forces (N) of the simulated patient transfer task between non-PD and PD, as calculated by the 3DMatch spine model, peak anterior and posterior bone-on-bone shear, peak anterior and posterior trunk reaction shear, left and right lateral reaction shear, as well as peak bone-on-bone compression forces were quantified (Figure 4.9) and compared using a two-tailed t-tested. Again, safe limits for the L4/L5 spine segment during occupational lifting were established by the National Institute for Occupational Safety and Health to be 3400N for peak compression force and 500 N for peak anterior-posterior shear force. The peak L4/L5 shear and compression forces observed in non-PD and PD were compared to these critical values. No differences were observed between non-PD and PD in any of the L4/L5 peak shear or compression forces ($p>0.082$). Specifically, peak bone-on-bone shear force values ranged from 0N to 87.53N, and non-PD and PD scored 29.19N (±32.96) and 3.01N (±7.38) in the anterior direction ($t_{11}=-1.89$, $p=0.082$), as well as 9.56N (±14.74) and 27.25N (±24.84) in the posterior direction ($t_{11}=0.166$, $p=0.166$), respectively. Peak trunk reaction shear force values ranged from 0N to 87.53N, and non-PD and PD scored 29.19N (±32.96) and 3.01N (±7.38) in the anterior direction ($t_{11}=-1.89$, $p=0.082$), as well as 6.24N (±14.80) and 19.25N (±13.05) in the posterior direction ($t_{11}=-1.67$, $p=0.120$), respectively. Peak lateral reaction shear force values ranged from 0N to 22.74N, and non-PD and PD scored 9.68N (±9.78) and 2.41N (±3.07) in the left direction ($t_{11}=1.74$, $p=0.103$), as well as 8.25N (±6.97) and 3.47N (±4.50) in the right direction ($t_{11}=-1.44$, $p=0.166$), respectively. Peak bone-on-bone compression force values ranged from 1859.37N to 4380.22N, and non-PD and PD scored 2692.23N (±788.80) and 2459.61N (±466.15), respectively ($t_{11}=1.36$, $p=0.186$). Only two participants exceeded the 3400N peak compression force action limit, with peak compression values of 3405.65N and 4380.22N. Both subjects were non-PD. No participants exceeded the 500N peak shear force action limit. These data suggested that non-PD and PD performed the task with similar quantities of peak L4/L5 shear and compression forces. Importantly, the data suggested that both groups performed the one-time lifting task with peak forces well below the safe limits established by the National Institute for Occupational Safety and Health.

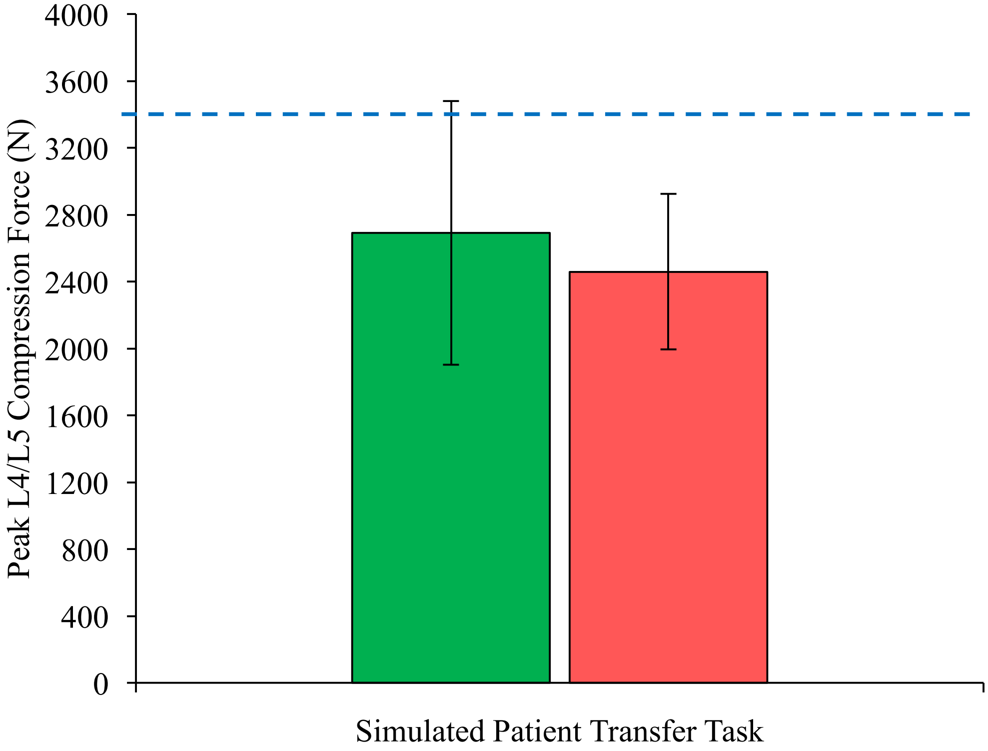


Figure 4.9. No difference was observed in the peak L4/L5 joint compression force (N), reported as a mean (±SD), during the simulated patient transfer task between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.100). The horizontal dashed blue line depicted the 3400N safe limit (Waters, 1993).

Kinematic information aggregated by the spine model of 3DMatch during the posture-matching component of the analysis was compared between non-PD and PD as percentage (%) of the task cycle spent in the defined trunk posture ranges (bins) (Figure 4.10). The comparisons were tested using a Fisher’s exact test. Nineteen outcome measures were used to compare groups, and so an adjusted critical p-value of $p=0.00263$ was used. The three bins that were relevant to the task for trunk flexion were: 'Neutral, <20°', 'Mild, 20-45°' and 'Severe, >45°', and for lateral flexion and axial rotation were 'Neutral, <15°', 'Mild, 15-30°' and 'Severe, >30°'. No differences were observed between non-PD and PD in any of the trunk postures ($p>0.164$). For the trunk flexion postures, non-PD executed the patient transfer task while in 'neutral' trunk flexion for 19.84% (±21.18) of the cycle, 'mild' trunk flexion for 38.60% (±25.50), and 'severe' for 41.60% (±38.10). PD, however, executed the simulated patient transfer task while in 'neutral' trunk flexion for 19.38% (±11.23) of the cycle, 'mild' trunk flexion for 48.50% (±16.30), and 'severe' for 29.90% (±14.40) ($p_{neutral}=0.962$, $p_{mild}=0.417$, $p_{severe}=0.475$). For the trunk lateral flexion postures, non-PD executed the task while in 'neutral' lateral flexion for 66.10% (±34.91) of the cycle, 'mild' lateral flexion for 26.90% (±23.90), and 'severe' for 7.00% (±14.00). PD, however, executed the task while in 'neutral' lateral flexion for 87.60% (±10.59) of the cycle, 'mild' lateral flexion for 12.40% (±10.60), and 'severe' for 0.00 (±0.00) ($p_{neutral}=0.164$, $p_{mild}=0.185$, $p_{severe}=0.233$). For the trunk axial rotation postures, non-PD executed the task while in 'neutral' axial rotation for 64.84% (±19.62) of the cycle, 'mild' axial rotation for 16.60% (±13.50), and 'severe' for 18.60% (±19.20). PD, however, executed the task while in 'neutral' axial rotation for 75.34% (±16.37) of the cycle, 'mild' axial rotation for 17.60% (±7.20), and 'severe' for 7.00% (±10.50) ($p_{neutral}=0.315$, $p_{mild}=0.869$, $p_{severe}=0.203$). These data suggested that non-PD and PD performed the simulated patient transfer task with similar percentages of time spent in neutral and non-neutral trunk postures.

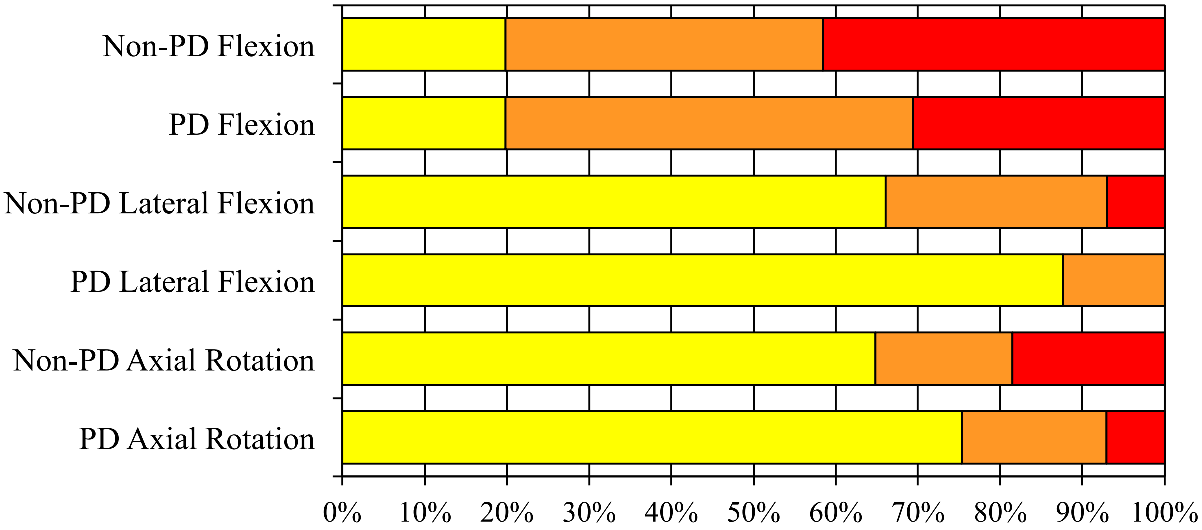


Figure 4.10. No differences were observed in the distribution of percent task (%) spent in neutral (🟨), mild non-neutral (🟧), and severe non-neutral (🟥) trunk postures, reported as a mean, during the simulated patient transfer task between non-PD (n=7) and PD (n=6) (p>0.160).

Similarly, kinematic information gathered by the left and right shoulder models of 3DMatch was compared between non-PD and PD as percentage (%) of the task spent in defined shoulder posture ranges (bins) (Figure 4.11). Again, the comparisons were tested using a Fisher's exact test. The two bins that were most relevant to the task for shoulder flexion were: 'Neutral, <20°', 'Mild, 20-90°' and 'Severe, >90°', and for shoulder abduction were 'Neutral, <45°' and 'Mild, 45-90°'. No statistical differences were observed between non-PD and PD in any of the right shoulder postures (p>0.080). For the right shoulder flexion postures, non-PD executed the task with 'neutral' shoulder flexion for 16.77% (±14.29) of the cycle, 'mild' shoulder flexion for 83.20% (±14.30), and 'severe' for 0.00% (±0.00). PD, however, executed the task with 25.00% (±18.31) of the cycle, 'mild' shoulder flexion for 73.40% (±18.50), and 'severe' for 1.60% (±3.90) ($p_{neutral}$=0.394, $p_{mild}$=0.315, $p_{severe}$=0.363). For the right shoulder abduction postures, non-PD executed the task with 'neutral' shoulder abduction for 65.60% (±20.90) of the lift, and ‘mild’ shoulder abduction for 34.40% (±20.90). PD, however, executed the task with ‘neutral’ shoulder abduction for 85.90% (±17.20) of the cycle, and ‘mild’ shoulder abduction for 14.10% (±17.20) ($p_{neutral}$=0.080, $p_{mild}$=0.080).

Similar to the right shoulder postures, no differences were observed between groups in terms of the right shoulder postures (p>0.023). Specifically, non-PD executed the task with ‘neutral’ left shoulder abduction for 73.70% (±21.80) of the cycle, and ‘mild’ for 26.30% (±21.80) PD, however, executed the task with ‘neutral’ left shoulder abduction for 98.60% (±3.40) of the cycle, and ‘mild’ for 1.40% (±3.40) ($p_{neutral}$=0.023; $p_{mild}$=0.023). Non-PD executed the task with ‘neutral’ shoulder flexion for 25.92% (±27.82) of the cycle, ‘mild’ shoulder flexion for 74.10% (±27.80), and ‘severe’ shoulder flexion for 0.00% (±0.00). PD, however, executed the task with ‘neutral’ shoulder flexion for 21.84% (±22.42) of the cycle, ‘mild’ shoulder flexion for 76.50% (±22.80), and ‘severe’ shoulder flexion for 1.60% (±3.90) ($p_{neutral}$=0.775, $p_{mild}$=0.864, $p_{severe}$=0.363).

These results, based on the left and right shoulder models of 3DMatch, suggested that non-PD and PD performed the simulated the one repetition of the patient transfer task with similar percent time in neutral and non-neutral shoulder postures, with the exception of left shoulder abduction.

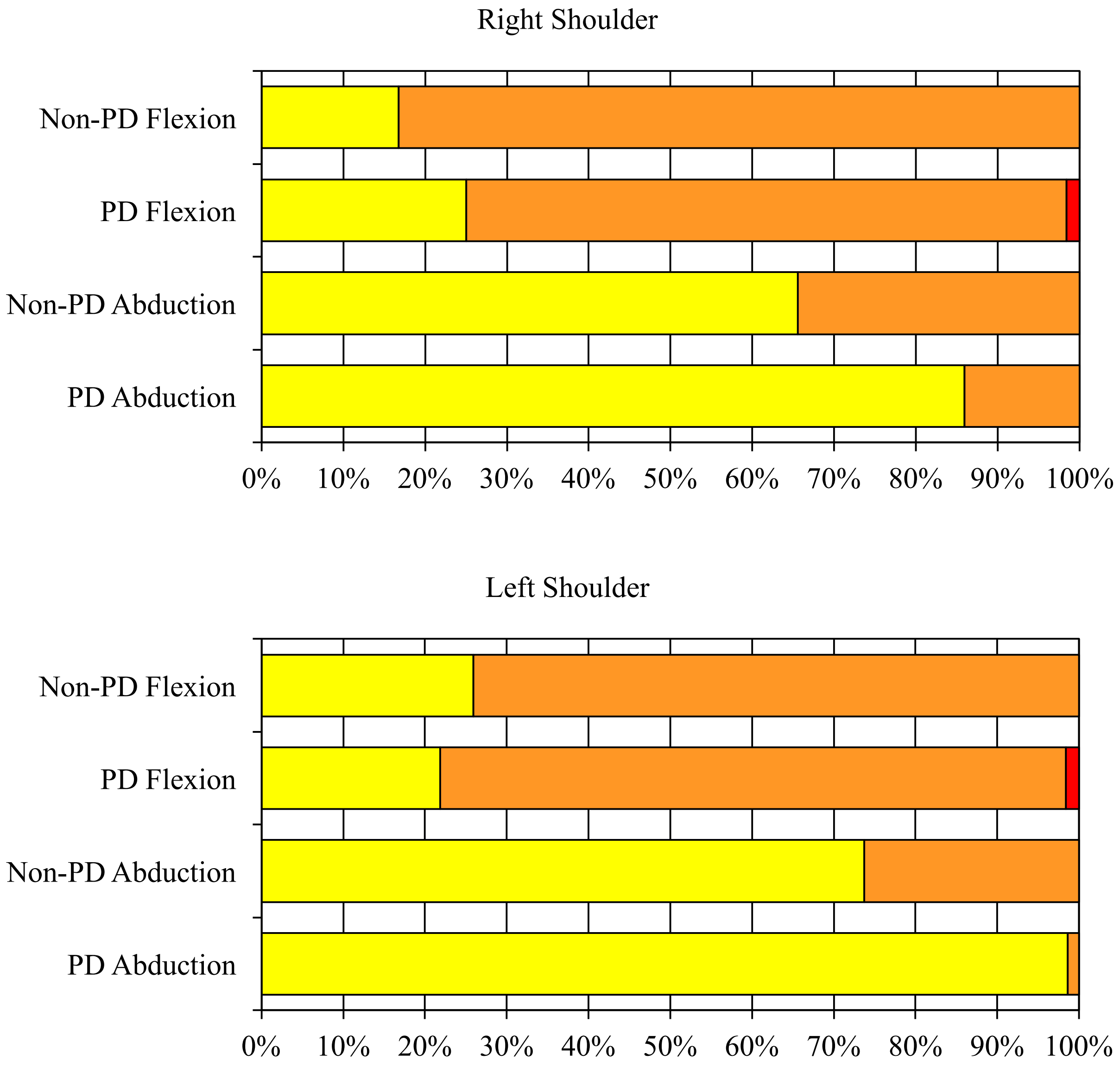


Figure 4.11. Distribution of neutral (🟨), mild non-neutral (🟧), and severe non-neutral (🟥) flexion and abduction postures of the A. right and B. left shoulder during the simulated patient transfer task, reported as average percentage (%) of the task cycle time, for non-PD (n=7) and PD (n=6). No differences were observed for any of the right or left shoulder postures (p>0.023).

To summarize, biomechanical measures were compared between non-PD and PD. The results of the biomechanical factor of this research study were summarized below (Table 4.8). The mediolateral sway distance during the quiet standing trial on the WBB was significantly smaller in non-PD when compared to PD (p=0.006).

Table 4.8. Summary of results for the biomechanical factor of this thesis. No differences were observed between groups in any of the biomechanical outcome measures with the exception of mediolateral sway distance during the quiet standing trial. Note: Adjusted p-values were used for some measures.

| **Outcome Measure** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Postural Control | | | |
| Mediolateral Sway Distance (mm) | | | |
| Quiet Stand | 7.15 (3.17) | 12.75 (2.13) | 0.006 |
| Forward Bend | 18.11 (4.45) | 17.44 (5.02) | 0.813 |
| Single Stance - Left | 34.37 (10.82) | 30.23 (3.05) | 0.403 |
| Single Stance - Right | 38.7 (19.3) | 29.8 (4.8) | 0.271 |
| Anteroposterior Sway Distance (mm) | | | |
| Quiet Stand | 17.8 (6.9) | 17.9 (5.9) | 0.982 |
| Forward Bend | 23.7 (8.7) | 26.9 (8.7) | 0.530 |
| Single Stance - Left | 40.8 (8.2) | 45.8 (10.2) | 0.372 |
| Single Stance - Right | 37.7 (5.7) | 37.6 (8.9) | 0.971 |
| COP Path Distance (mm) | | | |
| Quiet Stand | 205.2 (66.7) | 250 (86.4) | 0.339 |
| Forward Bend | 386.4 (120.1) | 409 (69.7) | 0.701 |
| Single Stance - Left | 939.7 (267.5) | 909.8 (166.6) | 0.822 |
| Single Stance - Right | 889.4 (238.1) | 896.1 (155.3) | 0.955 |
| Frontal Plane Lumbopelvic Control | | | |
| AHAbd Test - Left Side (rated: 0-3) | | | 0.266 |
| 1: Minimal | 6 (85.7%) | 3 (50%) | |
| 2: Moderate (positive test) | 1 (14.3%) | 3 (50%) | |
| AHAbd Test - Right Side (rated: 0-3) | | | 0.103 |
| 1: Minimal | 6 (85.7%) | 2 (33.3%) | |
| 2: Moderate (positive test) | 1 (14.3%) | 4 (66.7%) | |
| Movement Control | | | |
| Modified Deep Squat | | | 0.559 |
| 2: Heels off ground < 5.1cm | 6 (85.7%) | 4 (66.7%) | |
| 3: Heels off ground > 5.1cm | 1 (14.3%) | 2 (33.3%) | |
| Trunk Range of Motion | | | |
| Trunk flexion (°) | 60.9 (10.9) | 49.8 (11.8) | 0.112 |
| Lateral Flexion - Left (°) | 31.3 (4.7) | 31.8 (1.7) | 0.783 |
| Lateral Flexion - Right (°) | 36.7 (4.8) | 35.3 (4.9) | 0.619 |
| Axial Rotation - Left (°) | 33 (6) | 30 (8) | 0.474 |
| Axial Rotation - Right (°) | 32 (6) | 30 (8) | 0.474 |

|  |  |  |  |
|---|---|---|---|
| Nursing Student Behaviours |  |  |  |
| Sitting Bout | 2.07 (0.93) | 2.50 (1.22) | 0.501 |
| Sitting Cumulative | 7.86 (2.34) | 10.83 (3.92) | 0.143 |
| Standing Bout | 1.54 (1.40) | 1.00 (1.97) | 0.592 |
| Standing Cumulative | 2.71 (2.63) | 1.75 (1.41) | 0.421 |
| Simulated Patient Transfer Task |  |  |  |
| Peak Moments (N•m) |  |  |  |
| Extension | 6.8 (15.2) | 5.2 (12.7) | 0.843 |
| Flexion | -113.1 (12.5) | -119.3 (15) | 0.438 |
| Lateral Flexion - Left | -26.7 (18.6) | -11.5 (12.2) | 0.106 |
| Lateral Flexion - Right | 9.6 (15.2) | 17.8 (20.4) | 0.441 |
| Axial Rotation - Left | 16.2 (17.8) | 22.8 (12.6) | 0.456 |
| Axial Rotation - Right | -46.5 (30.6) | -18.6 (15.5) | 0.063 |
| Peak Forces (N) |  |  |  |
| Bone-on-bone Shear - Anterior | -29.2 (33.0) | -3.01 (7.4) | 0.082 |
| Bone-on-bone Shear - Posterior | 9.6 (14.7) | 27.3 (24.8) | 0.166 |
| Trunk Reaction Shear - Anterior | -29.2 (33.0) | -3.01 (7.4) | 0.082 |
| Trunk Reaction Shear - Posterior | 6.2 (14.8) | 19.3 (13.0) | 0.120 |
| Lateral Reaction Shear - Left | 9.7 (9.8) | 2.4 (3.1) | 0.103 |
| Lateral Reaction Shear - Right | - 8.3 (7.0) | -3.5 (4.5) | 0.166 |
| Bone-on-bone Compression | 2692.2 (788.8) | 2459.6 (466.2) | 0.186 |
| Kinematics (%) |  |  |  |
| Trunk Flexion |  |  | 0.962 |
| Trunk Lateral Flexion |  |  | 0.164 |
| Trunk Axial Rotation |  |  | 0.315 |
| Left Shoulder Flexion |  |  | 0.775 |
| Left Shoulder Abduction |  |  | 0.023 |
| Right Shoulder Flexion |  |  | 0.394 |
| Right Shoulder Abduction |  |  | 0.080 |

### *4.3. Physical Activity Results*

Self-report and accelerometer-based PA measures were compared between non-PD and PD in search of an association between the development of transient pain and differences in quality and quantity of PA. Specifically, the daily amount of time spent in sedentary, walking (or light), moderate, and vigorous intensity levels, as well as the daily cumulative totals, of PA were compared.

### *4.3.1. Self-reported Physical Activity*

To compare PA levels between non-PD and PD, the self-administered, long-form IPAQ was used to gather self-report data pertaining to time (MET-minutes/week) spent in each of the three PA intensities: Walking, moderate, and vigorous (Figure 4.12). Recall, the IPAQ assessed self-reported PA by analyzing the weekly time spent in three PA intensities within four PA domains: Job-related, Transportation, House and Family Work, Recreation and Leisure, and Sitting. The comparison in self-reported PA between non-PD and PD was reported as a median (±IQR), as per the IPAQ scoring guide (International Physical Activity Questionnaire, 2005), and was tested using a Wilcoxon-Mann-Whitney test. No differences were observed between non-PD and PD in any of the three intensities of PA ($p>0.099$). Specifically, for the time spent engaged in a walking intensity of PA (3.3METs), non-PD and PD reported 693.0 MET-minutes/week (±528.0) and 1963.5 MET-minutes/week (±1130.3), respectively ($p=0.099$). For the time spent engaged in moderate intensity PA (4.0METs), non-PD and PD reported 660.0 MET-minutes/week (±847.5) and 195.0 MET-minutes/week (±1170.0), respectively ($p=1.000$). Regarding time spent in vigorous intensity PA (8.0METs), non-PD and PD reported 0.0 MET-minutes/week (±2960.0) and 0.0 MET-minutes/week (±0.0), respectively ($p=0.127$). PA was reported at a vigorous intensity by only three non-PD (and zero PD) nursing students, who reported a mean average of 7573.3 MET-minutes/week at the vigorous intensity level. Based on the duration reported in each of the three intensities, each nursing student was classified by the IPAQ as either “inactive”, “minimally active”, or “highly active” relative to public health guidelines. For the non-PD group, 28.6% (2 of 7) of participants were categorized as “inactive” and the other 71.4% (5 of 7) were “minimally active”. For the PD group, 66.7% (4 of 6) were categorized as “inactive” and the other 33.3% were “minimally active”. A comparison in distribution of category levels between groups was conducted using a Fisher’s exact test, and no differences were observed between groups (p=0.286). These observations suggested that the two groups displayed a similar amount of weekly activity in job-related, transportation, house and family work, as well as recreation and leisure domains.

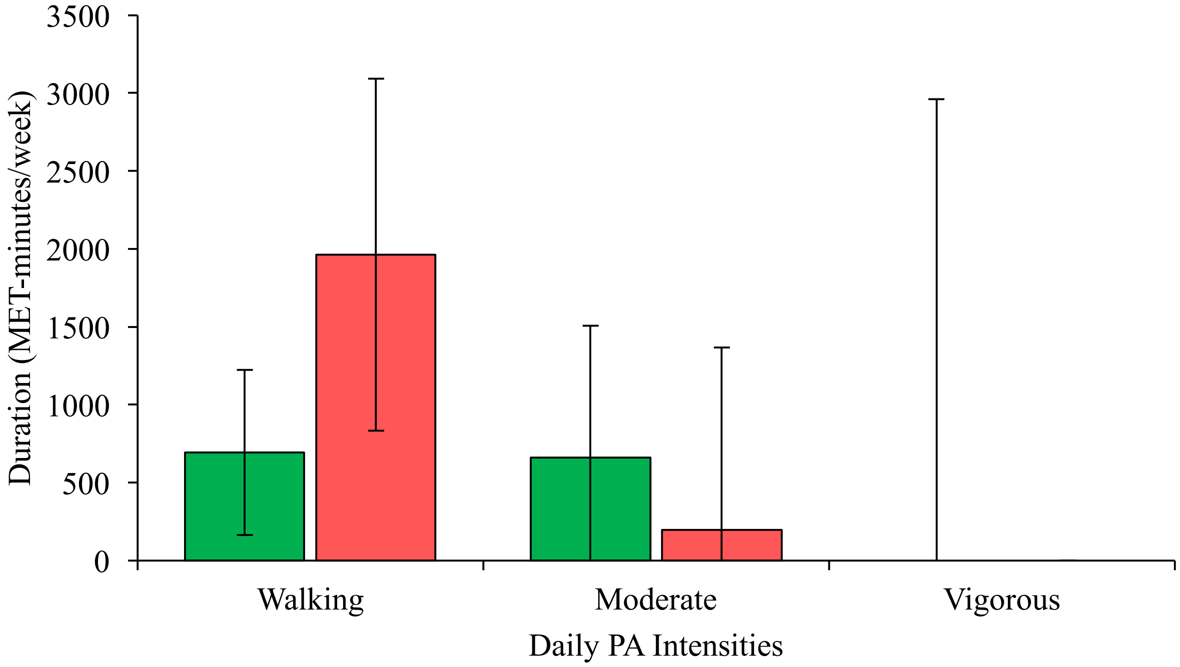


Figure 4.12. No differences were observed in self-reported duration (MET-minutes/week) of weekly activities at a walking, moderate, or vigorous intensity, reported as a median (±IQR), between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.099).

### *4.3.2. Accelerometry-based Physical Activity*

In addition to the self-reported PA data that was assessed using the IPAQ questionnaire, daily PA was also compared between non-PD and PD using an accelerometer worn on the right hip by each participant (Figure 4.13). Briefly, the accelerometer data for a complete 24-hour (midnight-to-midnight) day was downloaded into 10s epochs using Actilife™ software. Counts within each epoch were used to calculate the daily MET average, which was used to compare total daily PA between non-PD and PD. Furthermore, previously established cut points (measured in counts per minute) were used to separate each epoch into one of four levels of PA to determine the amount of time spent daily within each level: Sedentary, light, moderate, and vigorous. Differences were compared between groups using a two-tailed t-test. The data from one non-PD participant was not collected due to a technical error, and was excluded from the analysis. Nine outcome measures were compared between groups, and so an adjusted critical p-value of $p=0.00555$ was used.

No differences were observed in any of the four levels or in daily MET average ($p>0.334$). Specifically, for the daily amount of time spent in a sedentary level of PA, non-PD and PD averaged 1232.1 (±76.1) minutes and 1265.6 (±90.9) minutes, respectively ($t_{10}=-0.65$, $p=0.522$). For the daily amount of time spent in a light level of PA, non-PD and PD averaged 182.1 minutes (±50.6) and 159.4 minutes (±80.7), respectively ($t_{10}=0.54$, $p=0.585$). For the daily amount of time spent in a moderate level of PA, non-PD and PD reported 23.5minutes (±26.6) and 14.8 minutes (±12.2), respectively ($t_{10}=0.72$, $p=0.527$). For the daily amount of time spent in a vigorous level of PA, non-PD and PD reported 2.3minutes (±4.4) and 0.1minutes (±0.1), respectively ($t_{10}=1.21$, $p=0.334$). Finally, for the daily MET average, non-PD and PD reported 1.5 minutes (±0.2) and 1.4 minutes (±0.2), respectively ($t_{10}=0.81$, $p=0.444$). These observations, similar to the self-reported PA, suggested that the two groups displayed a similar amount of activity within four specified intensities and a similar amount of total daily activity.

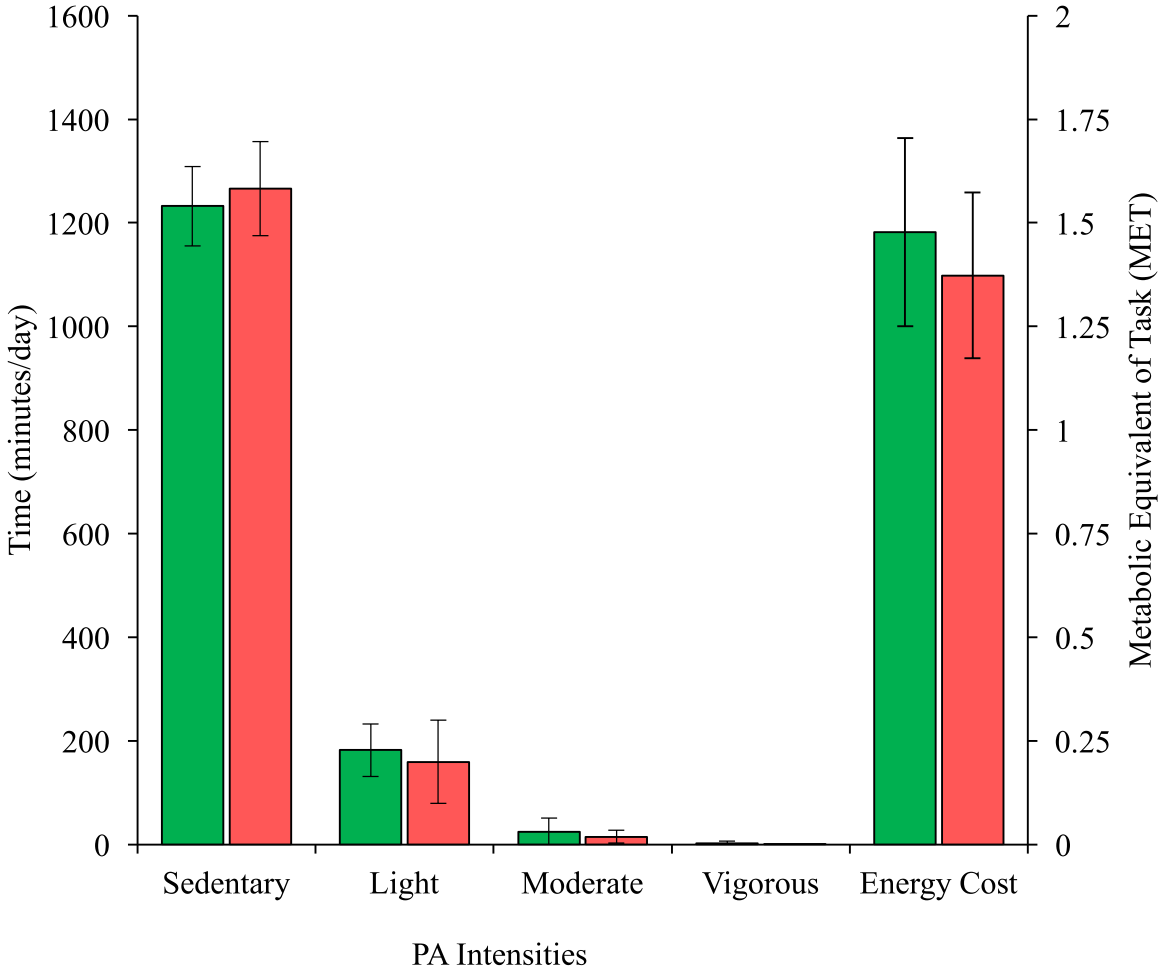


Figure 4.13. No differences were observed in the accelerometer-based durations of physical activity (minutes/ day) at a sedentary, light, moderate, or vigorous intensity, or in total daily energy cost (METs), reported as a mean (±SD), between non-PD (n=6; 🟩) and PD (n=6; 🟥) (p>0.334).

In addition to the MET score and time per day spent in each of the sedentary, light, moderate, and vigorous PA intensities, the accelerometer had an inclinometer function which was used to compare sitting and standing time data between non-PD and PD using a two-tailed t-test (Figure 4.14). To compare sitting and standing duration, the duration of the longest single bout as well as the cumulative duration per day were analyzed for both postures.

No differences were observed in the sitting and standing time data between non-PD and PD (p>0.033). Specifically, for the sitting time data, non-PD displayed a maximal sitting bout duration of 19.9 minutes (±9.9), while PD averaged 34.6 minutes (±9.0) ($t_{10}$=-2.59, p=0.033). For the standing time data, non-PD and PD exhibited a maximal standing bout duration of 20.1 minutes (±5.0) and 22.4 minutes (±7.8), respectively ($t_{10}$=-0.57, p=0.566). For the cumulative duration of sitting per day, non-PD averaged 425.2 minutes (±178.9) per day, while PD averaged 547.6 minutes (±103.1) per day ($t_{10}$=-1.42, p=0.224). Finally, for the cumulative duration of standing per day, non-PD averaged 369.5 minutes (±61.1) per day, while PD averaged 337.0 minutes (±155.4) ($t_{10}$=0.44, p=0.652). These results suggested that, except for the duration of the longest sitting bout, non-PD and PD are similar in terms of sitting and standing duration.

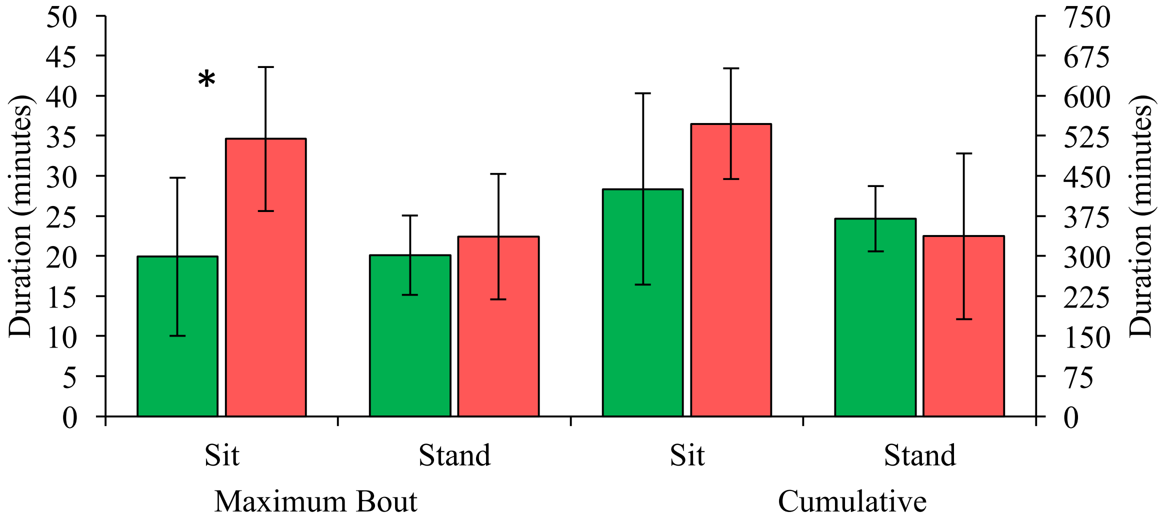


Figure 4.14. No differences were observed in the inclinometer-based sitting and standing time data, reported as a mean (±SD), between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.033).

To summarize, self-report and accelerometer-based PA measures were compared between non-PD and PD in search of an association between the development of transient pain and differences in quality and quantity of PA. The results of the PA factor of this research study were summarized below (Table 4.9). The only difference observed between groups was in accelerometer-based maximum duration of a sitting bout, in which non-PD spent a significantly shorter duration than PD (p=0.033).

Table 4.9. Summary of results for the physical activity factor of this thesis. Note: Adjusted p-values were used for some measures.

| Outcome Measure | Non-PD | PD | p-Values |
|---|---|---|---|
| Self-reported (MET-minutes/week) | | | |
| Walking | 693.0 (528.0) | 1963.5 (1130.3) | 0.099 |
| Moderate | 660.0 (847.5) | 195.0 (1170.0) | 1.000 |
| Vigorous | 0.0 (2960.0) | 0.0 (0.0) | 0.127 |
| Accelerometer-based | | | |
| Sedentary (minutes) | 1232.1 (76.1) | 1265.6 (90.9) | 0.522 |
| Light (minutes) | 182.1 (50.6) | 159.4 (80.7) | 0.585 |
| Moderate (minutes) | 23.5 (26.6) | 14.8 (12.2) | 0.527 |
| Vigorous (minutes) | 2.3 (4.4) | 0.1 (0.1) | 0.334 |
| Energy Cost (MET) | 1.5 (0.2) | 1.4 (0.2) | 0.444 |
| Bout of Sitting (minutes) | 19.9 (9.9) | 34.6 (9) | 0.033 |
| Bout of Standing (minutes) | 20.1 (5) | 22.4 (7.8) | 0.566 |
| Cumulative Sitting (minutes) | 425.2 (178.9) | 547.6 (103.1) | 0.224 |
| Cumulative Standing (minutes) | 369.5 (61.1) | 337.0 (155.4) | 0.652 |

### *4.4. Physical Fitness Results*

PF measures were compared between non-PD and PD in search of an association between the development of transient pain and differences in muscular strength, endurance, and flexibility.

*4.4.1. Muscular Strength*

Grip strength, measured in terms of resistance (kilograms), was measured to compare muscular strength between non-PD and PD (Figure 4.15) using a two-tailed t-test. Again, the measurement of grip strength was used as a surrogate test for muscular strength because it was established to be a quick, simple, and accurate indicator of overall muscular strength. Non-PD displayed significantly higher grip strength, scoring 53.7kg (±6.5), than did PD, who scored 44.9kg (±4.3) ($t_{11}$=2.82, p=0.015). These results suggested that non-PD had a significantly higher level of overall muscular strength than the participants in the PD group.

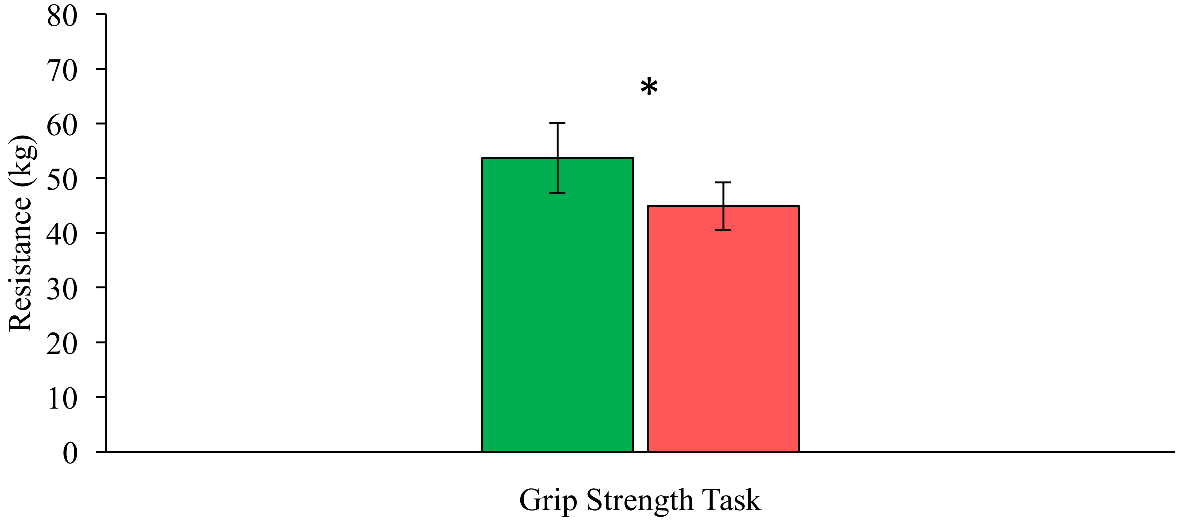


Figure 4.15. Grip strength, measured in resistance (kg) and plotted by mean (±SD), was greater (p=0.015, significance indicated with an asterisk, *) for non-PD (n=7; 🟩) than for PD (n=6; 🟥).

*4.4.2. Muscular Endurance*

To compare muscular endurance between non-PD and PD, the back extension test (s), the oblique trunk hold test (s), and the partial curl-ups test (repetitions) were measured (Figure 4.16) and tested using a two-tailed t-test. Recall, the back extension test and oblique trunk hold test are both measurements of static muscular endurance, testing the trunk extensor muscles and the trunk lateral flexor muscles, respectively. The partial curl-ups test, however, is a measurement of dynamic muscular endurance that tests the trunk flexor muscles. No differences were observed between non-PD and PD in any of the muscular endurance tests (p>0.119). Specifically, for the back extension test, non-PD scored 113.1s (±56.9) and PD scored 82.4s (±38.9) ($t_{11}$=1.12, p=0.276). For the oblique trunk hold test, non-PD scored 89.5s (±62.9) and PD scored 64.4s (±37.9) ($t_{11}$=0.85, p=0.398). Finally, for the partial curl-ups test, non-PD scored 18.3 repetitions (±8.1) and PD scored 11.5 repetitions (±6.4) ($t_{11}$=1.93, p=0.119). These data suggested that non-PD and PD had similar levels of trunk muscular endurance.

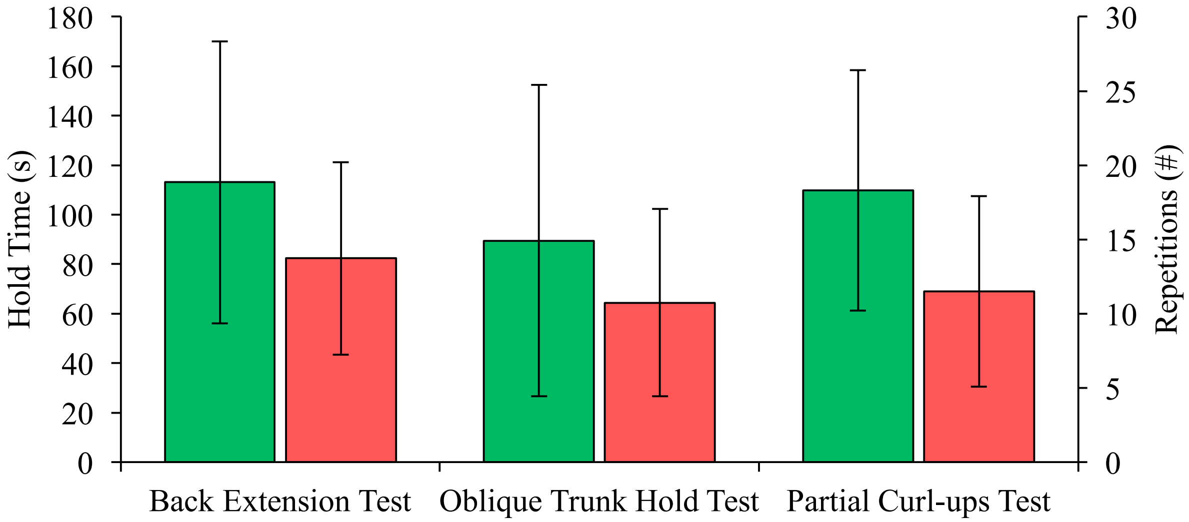


Figure 4.16. No differences were observed in the back extension test (s), oblique trunk hold test (s), or in the partial curl-ups test (#), reported as a mean (±SD), between non-PD (n=7; 🟩) and PD (n=6; 🟥) (p>0.119).

### *4.4.3. Muscular Flexibility*

To compare flexibility between non-PD and PD, the ASLR test was conducted. Recall, the ASLR test consisted of the participant, who was laying supine on the massage table, raising one leg as high as possible while keeping the opposing knee flat against the table. The participant was scored on each side from 0-3 based on the location of the malleolus relative to the mid-patella, mid-thigh, and ASIS, and whether the movement was painful for the participant. A Fisher's Exact Test was conducted to compare the ASLR scores of non-PD and PD, and the scores were plotted as a mean (±SD) (Table 4.10).

On both the left and right sides, non-PD executed the ASLR test with significantly better results. Specifically, for the left leg, 57.1% (4 of 7) of non-PD scored a 2 and the remaining 42.9% (3 of 7) scored a 3, whereas 66.7% (4 of 6) of PD scored a 1 and the remaining 33.3% (2 of 6) scored a 2 (p=0.013). For the right leg, 42.9% (3 of 7) of non-PD scored a 2 and the remaining 57.1% (4 of 7) scored a 3, whereas 50.0% (3 of 6) of PD scored a 1 and the remaining 50.0% (3 of 6) scored a 2 (p=0.046). These data suggested that non-PD displayed better muscular flexibility than PD.

Table 4.10. The distributions of left and right Active Straight Leg Raise scores, rated 0-3, were higher in non-PD (n=7) than in PD (n=6) (p<0.046, significance indicated with shading).

| **Muscular Flexibility** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| ASLR Test – Left (rated: 0-3) | | | 0.013 |
| 1: Below mid-patella | 0 (0%) | 4 (66.7%) | |
| 2: Between mid-patella and mid-thigh | 4 (57.1%) | 2 (33.3%) | |
| 3: Between mid-thigh and ASIS | 3 (42.9%) | 0 (0.0%) | |
| ASLR Test – Left (rated: 0-3) | | | 0.046 |
| 1: Below mid-patella | 0 (0.0%) | 3 (50.0%) | |
| 2: Between mid-patella and mid-thigh | 3 (42.9%) | 3 (50.0%) | |
| 3: Between mid-thigh and ASIS | 4 (57.1%) | 0 (0.0%) | |

To summarize, PF measures were compared between non-PD and PD for differences in muscular strength, endurance, and flexibility. The results of the PF factor of this research study were summarized below (Table 4.11). Non-PD displayed significantly greater muscular strength (p=0.015) and muscular flexibility (p<0.046) than did PD.

Table 4.11. Summary of results for the physical fitness factor of this thesis. Differences were observed in grip strength and in Active Straight Leg Raise scores (p<0.046). No differences were observed between groups in any of the remaining physical fitness outcome measures (p>0.119).

| **Outcome Measure** | **Non-PD** | **PD** | **p-Values** |
|---|---|---|---|
| Muscular Strength | | | |
| Grip strength (kg) | 53.7 (6.5) | 44.9 (4.3) | 0.015 |
| Muscular Endurance | | | |
| Back Extension Test (s) | 113.1 (56.9) | 82.4 (38.9) | 0.276 |
| Oblique Trunk Hold Test (s) | 89.5 (62.9) | 64.4 (37.9) | 0.398 |
| Partial Curl-ups Test (#) | 18.3 (8.1) | 11.5 (6.4) | 0.119 |
| Muscular Flexibility | | | |
| ASLR test - Left (rated: 0-3) | | | 0.013 |
| 0: Pain | 0 (0%) | 0 (0%) | |
| 1: Below mid-patella | 0 (0%) | 4 (66.7%) | |
| 2: Between mid-thigh and mid-patella | 4 (57.1%) | 2 (33.3%) | |
| 3: Between mid-thigh and ASIS | 3 (42.9%) | 0 (0.0%) | |
| ASLR test – Right (rated: 0-3) | | | 0.046 |
| 0: Pain | 0 (0%) | 0 (0%) | |
| 1: Below mid-patella | 0 (0.0%) | 3 (50.0%) | |
| 2: Between mid-thigh and mid-patella | 3 (42.9%) | 3 (50.0%) | |
| 3: Between mid-thigh and ASIS | 4 (57.1%) | 0 (0.0%) | |

## **5.0. Discussion**

Low back injury was identified as the most prevalent cause of disability worldwide (Driscoll et al., 2014). Canadian female nurses incur low back injuries at an incident rate significantly higher than either sex experiences in any other Canadian occupation (Shields & Wilkins, 2006). The high incidence of low back injury within the nursing occupation could be attributed to the high physical demands (Jang et al., 2007), prolonged standing (Omokhodion et al., 2000), and the heavy and sudden loads placed on the spine while in flexed and axially rotated postures during MPH tasks (Marras et al., 1999) observed in working nurses. At time, nurses work through unavoidable but suspected high-risk loading scenarios. Recent research was able to distinguish working nurses with and without recent low back injuries from PA, PF, and biomechanical measures (Babiolakis et al., 2015). Again however, these results were interpreted with caution, and investigators questioned whether the data had been impacted by a potential "survivor effect" and or side-effect of nurses avoiding absenteeism despite their impaired capacity. Therefore, the purpose of this thesis was to compare the biomechanical, PA, and PF factors, and risk of developing a future low back injury in asymptomatic female nursing students. Each participant was classified as either low- or high-risk of developing a future low back injury, based on whether or not they developed clinically relevant levels of transient pain (>10mm change on VAS) during the 60 minute testing in visit two. The biomechanical, PA, and PF factors were then compared between the PD (low-risk) and non-PD (high-risk) nursing students.

### *5.1. Transient Pain Development*

The 10mm threshold for change in self-reported transient pain was used for this data collection given that a 10mm threshold was used by Nelson-Wong et al. (2009) and that the age and condition (asymptomatic) of the participants of this thesis, as well as the intensity level of the data collection itself, were relatable. Prior to the data collection, two methods of screening were used to ensure that each nursing student was in fact asymptomatic. A participant was excluded if any recent history of low back injury was reported to have occurred within the last 12 months or if "moderate" or worse ( ≥30%) disability was identified by the ODI.

The distribution of the asymptomatic participants into non-PD and PD groups in this study were similar Nelson-Wong et al. (2009). In this thesis, 46.1% of asymptomatic nursing students were classified as PD, which compared well with the 39.5% PD classification of Nelson-Wong et al. (2009) using the same pre-determined 10mm threshold and a asymptomatic university aged population. The maximum change in self-reported pain during the data collection, and between-group comparisons at each 15-minute time point in this study (which again revealed significant differences between groups at 15- 45-, and 60-minutes), were similar to the responses of the PD and non-PD groups in Nelson-Wong et al. (2009). Despite the lack of a 3-year follow up in the thesis, the similarities of the non-PD and PD background and time varying behaviour in Nelson-Wong et al. (2009) suggested that the non-PD and PD groups in this thesis were likely low- and high-risk respectively of developing a future low back injury. Therefore, the differences observed between non-PD and PD in the biomechanical, PA, and PF variables may be possible risk factors for future occupational LBP in the nursing workforce.

### *5.2. Biomechanical Risk Factors and LBP*

Biomechanical research investigating occupational low back injury in working nurses has focused predominantly on task-related variables. Babiolakis et al. (2015) suggested that PA, PF, and biomechanical factors may play individual roles in the development of low back injury, but more likely have an inter-dependent relationship. In this thesis, postural control, movement control, lumbopelvic control, trunk ROM, nursing student behaviours, as well as the kinetics and kinematics of one repetition of a simulated patient transfer task were the biomechanical measures. Only one statistical difference was observed between the PD and non-PD groups, and that was in postural control (COP mediolateral sway distance in quiet standing). However, the use of arguably overly conservative statistical corrections due to the unbalanced participant groups and relatively low sample size overall likely masked some statistical differences. Clinically-relevant outcomes, but not statistically significant findings, could be interpreted from the AHAbd test. For the non-PD group the right and left sides were identical, with 14.3% (or 1 of 7) having poor, and 85.7% (or 6 of 7) having lumbopelvic control respectively. Whereas, 50% (or 3 of 6) had poor control for the left side, and 66.7% (or 4 of 6) had poor control for the right side in the PD group. Impaired postural control was observed in patients with a low back injury when compared to healthy controls (Radebold et al., 2001; Luoto et al., 1996), was shown in working nurses to be impaired following an injury relative to their uninjured counterparts (Babiolakis et al., 2015). Likewise, these AHAbd test results in this thesis suggest that lumbopelvic control may have a role in the development of a low back injury in nursing students.

The intra- and inter-rater reliability statistics suggested that the observed data in the AHAbd test for lumbopelvic control were as reliable when compared to (Davis et al., 2011), and so investigators were confident in the scored observations. When compared to unaffected working nurses (Babiolakis et al., 2015), the low-risk group of asymptomatic nursing students performed at least 9% better on the AHAbd test, while the high-risk group performed at least 37% worse. This comparison to a working nurse population may indicate the sample sized used in this thesis was insufficient to detect a difference between groups for the frontal plane lumbopelvic control.

The Babiolakis et al. (2015) student also compared the movement control between recently-injured and not-recently-injured working nurses using a modified deep squat test, and observed no differences between groups. Again, the modified deep squat test was developed to assess the coordinated mobility of the upper and lower extremities, as well as the stability of the trunk and hips (Reiman & Manske, 2009), where poor coordinated mobility and stability both increase one's risk of low back injury. Consistent with Babiolakis et al. (2015), no differences were observed between the PD and non-PD groups in this thesis, which suggested if deficits exist in the PD albeit asymptomatic nursing students they have not progressed enough to be identified by the modified deep squat test. The distribution of scores across the PD and non-PD groups related well to the distribution previously observed in unaffected working nurses (Babiolakis et al., 2015), which suggested similar movement control between the students and working nurses.

Differences in trunk ROM have been observed between patients with a low back injury and unaffected controls in terms of trunk flexion, trunk lateral flexion, and trunk axial rotation. However, further research is still necessary to understand how trunk ROM influences future low back injury (McGill, 2016). Trunk flexion, trunk lateral flexion, and trunk axial rotation were compared between PD and non-PD nursing students, and no differences were observed. The lateral flexion and axial rotation ROM of nursing students related well to the ROM observed in a working nurse population (Babiolakis et al., 2015), whereas the trunk flexion ROM observed was smaller relative to the working population.

Finally, the kinetics and kinematics of the one repetition of a simulated patient transfer task were assessed in asymptomatic nursing students using the 3DMatch video-based posture matching software. Sufficient evidence exists in the literature to classify MPH tasks as high risk for the development of a low back injury in nurses (Yassi & Lockhart, 2013, Marras et al., 1999). In this thesis, peak moments, and peak shear and peak compression forces, acting on the L4/L5 joint were compared between non-PD and PD nursing students to assess the kinetics of the task. Further, normalized time in neutral and non-neutral trunk and shoulder postures were compared between non-PD and PD nursing students to assess the kinematics of the task. No differences were observed between groups in any of the kinetic or kinematic outcome measures. Given that none of the peak L4/L5 joint shear forces exceeded 20% of the Action Limit (500N) during the one repetition of the task, the highest risk that was quantifiable for the simulated patient transfer task occurred through the peak L4/L5 joint compression force. Specifically, both groups came within 28% of the Action Limit (3400N), and two non-PD participants exceeded the Action Limit. Approaching the Action Limit was determined to be safe for 75% of female workers (Waters et al., 1993). The biggest issue with interpreting the results of the simulated patient transfer was that it was only completed once for the most common type of transfer.  It is possible that additional repetitions would have revealed more useful information.

### *5.3. PA Risk Factors and LBP*

Both a lack and excess of PA have been associated with the development of low back injuries through disuse- and overuse-related mechanisms, respectively (Auvinen et al., 2008). Associations between PA and low back injury have been observed using self-report questionnaires (Craig et al., 2003) and using accelerometry-based activity monitors (Van Weering et al., 2009). In this thesis, both self-reported and accelerometry-based measures were compared between the PD and non-PD groups. By assessing PA factors in an asymptomatic population and comparing the factors based on risk of a future low back injury, any differences observed between groups could be targeted in prevention and/or rehabilitative efforts.

To compare self-reported PA between nursing students at a low- and high-risk of developing a future low back injury, the IPAQ was used to assess total weekly duration (MET-minutes/week) engaged in walking, moderate, and vigorous intensities of PA in the job-related, transportation, house/family work, and recreational/leisure domains. Compared to unaffected working nurses (Babiolakis et al., 2015), both groups displayed lower levels of PA in all three categories. While much of the difference is likely due to differences in the job-related domain, the differences suggested that the nursing students were sedentary in general. The category score designated by the IPAQ results, indicating that nearly half of the nursing students were "inactive" while the other half were "minimally active" supported the suggestion that the nursing students were sedentary.

To compare accelerometry-based PA between nursing students at a low- and high-risk of developing a future low back injury, a tri-axial ActiGraph™ GT3X+ accelerometer was worn on the right hip for seven days between visits one and two to assess total daily duration engaged in sedentary, light, moderate, and vigorous intensities of PA, as well as to assess daily average energy expenditure. An algorithm used to detect non-wear time (Choi et al., 2011) revealed large periods of non-compliance throughout the seven-day wear period, and so only one full calendar date was used for analysis to compare a full 24-hour period without any identified non-wear time periods. The 24-hour period ranged from Monday to Friday across all of the nursing participants which may have influenced the data given the students' academic schedule is different day-to-day. However, no differences were found from the inclinometer function of the tri-axial accelerometer (used to compare the durations of sitting and standing postures in terms of cumulative daily total). This suggests that the day of the week the 24-hour period was on did not impact the lack of difference in the accelerometer-based PA. Similar to the self-reported PA data, the accelerometry-based PA data suggested that both groups were sedentary. Both groups were in the sedentary range of cut point values for at least 85% of the day. Furthermore, in terms of daily average energy expenditure, 75.0% of nursing students averaged less than 1.5 MET, a threshold previously established for sedentary behaviours (Mansoubi et al., 2015). The thesis data agrees with previous research that observed that a majority of nursing students were sedentary (Pires et al., 2013) and not sufficiently active. Furthermore, when compared to the PA recommendations of the Canadian government, 75.0% of nursing students failed to meet the guidelines for daily total activity, while 83.3% failed to meet the guidelines for daily activity at a moderate-to-vigorous intensity level (Statistics Canada, 2015).

### *5.4. PF Risk Factors and LBP*

Previous research has suggested that improvements in PA is only protect against low back injury when the improvement yields simultaneous changes in PF (Heneweer et al., 2012). PF factors that have been associated with low back injury include muscular strength (Bayramoglu et al., 2001), muscular endurance (Biering-Sørensen, 1984), and muscular flexibility (Halbertsma et al., 2001). However, it remained unclear whether or not a change in the three factors preceded a low back injury or if the changes were result of the injury. In this thesis, all three PF factors were compared between nursing students at a low- and high-risk of developing a future low back injury.

Previous research has observed that insufficient strength of the trunk muscles was related to the development of a low back injury (Besler & Can, 2003), or is only related to low back injury when matched to specific job requirements (Marras, 2000). In this thesis, the low-risk non-PD group was observed to display 16% higher muscular strength (maximal isometric grip strength) when compared to the high-risk PD group. Compared to a previously established reference value for similarly aged female Canadians (Wong, 2016), 42.9% of non-PD were above average while the remaining 57.1% were below average, and all six participants in the PD group were below the reference value. When compared to unaffected working nurses (Babiolakis et al., 2015), non-PD displayed nearly 16% higher muscular strength, while PD displayed similar muscular strength to the unaffected working nurses. These comparisons suggested that the low-risk group of nursing students displayed a high amount of muscular strength when compared to the high-risk group, and when compared to other populations.

Insufficient muscular endurance of the trunk muscles was shown in previous research to be a risk factor for the first occurrence of a low back injury (Biering-Sørensen, 1984; Luoto et al., 1995). McGill (2016) advocated improving muscular endurance for low back injury prevention, on the basis that low back injuries may be prevented by the ability to continually contract trunk muscles at a low-level without fatigue during movement. In this thesis, the muscular endurance was assessed using the partial curl-ups test, oblique trunk hold test, and back extension test to compare the anterior, lateral, and posterior trunk muscular endurance, respectively, in the PD and non-PD groups. No differences were observed between groups in any of the three measures, which suggested that similar muscular endurance exists. It is important to note, that this thesis did not assess any participant's muscle endurance in a movement task.

According to established ratings of the partial curl-ups test (Canadian Society for Exercise Physiology, 2003), 71.4% (5 of 7) of non-PD were labelled "good" or better, whereas 50% (3 of 6) of PD were labelled "good" or better. Relative to oblique trunk hold test average values for female university students (McGill, 2016), only one non-PD participant exceeded the average, while the remaining 12 participants displayed below average durations. Finally, when the back extension times were compared to normative values for female adults (Adedoyin et al., 2011), 57.1% (4 of 7) of non-PD exceeded the average duration, while only 16.6% (1 of 6) of the PD group displayed above average endurance. When compared to unaffected working nurses (Babiolakis et al., 2015), the non-PD group of nursing students outperformed in all three tests of muscular endurance, while the PD group of nursing students performed similarly to working nurses. These comparisons, along with the data relating muscular endurance to the first occurrence of a low back injury (Biering- Sørensen, 1984; Luoto et al., 1995), suggested that though the non-PD nursing students (those at low-risk of developing a future low back injury) were not statistically different from the PD group, the non-PD group displayed higher functional levels of muscular endurance. The lack of statistical significane may have been due to the conservative tests used, unbalanced groups, and/or the somewhat limited sample size.

Some previous research has observed an association between muscular flexibility and low back injury (Halbertsma et al., 2001), but most data in the literature has suggested that muscular flexibility does not protect against the development of low back injury (McGill, 2016). Recently, muscular flexibility was compared between recently-injured and unaffected working nurses using the ASLR test (Babiolakis et al., 2015; Reiman & Manske, 2009), and no differences were observed. In addition to flexibility, the ASLR test was used similarly in other research to assess lumbopelvic control, although it is acknowledged that ASLR was shown to be less effective when compared to the AHAbd test, as the supine position is inherently less challenging (Nelson-Wong et al., 2009). In this thesis, the low-risk non-PD group outperformed the high-risk PD group on both sides of the ASLR test, which suggested that the low-risk nursing students displayed better muscular flexibility and better lumbopelvic control in the sagittal plane when compared to high-risk students. Relative to the unaffected working nurses assessed by Babiolakis et al. (2015), the low-risk non-PD group performed 20% better on the ASLR test, while the high-risk PD group performed 30% worse. The comparisons in ASLR test scores of non-PD and PD to the unaffected working nurses further suggested that non-PD nursing students displayed better sagittal plane lumbopelvic control than the PD group. A recent study used the AHAbd test and ASLR test together to assess multiplanar lumbopelvic control, and observed that 21% of participants with a low back injury only displayed insufficient lumbopelvic control in the sagittal plane (Nelson-Wong et al., 2016). Perhaps in this thesis, only the sagittal plane lumbopelvic control was able to statistically separate the PD and non-PD nursing students.

### *5.5. Limitations*

There are several important limitations in this thesis that need to be addressed. The objective of this research was to assess biomechanical, PA, and PF factors between nursing students at a low- and high-risk of developing a future low back injury. The main limitation of this thesis was the small sample size used for the comparison of the PD and non-PD groups. To participate in this study, the nursing student was required to be female, free of a recent history of low back injury, asymptomatic at the time of the data collection, and currently enrolled in either the third or fourth year of the nursing program at York University. The recruitment process was difficult due to the criteria and the logistics of collecting around the busy school and work placement schedules required of students by the nursing program. Nonetheless, the limited sample size presented the most noteworthy limitation of this thesis in that there was possibly insufficient power to detect differences between groups in the outcome measures. Furthermore, the research design was unbalanced, which even further reduced the power of the sample size to detect differences between groups, especially given the use of arguably overly conservative adjustments in the statistical measures. The last main limitation was the use of too few repetitions, especially in the simulated patient transfer task and the ROM tasks. Typically in biomechanical studies, such tasks would be repeated at least three times if not more to provide stable estimates and evaluation of repeatability. This is especially the case when angle data must be estimated from a posture-matching software program (3DMatch) versus direct measurement, and when calculating internal joint loading using inverse dynamics. Future research in this area should address these limitations.

### *5.6. Conclusion*

The nursing occupation is limited by a high incidence of low back injury, which has caused absenteeism, reduced productivity in nurses who commonly fail to report the injuries, both of which potentially reduced patient quality of care. Biomechanical, PA, and PF factors have been previously shown in the literature to relate to low back injuries, with recent research having had some success in distinguishing working nurses with and without recent low back injuries. However, it remained unclear as to why some working nurses develop low back injuries while others seem to be protected, and it was speculated that work experience and variable work-related exposures may have impacted previous findings. This thesis investigated whether the PA, PF, and biomechanical factors were related to the risk of developing a low back injury in asymptomatic upper-year nursing students. Risk of developing a low back injury was identified using the transient pain developer approach and participants were classified as either non-PD (low risk) or PD (high risk) based on their self-reported pain that developed during the 60 minute testing.

In this thesis, comparisons were made in the biomechanical, PA, and PF factors between the non-PD and PD group. This concurrent assessment in an asymptomatic nursing student population, may have helped identify the variables deserving focus to reduce the risk of future low back injury in future studies. Statistical differences were observed between groups in muscular strength and muscular flexibility, and postural control, but not in any of the other measures. These observations suggested that nursing students with poor muscular strength and poor muscular flexibility are at a higher risk of developing a future low back injury within the next three years. It was argued that there may have been functional differences between the groups in the biomechanical measures of lumbopelvic control and muscular endurance. Further investigation into these factors is required to properly understand if and how they relate to the development of a low back injury within a nursing student population.

## 6.0. General Thesis Overview

### *6.1. Revisiting Hypotheses*

This research quantified PA, PF, and biomechanical variables, in relation to the risk of developing a low back injury in fourteen asymptomatic female nursing students. These participants were classified as PD (n=6) and non-PD based on whether they did or did not develop clinically-relevant transient pain (>10mm from baseline) respectively during the 60 minute testing (Visit Two). Differences were observed between low- and high-risk nursing students in muscular strength and muscular flexibility:

Hypothesis #1 stated: ***PD will have lower self-reported and accelerometer-based PA.***

**This hypothesis was REJECTED.**

No differences were observed in the accelerometry-based or self-reported PA between non-PD and PD groups. Neither the quality of PA, as assessed using the duration in different intensity levels, nor the quantity of PA, as assessed using daily total energy expenditure, was different between groups. These observations suggested that asymptomatic nursing students at a low- and high-risk of developing a future low back injury displayed similar levels of self-reported and accelerometer-based PA.

Hypothesis #2 stated: ***PD will display less muscular strength (quantified using handgrip strength as the surrogate measure for total muscular strength).***

**This hypothesis was ACCEPTED.**

The PD group of nursing students displayed 16% less handgrip strength than the non-PD participants. Given that the handgrip strength task was previously established to be a valid surrogate measure for total muscular strength, these observations suggested that the high-risk PD group of asymptomatic nursing students displayed less muscular strength than the low-risk non-PD group.

Hypothesis #3 stated: ***PD will display less muscular endurance, with lower time scores in the oblique trunk hold, back extension test, and lower repetition counts in the partial curl-ups test.***

**This hypothesis was REJECTED.**

No differences were observed between non-PD and PD groups in the oblique trunk test, back extension test, or in the partial curl-ups test. All three tests were previously established (Reiman & Manske, 2009) to assess the muscular endurance of the lateral, posterior, and anterior trunk muscles, respectively. Likewise, the statistical differences suggested that the asymptomatic nursing students at a low- and high-risks of developing a future low back injury displayed similar muscular endurance. However, as discussed above, the non-PD group may functionally have higher muscular endurance than the PD nursing students.

Hypothesis #4 stated: ***PD will display less muscular flexibility, with lower scores in the Active Straight Leg Raise (ASLR) test.***

**This hypothesis was ACCEPTED.**

The distribution of both the right and left leg ASLR scores were significantly higher in the high-risk PD group. The ASLR test, previously established to assess muscular flexibility of the hamstring and gastrocnemius muscles (Reiman & Manske, 2009) as well as to indicate lumbopelvic control in the sagittal plane, was used as the only measure for muscular flexibility. The observations on the left and right sides suggested that the high-risk PD group of asymptomatic nursing students displayed less muscular flexibility than the low-risk group.

Hypothesis #5 stated: ***PD will perform the postural control task with greater anteroposterior and mediolateral sway distance and will have greater total COP path distance.***

**This hypothesis was REJECTED.**

No differences were observed between non-PD and PD groups in either of the anteroposterior or mediolateral sway distance, or in the total COP path distance. All three outcome measures were compared between groups during four static standing posture tasks: Quiet standing, forward bent, as well as single stance on both the left and right sides. In particular, the forward bend trial was of interest as it required higher activation of the posterior trunk muscles to hold the posture. Whereas, the single stance trials presented a greater challenge (required higher activation) of the gluteus medius muscles. The lack of differences between groups observed in these tasks suggested that the asymptomatic nursing students regardless of risk for the development of a low back injury displayed similar ability of postural control in each of the four static standing postures.

Hypothesis #6 stated: ***PD will perform a side-lying leg raise with less frontal plane lumbopelvic control resulting in higher scores in the Active Hip Abduction (AHAbd) test.***

**This hypothesis was REJECTED.**

The hypothesis was rejected as the distribution of ‘pass’ (test score ≤1) and ‘fail’ (test score > 1) AHAbd scores were not statistically different between non-PD and PD groups on either the left or right side. The AHAbd test was previously established to assess lumbopelvic control in the frontal plane during a side-lying leg raise movement (Nelson-Wong et al., 2009). However, as discussed above, the data may support a functional difference with PD having poorer lumbopelvic control relative to the non-PD nursing students.

Hypothesis #7 stated: ***PD will perform the simulated patient transfer task with greater peak lumbar (L4/L5) joint shear and compression forces and with a greater percentage of the lifting cycle in non-neutral trunk and shoulder postures.***

**This hypothesis was REJECTED.**

No differences were observed between non-PD and PD groups in the kinetics or kinematics of the simulated patient transfer task. Specifically, peak joint shear and joint compression forces were assessed to compare the kinetics of the task between groups. Kinematics of the task, however, were compared between groups by assessing normalized time of the task that required neutral and non-neutral trunk and shoulder postures. These observations suggested that nursing students at a low- and high-risk of developing a future low back injury performed the one trial of simulated patient transfer task with similar kinetics and kinematics.

### *6.2. Relevance*

The leading source of absenteeism within the nursing occupation is low back injury. While biomechanical, PA, and PF factors have been related to low back injury, it remained unclear why nurses develop low back injuries and others seem to be protected. In order to develop strategies to prevent low back injury within the occupation, factors that are most likely predictive of the injury within this population needed to be identified. The observations of this thesis suggested that the factors that are most likely predictive of low back injury include muscular strength, muscular endurance, and possibly lumbopelvic control.

In this thesis, a relatively homogenous group of asymptomatic nursing students were assessed using the biomechanical, PA, and PF factors previously related to low back injury. This thesis represented the first study to assess these three factors simultaneously using a sample of upper-year nursing students who will soon enter the workforce. Furthermore, changes in self-reported transient pain of the nursing students were measured during the data collection to classify each participant as either low- or high-risk of developing a future low back injury (Nelson-Wong et al., 2009). Comparisons between low-risk non-PD and high-risk PD groups allowed the investigators to gain insight into differences between nursing students likely to and those who are not likely to develop a low back injury. The nursing students were asymptomatic at the time of the data collection, only being separated by the transient pain developed during the data collection, and so the factors of muscular strength, muscular endurance, and possibly lumbopelvic control were therefore related to risk of developing a future low back injury in a nursing student population. However, more research is required before such an association is made.

### *6.3. Future Directions*

Differences in muscular strength, muscular flexibility, and possibly in lumbopelvic control were observed between non-PD and PD nursing students. But before these three factors can be suggested to be predictive of low back injury in an asymptomatic nursing student population, a much larger sample of nursing students must be tested, as well as data collected from age-matched non-nursing students (for context) is required, as is a longitudinal study following the non-PD and PD students over the first 5-10 years of their career.

In the future longitudinal design, every factor that was compared between groups in this thesis will ideally be assessed, as all comparisons were necessary to identify the specific differences between non-PD and PD groups. For example, although the postural control observations did not reveal any differences between groups that require further investigation, the single stance trials were very important to the understanding of the gluteus medius function, which in turn influenced the understanding of frontal plane lumbopelvic control. In this example, both the single stance trials and the AHAbd test comparisons were not significant, and so it was suggested that gluteus medius function was not different between groups. Every comparison made in this thesis was necessary for the understanding of differences between low- and high-risk nursing students, and so future research would ideally assess each of these factors.

The longitudinal study design will enable time varying comparisons, which may be particularly important in muscle function (strength, endurance, flexibility) and lumbopelvic control. McGill (2016), describes the co-dependence of muscle function and neuromuscular control and the changes in one factor can cause deficits in another increasing risk of injury. As previously stated, due to the consistently high demands associated with nursing and the limitations ergonomic approaches have had in reducing these demands, understanding how these PA, PF, and biomechanical measures are related to the risk of developing a low back injury before injuries occur in efforts to reduce the impact on the lives of the nurses and the quality of care for patients.

## 7.0. References

Adedoyin, R.A., Mbada, C.E., Farotimi, A.O., Johnson, O.E., & Emechete, A.A. (2011). Endurance of low back musculature: normative data for adults. *Journal of Back and Musculoskeletal Rehabilitation, 24*(2): 101-109.

American College of Sports Medicine. (2013). ACSM Information on Resistance Training for Health and Fitness. [online]. Retrieved April 11, 2016, from https://www.acsm.org/docs/brochures/resistance-training.pdf

Adams, M.A., Mannion, A.F., & Dolan, P. (1999). Personal risk factors for first-time low back pain. *Spine, 24*(23): 2497.

American Nurses Association. (2003). American Nurses Association Position Statement: Elimination of Manual Patient Handling to Prevent Work-Related Musculoskeletal Disorders. [online]. Retrieved April 18, 2017, from http://www.unap.org/images/stories/files/Safe_Patient_Handling_-_ANA_position.pdf.

Andrews, D.M., Weir, P.L., & Lowe, B.D. (2016). Observation-based posture assessment practices. [online]. Retrieved June 5, 2017, from https://uwaterloo.ca/centre-of-research-expertise-for-the-prevention-of-musculoskeletal-disorders/resources/position-papers/observation-based-posture-assessment-practices.

Auvinen, J., Tammelin, T., Taimela, S., Zitting, P., & Karppinen, J. (2008). Associations of physical activity and inactivity with low back pain in adolescents. *Scandinavian Journal of Medicine & Science in Sports, 18*(2): 188-194.

Babiolakis, C.S., Kuk, J.L., & Drake, J.D. (2015). Differences in lumbopelvic control and occupational behaviours in female nurses with and without a recent history of low back pain due to back injury. *Ergonomics, 58*(2): 235-245.

Bartlett, H.L., Ting, L.H., & Bingham, J.T. (2014). Accuracy of force and center of pressure measures of the Wii Balance Board. *Gait & Posture*, *39*(1): 224-228.

Bayramoglu, M., Akman, M.N., Klnç, S., Çetin, N., Yavuz, N., & Özker, R. (2001). Isokinetic measurement of trunk muscle strength in women with chronic low-back pain. *American Journal of Physical Medicine & Rehabilitation, 80*(9): 650-655.

Bell, J.L., Collins, J.W., Tiesman, H.M., Ridenour, M., Konda, S., Wolf, L., & Evanoff, B. (2013). Slip, trip, and fall injuries among nursing care facility workers. *Workplace Health & Safety*, *61*(4): 147-152.

Benvenuti, F., Mecacci, R., Gineprari, I., Bandinelli, S., Benvenuti, E., Ferrucci, L., …, & Stanhope, S.J. (1999). Kinematic characteristics of standing disequilibrium: reliability and validity of a posturographic protocol. *Archives of Physical Medicine and Rehabilitation, 80*(3): 278-287.

Besler, A., & Can, F. (2003). Correlation between pain, trunk muscle strength, and functional state in low back pain. *The Pain Clinic, 15*(4): 415-419.

Biering-Sørensen, F. (1984). Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine, 9*(2): 106-119.

Blue, C.L. (1996). Preventing back injury among nurses. *Orthopaedic Nursing*, *15*(6): 9-22.

Bohannon, R.W., Magasi, S.R., Bubela, D.J., Wang, Y.C., & Gershon, R.C. (2012). Grip and knee extension muscle strength reflect a common construct among adults. *Muscle & Nerve*, *46*(4): 555-558.

Callaghan, J.P., Jackson, J., Albert, W.J., Andrews, D.M., & Potvin, J.R. (2003). The design and preliminary validation of '3DMatch': a posture matching tool for estimating three-dimensional cumulative loading on the low back. Proceedings of the 24th Association of Canadian Ergonomists Conference, London ON.

Callaghan, J.P., & McGill, S.M. (2001). Intervertebral disc herniation: studies on a porcine model exposed to highly repetitive flexion/extension motion with compressive force. *Clinical Biomechanics, 16*(1): 28-37.

Callison, M.C., & Nussbaum, M.A. (2012). Identification of physically demanding patient handling tasks in an acute care hospital. *International Journal of Industrial Ergonomics, 42*(3): 261-267.

Campello, M., Nordin, M., & Weiser, S. (1996). Physical exercise and low back pain. *Scandinavian Journal of Medicine & Science in Sports, 6*(2): 63-72.

Canadian Society for Exercise Physiology. (2003). Canadian Physical activity, Fitness & Lifestyle Approach: CSEP – Health & Fitness Program's Appraisal and Counselling Strategy (3rd ed.). *Ottawa, ON: Canadian Society for Exercise Physiology.*

Cann, A.P., Connolly, M., Ruuska, R., MacNeil, M., Birmingham, T.B., Vandervoort, A.A., & Callaghan, J.P. (2008). Inter-rater reliability of output measures for a posture matching assessment approach: a pilot study with food service workers. *Ergonomics, 51*(4): 556-572.

Centers for Disease Control and Prevention. (2015). Glossary of Terms. [online]. Retrieved June 28, 2017, from http://www.cdc.gov/physicalactivity/basics/glossary/index.htm.

Cho, K., Lee, K., Lee, B., Lee, H., & Lee, W. (2014). Relationship between postural sway and dynamic balance in stroke patients. *Journal of Physical Therapy Science, 26*(12): 1989-1992.

Choi, L., Liu, Z., Matthews, C.E., & Buchowski, M.S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and Science in Sports and Exercise*, *43*(2): 357.

Chung, Y.C., Hung, C.T., Li, S.F., Lee, H.M., Wang, S.G., Chang, S.C., …, & Yang, J.H. (2013). Risk of musculoskeletal disorder among Taiwanese nurses cohort: a nationwide population-based study. *BMC Musculoskeletal Disorders, 14*(1): 144.

College of Nurses of Ontario. (2015). Membership statistics highlights 2014. [online]. Retrieved April 12, 2016, from http://www.cno.org/globalassets/docs/general/.../43069_membershipstatistics-highlights.pdf.

Craig, C.L., Marshall, A.L., Sjostrom, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., …, & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8): 1381-1395.

Crouter, S.E., Kuffel, E., Haas, J.D., Frongillo, E.A., & Bassett Jr., D.R. (2010). A refined 2 regression model for the actigraph accelerometer. *Medicine & Science in Sports & Exercise, 42*(5): 1029-1037.

D'Arcy, L.P., Sasai, Y., & Stearns, S.C. (2012). Do assistive devices, training, and workload affect injury incidence? Prevention efforts by nursing homes and back injuries among nursing assistants. *Journal of Advanced Nursing, 68*(4): 836-45.

Davis, A.M., Bridge, P., Miller, J., & Nelson-Wong, E. (2011). Interrater and intrarater reliability of the active hip abduction test. *Journal of Orthopaedic & Sports Physical Therapy, 41*(12): 953-960.

Driscoll, T., Jacklyn, G., Orchard, J., Passmore, E., Vos, T., Freedman, G., …, & Punnett, L. (2014). The global burden of occupationally related low back pain: estimates from the Global Burden of Disease 2010 study. *Annals of the Rheumatic Diseases*, *73*(6):975-981.

Edlich, R., Winters, K.L., Hudson, M.A., Britt, L.D., & Long III, W.B. (2004). Prevention of disabling back injuries in nurses by the use of mechanical patient lift systems. *Journal of Long-term Effects of Medical Implants, 14*(6).

Engels, J.A., Van Der Gulden, J.W., Senden, T.F., & van't Hof, B. (1996). Work related risk factors for musculoskeletal complaints in the nursing profession: results of a questionnaire survey. *Occupational and Environmental Medicine*, *53*(9): 636-641.

Evanoff, B., Wolf, L., Aton, E., Canos, J., & Collins, J. (2003). Reduction in injury rates in nursing personnel through introduction of mechanical lifts in the workplace. *American Journal of Industrial Medicine, 44*(5): 451-457.

Fritz, J.M., & Irrgang, J.J. (2001). A comparison of a modified oswestry low back pain disability questionnaire and the Quebec back pain disability scale. *Physical Therapy, 81*(2): 776-788.

Hägg, O., Fritzell, P., Nordwall, A., & the Swedish Lumbar Spine Study Group. (2003). The clinical importance of changes in outcome scores after treatment for chronic low back pain. *European Spine Journal, 12*(1): 12-20.

Halbertsma, J.P., Göeken, L.N., Hof, A.L., Groothoff, J.W., & Eisma, W.H. (2001). Extensibility and stiffness of the hamstrings in patients with nonspecific low back pain. *Archives of Physical Medicine and Rehabilitation, 82*(2): 232-238.

Health and Safety Executive. (2016). Manual Handling Operations Regulations 1992. [online]. Retrieved June 28, 2017, from www.hse.gov.uk/pUbns/priced/l23.pdf.

Heneweer, H., Picavet, H.S.J., Staes, F., Kiers, H., & Vanhees, L. (2012). Physical fitness, rather than self-reported physical activities, is more strongly associated with low back pain: evidence from a working population. *European Spine Journal, 21*(7): 1265-1272.

Heneweer, H., Staes, F., Aufdemkampe, G., van Rijn, M., & Vanhees, L. (2011). Physical activity and low back pain: a systematic review of recent literature. *European Spine Journal, 20*(6): 826-845.

Heneweer, H., Vanhees, L., & Picavet, H.S.J. (2009). Physical activity and low back pain: A U-shaped relation?. *Pain, 143*(1): 21-25.

Hodges, P.W., & Moseley, G.L. (2003). Pain and motor control of the lumbopelvic region: effect and possible mechanisms. *Journal of Electromyography and Kinesiology, 13*(4): 361-370.

Hodges, P.W., Moseley, G.L., Gabrielsson, A., & Gandevia, S.C. (2003). Experimental muscle pain changes feedforward postural responses of the trunk muscles. *Experimental Brain Research, 151*(2): 262-271.

Hodges, P., Cresswell, A., & Thorstensson, A. (1999). Preparatory trunk motion accompanies rapid upper limb movement. *Experimental Brain Research, 124*(1): 69-79.

Hodges, P.W., & Richardson, C.A. (1998). Delayed postural contraction of transversus abdominis in low back pain associated with movement of the lower limb. *Clinical Spine Surgery, 11*(1): 46-56.

Hoogendoorn, W.E., van Poppel, M.N., Bongers, P.M., Koes, B.W., & Bouter, L.M. (1999). Physical load during work and leisure time as risk factors for back pain. *Scandinavian Journal of Work, Environment & Health,* 387-403.

Hoy, D., March, L., Brooks, P., Blyth, F., Woolf, A., Bain, C., … Buchbinder, R. (2014). The global burden of low back pain: Estimates from the global burden of disease 2010 study. *Annals of Rheumatic Diseases, 73*(6): 968-74.

International Physical Activity Questionnaire. (2005). IPAQ scoring protocol. [online]. Retrieved April 12, 2016, from https://sites.google.com/site/theipaq/scoring-protocol.

International Physical Activity Questionnaire. (2002). Long last 7 days self-administered format. [online]. Retrieved April 12, 2016, from https://sites.google.com/site/theipaq/questionnaire_links.Jang, R., Karwowski, W., Quesada, P.M., Rodrick, D., Sherehiy, B., Cronin, S.N., & Layer, J.K. (2007). Biomechanical evaluation of nursing tasks in a hospital setting. *Ergonomics, 50*(11): 1835-1855.

Jones, D.W. (2012). Development of a bariatric patient readiness assessment tool for the emergency department. *Advanced Emergency Nursing Journal, 34*(3): 238-249.

Kerr, M.S., Frank, J.W., Shannon, H.S., Norman, R.W.K., Wells, R.P. Neumann, W.P., …, & The Ontario Universities Back Pain Study Group. (2001). Biomechanical and psychosocial risk factors for low back pain at work. *American Journal of Public Health, 91*(7): 1069-1075.

Knibbe, J.J., & Friele, R.D. (1996). Prevalence of back pain and characteristics of the physical workload of community nurses. *Ergonomics, 39*(2): 186-198.

Kovacs, F.M., Abraira, V., Royuela, A., Corcoll, J., Alegre, L., Tomás, M., …, & Del Real, M.T.G. (2008). Minimum detectable and minimal clinically important changes for pain in patients with nonspecific neck pain. *BMC Musculoskeletal Disorders*, *9*(1): 43.

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P.S. (2011). Validation of wearable monitors for assessing sedentary behaviour. *Medicine & Science in Sports & Exercise, 43*(8): 1561-1567.

Kujala, U.M., Taimela, S., Viljanen, T., Jutila, H., Vitasalo, J.T., Videman, T., & Battié, M.C. (1996). Physical loading and performance as predictors of back pain in healthy adults A 5-year prospective study. *European Journal of Applied Physiology and Occupational Physiology, 73*(5): 452-458.

Leach, J.M., Mancini, M., Peterka, R.J., Hayes, T.L., & Horak, F.B. (2014). Validating and calibrating the Nintendo Wii balance board to derive reliable center of pressure measures. *Sensors, 14*(10): 18244-18267.

Lela, M. & Frantz, J.M. (2012). Physical activity among nurses in Kanombe Military Hospital. *African Journal of Physiotherapy and Rehabilitation Sciences, 4*(1-2): 63-66.

Luoto, S., Taimela, S., Hurri, H., Aalto, H., Pyykkö, I., & Alaranta, H. (1996). Psychomotor Speed and Postural Control in Chronic Low Back Pain Patients: A Controlled Follow-Up Study. *Spine, 21*(22): 2621-2627.

Luoto, S., Heliövaara, M., Hurri, H., & Alaranta, H. (1995). Static back endurance and the risk of low-back pain. *Clinical Biomechanics, 10*(6): 323-324.

Mansoubi, M., Pearson, N., Clemes, S.A., Biddle, S.J., Bodicoat, D.H., Tolfrey, K., …, & Yates, T. (2015). Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. *BMC Public Health, 15*: 516-523.

Marras, W.S., & Karwowski, W. (2006). Fundamentals and assessment tools for occupational ergonomics. *Boca Raton, FL: CRC Press*.

Marras, W.S. (2000). Occupational low back disorder causation and control. *Ergonomics, 43*(7): 880-902.

Marras, W.S., Davis, K.G., Kirking, B.C., & Bertsche, P.K. (1999). A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques. *Ergonomics, 42*(7): 904-926.

McGill, S. (2016). Low back disorders: evidence-based prevention and rehabilitation (3rd ed.). *Champaign, IL: Human Kinetics*.

McGill, S.M., Norman, R.W., Yingling, V.R., Wells, R.P., & Neumann, P. (1998). Shear happens! Suggested guidelines for ergonomists to reduce the risk of low back injury from shear loading. *30th Annual Conference of the Human Factors Association of Canada,* Mississauga, Canada: pp. 157-161.

Mitchell, T., O'Sullivan, P.B., Smith, A., Burnett, A.F., Straker, L., …., & Rudd, C.J. (2009). Biopsychosocial factors are associated with low back pain in female nursing students: A cross-sectional study. *International Journal of Nursing Studies, 46*(5): 678-688.

Mok, N.W., Brauer, S.G., & Hodges, P.W. (2004). Hip strategy for balance control in quiet standing is reduced in people with low back pain. *Spine, 29*(6): E107-E112.

Naclerio, F.J., Colado, J.C., Rhea, M.R., Bunker, D., & Triplett, N.T. (2009). The influence of strength and power on muscular endurance test performance. *Journal of Strength and Conditioning Research, 23*(5): 1482-1488.

Nelson-Wong, E., Gallant, P., Alexander, S., Dehmer, K., Ingvalson, S., …., & Davis, A.M. (2016). Multiplanar lumbopelvic control in patients with low back pain: is multiplanar assessment better than single plane assessment in discriminating between patients and healthy controls?. *Journal of Manual & Manipulative Therapy, 24*(1): 45-50.

Nelson-Wong, E. and Callaghan, J.P. (2014). Transient low back pain development during standing predicts future clinical low back pain in previously asymptomatic individuals. *Spine, 39*(6), pp.E379-E383.

Nelson-Wong, E., Poupore, K., Ingvalson, S., Dehmer, K., Piatte, A., …., & Davis, A.M. (2013). Neuromuscular strategies for lumbopelvic control during frontal and sagittal plane movement challenges differ between people with and without low back pain. *Journal of Electromyography and Kinesiology, 23*(6): 1317-1324.

Nelson-Wong, E., & Callaghan, J.P. (2010). Is muscle co-activation a predisposing factor for low back pain development during standing? A multifactorial approach for early identification of at-risk individuals. *Journal of Electromyography and Kinesiology, 20*(2): 256-263.

Nelson-Wong, E., Flynn, T., & Callaghan, J.P. (2009). Development of active hip abduction as a screening test for identifying occupational low back pain. *Journal of Orthopaedic & Sports Physical Therapy, 39*(9): 649-657.

Nelson-Wong, E., Gregory, D.E., Winter, D.A., & Callaghan, J.P. (2008). Gluteus medius muscle activation patterns as a predictor of low back pain during standing. *Clinical Biomechanics*, *23*(5): 545-553.

Norman, R., Wells, R., Neumann, P., Frank, J., Shannon, H., & Kerr, M. (1998). A comparison of peak vs cumulative physical work exposure risk factors for the reporting of low back pain in the automotive industry. *Clinical Biomechanics, 13*(8): 561-573.

Omokhodion, F.O., Umar, U.S., & Ogunnowo, B.E. (2000). Prevalence of low back pain among staff in a rural hospital in Nigeria. *Occupational Medicine*, *50*(2): 107-110.

Ontario Ministry of Labour. (2015). Safe At Work Ontario: Prevent Slips, Trips and Falls in all Workplaces. [online]. Retrieved April 11, 2016, from https://www.labour.gov.on.ca/english/hs/sawo/pubs/fs_falls.php

Panjabi, M.M. (2003). Clinical spinal instability and low back pain. *Journal of Electromyography and Kinesiology, 13*(4): 371-379.

Parkinson, R.J., Bezaire, M., & Callaghan, J.P. (2011). A comparison of low back kinetic estimates obtained through posture matching, rigid link modeling and an EMG-assisted model. *Applied Ergonomics, 42*(5): 644-651.

Parks, K.A., Crichton, K.S., Goldford, R.J., & McGill, S.M. (2003). A comparison of lumbar range of motion and functional ability scores in patients with low back pain: assessment for range of motion validity. *Spine, 28*(4): 380-384.

Peeters, G., van Gellecum, Y., Ryde, G., Aguilar Farías, N., Brown, W.J. (2013). Is the pain of activity log-books worth the gain in precision when distinguishing wear and non-wear time for tri-axial accelerometers? *Journal of Science and Medicine in Sport, 16*(6): 515-519.

Picavet, H.S.J., & Schuit, A.J. (2003). Physical inactivity: a risk factor for low back pain in the general population?. *Journal of Epidemiology & Community Health*, *57*(7): 517-518.

Pires, C.G., Mussi, F.C., Cerqueira, B.B., Pitanga, F.J.G., & Silva, D.O. (2013). Physical activity practice among undergraduate students in nursing. *Acta Paulista de Enfermagem, 26*(5): 436-443.

Pope, M.H., Bevins, T., Wilder, D.G., & Frymoyer, J.W. (1985). The relationship between anthropometric, postural, muscular, and mobility characteristics of males ages 18-55. *Spine, 10*(7): 644-648.

Radebold, A., Cholewicki, J., Polzhofer, G.K., & Greene, H.S. (2001). Impaired postural control of the lumbar spine is associated with delayed muscle response times in patients with chronic idiopathic low back pain. *Spine, 26*(7): 724-730.

Reiman, M.P., & Manske, R.C. (2009). *Functional testing in human performance* (pp. 88-92). Champaign: Human Kinetics.

Revill, S.I., Robinson, J.O., Roden, M., & Hogg, M.I.J. (1976). The reliability of a linear analogue for evaluating pain. *Anaesthesia, 31*(9): 1191-1198.

Ropponen, A., Silventoinen, K., Tynelius, P., & Rasmussen, F. (2011). Association between hand grip/body weight ratio and disability pension due to musculoskeletal disorders: a population-based cohort study of 1 million Swedish men. *Scandinavian Journal of Social Medicine, 39*(8): 830-838.

Ruhe, A., Fejer, R., & Walker, B. (2011). Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: a systematic review of the literature. *European Spine Journal, 20*(3): 358-368.

Seaman, F.A., Albert, W.J., Weldon, N.R.E., Croll, J., & Callaghan, J.P. (2010). Biomechanical shoulder loads and postures in light automotive assembly workers: comparison between shoulder pain/no pain groups. *Work, 35*(1): 39-48.

Schenk, P., Läubli, T., Hodler, J., & Klipstein, A. (2007). Symptomatology of recurrent low back pain in nursing and administrative professions. *European Spine Journal, 16*(11): 1789-1798.

Sherehiy, B., Karwowski, W., & Marek, T. (2004). Relationship between risk factors and musculoskeletal disorders in the nursing profession: A systematic review. *Occupational Ergonomics, 4*(4): 241-279.

Shields, M., & Wilkins, K. (2006). Findings from the 2005 national survey of the work and health of nurses. *Health Canada*. Retrieved April 4, 2016, from: www.statscan.gc.ca/pub/83-003-x/83-003-x2006001-eng.pdf.

Sorensen, C.J., George, S.Z., Callaghan, J.P., & Van Dillen, L.R. (2016). Psychological factors are related to pain intensity in back-healthy people who develop clinically relevant pain during prolonged standing: a preliminary study. *PM&R, 8*(11): 1031-1038.

Sorensen, C.J., Johnson, M.B., Callaghan, J.P., George, S.Z., & Van Dillen, L.R. (2015). Validity of a paradigm for low back symptom development during prolonged standing. *Clinical Journal of Pain, 31*(7): 652-659.

Statistics Canada. (2015). Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. [online]. Retrieved May 12, 2017, from http://www.statcan.gc.ca/pub/82-003-x/2011001/article/11396-eng.htm.

Statistics Canada. (2003). Work injuries: Findings. [online]. Retrieved June 3, 2017, from http://www.statcan.gc.ca/pub/82-003-x/2006007/article/injuries-blessures/4149017-eng.htm.

Strøyer, J., & Jensen, L.D. (2008). The role of physical fitness as risk indicator of increased low back pain intensity among people working with physically and mentally disabled persons: a 30-month prospective study. *Spine, 33*(5): 546-554.

Summers, S. (2001). Evidence-based practice part 2: Reliability and validity of selected acute pain instruments. *Journal of PeriAnesthesia Nursing, 16*(1): 35-40.

Sutherland, C.A., Albert, W.J., Wrigley, A.T., & Callaghan, J.P. (2008). A validation of a posture matching approach for the determination of 3D cumulative back loads. *Applied Ergonomics, 39*(2): 199-208.

Sutherland, C.A., Albert, W.J., Wrigley, A.T., & Callaghan, J.P. (2007). The effect of camera viewing angle on posture assessment repeatability and cumulative spinal loading. *Ergonomics, 50*(6): 877-889.

Taanila, H., Suni, J.H., Pihlajamäki, H., Mattila, V.M., Ohrankämmen, O., Vuorinen, P., & Parkkari, J.P. (2012). Predictors of low back pain in physically active conscripts with special emphasis on muscular fitness. *Spine Journal, 12*(9): 737-748.

Timpka, S., Petersson, I.F., Zhou, C., & Englund, M. (2013). Muscle strength in adolescent men and future musculoskeletal pain: a cohort study with 17 years of follow-up. *BMJ open, 3*(5): e002656.

Tuohy-Main, K. (1997). Why manual handling should be eliminated for resident and career safety. *Geriaction, 15*(1): 10-14.

Van Weering, M.G., Vollenbroek-Hutten, M.M., Tönis, T.M., & Hermens, H.J. (2009). Daily physical activities in chronic lower back pain patients assessed with accelerometry. *European Journal of Pain, 13*(6): 649-654.

Van Wyk, P.M., Weir, P.L., & Andrews, D.M. (2015). Manual patient transfers used most often by student and staff nurses are consistent with their perceptions of transfer training and performance confidence. *Work, 50*(2): 249-260.

Vieira, E.R., & Kumar, S. (2009). Safety analysis of patient transfers and handling tasks. *Quality and Safety in Health Care, 18*(5): 380-384.

Waters, T.R. (2007). When is it safe to manually lift a patient? *The American Journal of Nursing*, *107*(8): 53-58.

Waters, T.R., Putz-Anderson, V., Garg, A., & Fine, L.J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics, 36*(7): 749-776.

World Health Organization. (2016). Definition of Physical Activity. [online]. Retrieved April 11, 2016, from http://www.who.int/topics/physical_activity/en/.

Winter, D.A. (2009). Biomechanics and motor control of human movement (4th ed.). *Hoboken, NJ: John Wiley & Sons, Inc.*

Winter, D.A., Patla, A.E., Prince, F., Ishac, M., & Gielo-Perczak, K. (1998). Stiffness control of balance in quiet standing. *Journal of neurophysiology, 80*(3): 1211-1221.

Wong, S.L. (2016). Grip strength reference values for Canadians aged 6 to 79: Canadian Health Measures Survey, 2007 to 2013. [online]. Retrieved June 25, 2017, from http://www.statcan.gc.ca/pub/82-003-x/2016010/article/14665-eng.htm.

Workplace Safety and Insurance Board. (2014). By The Numbers: 2014 WSIB Statistical Report. [online]. Retrieved April 11, 2016, from http://www.wsibstatistics.ca/en/s1home/.

Yassi, A., & Lockhart, K. (2013). Work-relatedness of low back pain in nursing personnel: A systematic review. *International Journal of Occupational and Environmental Health, 19*(3): 223-244.

Yingling, V.R., & McGill, S.M. (1999). Anterior shear of spinal motion segments: Kinematics, kinetics, and resultant injuries observed in a porcine model. *Spine, 24*(18): 1882.

**Appendix A: Collection Protocol Form - Page 1 of 6**

**<u>***STRICTLY CONFIDENTIAL***</u>**

**Subject ID:**

**Date:**

**Test Time:**

**Circle:** NURSING STUDENT or NURSE

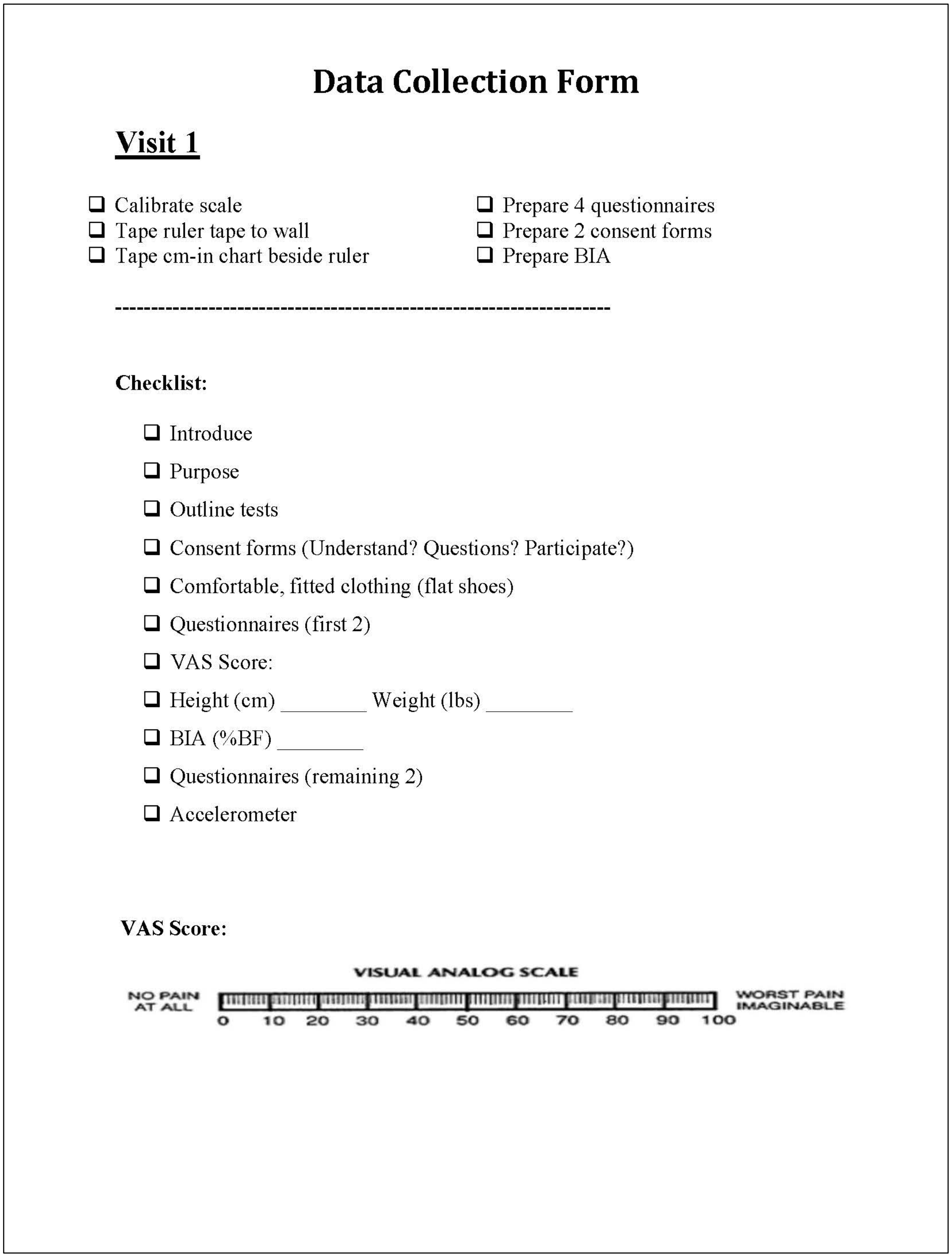
**Shift time (if applicable):**

**Investigator:**

**Recorder:**

**<u>***STRICTLY CONFIDENTIAL***</u>**

**Appendix A: Collection Protocol Form - Page 2 of 6**



# Data Collection Form

## Visit 1

- ☐ Calibrate scale
- ☐ Tape ruler tape to wall
- ☐ Tape cm-in chart beside ruler
- ☐ Prepare 4 questionnaires
- ☐ Prepare 2 consent forms
- ☐ Prepare BIA

-----------------------------------------------------------------------

**Checklist:**

- ☐ Introduce
- ☐ Purpose
- ☐ Outline tests
- ☐ Consent forms (Understand? Questions? Participate?)
- ☐ Comfortable, fitted clothing (flat shoes)
- ☐ Questionnaires (first 2)
- ☐ VAS Score:
- ☐ Height (cm) ________ Weight (lbs) ________
- ☐ BIA (%BF) ________
- ☐ Questionnaires (remaining 2)
- ☐ Accelerometer

**VAS Score:**

## Appendix A: Collection Protocol Form - Page 3 of 6

# Data Collection Form

## Visit 2

- ☐ Check SIM card and battery life of both cameras
- ☐ Prepare myotape, ruler stick, stopwatch, metronome, counter
- ☐ Tape on table for curl-up
- ☐ Tape on ground for flexibility
- ☐ Prepare tape (x30) and "X" marks for landmarks
- ☐ Set up and calibrate Wii balance board
- ☐ Turn cameras on

----------------------------------------------------------------------

**Anthropometry (circumference):**

Waist (Umbilicus):

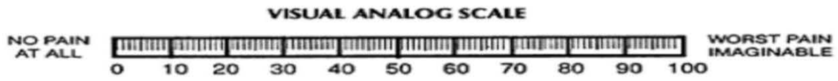
Hip (Gluteal Fold):

Thigh:

Biceps:

| Wii Balance Board: | |
|---|---|
| Calibration | "StudyID"_WBB QS<br>Calibration |
| 1. Quiet Standing - 2 legs (30s) | Wii Physics (StudyID_QS) |
| 2. Standing to one leg – bilateral (30s) | Wii Physics (StudyID_SSR) or (StudyID_SSL) |
| 3. Forward bend (30s) | Wii Physics (StudyID_FB) |

**VAS Score:**



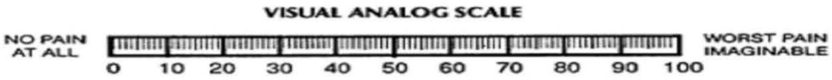
**Notes:**

## Appendix A: Collection Protocol Form - Page 4 of 6

# Data Collection Form

| Rated Tests: | | |
|---|---|---|
| Active Straight Leg Raise | **Right:**<br>Grade: 3 2 1 0 | **Left:**<br>Grade: 3 2 1 0 |
| AHAbd Test | **Right:**<br>Grade: 3 2 1 0 | **Left:**<br>Grade: 3 2 1 0 |
| Deep Knee Squats | Grade: 3 2 1 0<br>Distance Heels off of ground:<br>__________cm. | |

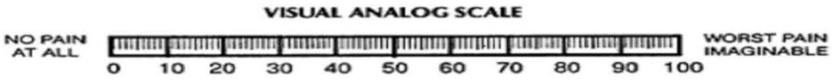
**VAS Score:**



**Notes:**

| Flexibility: |
|---|
| 1. **Forward flexion (5s)**<br>2. **Lateral flexion (left – 5s)**<br>3. **Lateral flexion (right – 5s)**<br>4. **Twist (left – 5s)**<br>5. **Twist (right – 5s)** |

**VAS Score:**



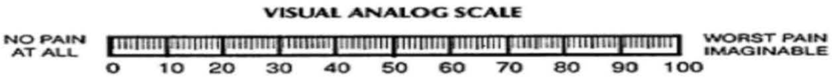
**Notes:**

## Appendix A: Collection Protocol Form - Page 5 of 6

# Data Collection Form

| Muscular Endurance: | |
|---|---|
| Partial Curl-Ups | Reps: |
| Oblique Trunk Hold | |
| a. Left | Grade: 5 4 3 2 1 0<br>Time: ______s |
| b. Right | Grade: 5 4 3 2 1 0<br>Time: ______s |
| Back Extension | Time: ______s |

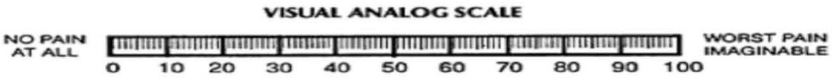
**VAS Score:**



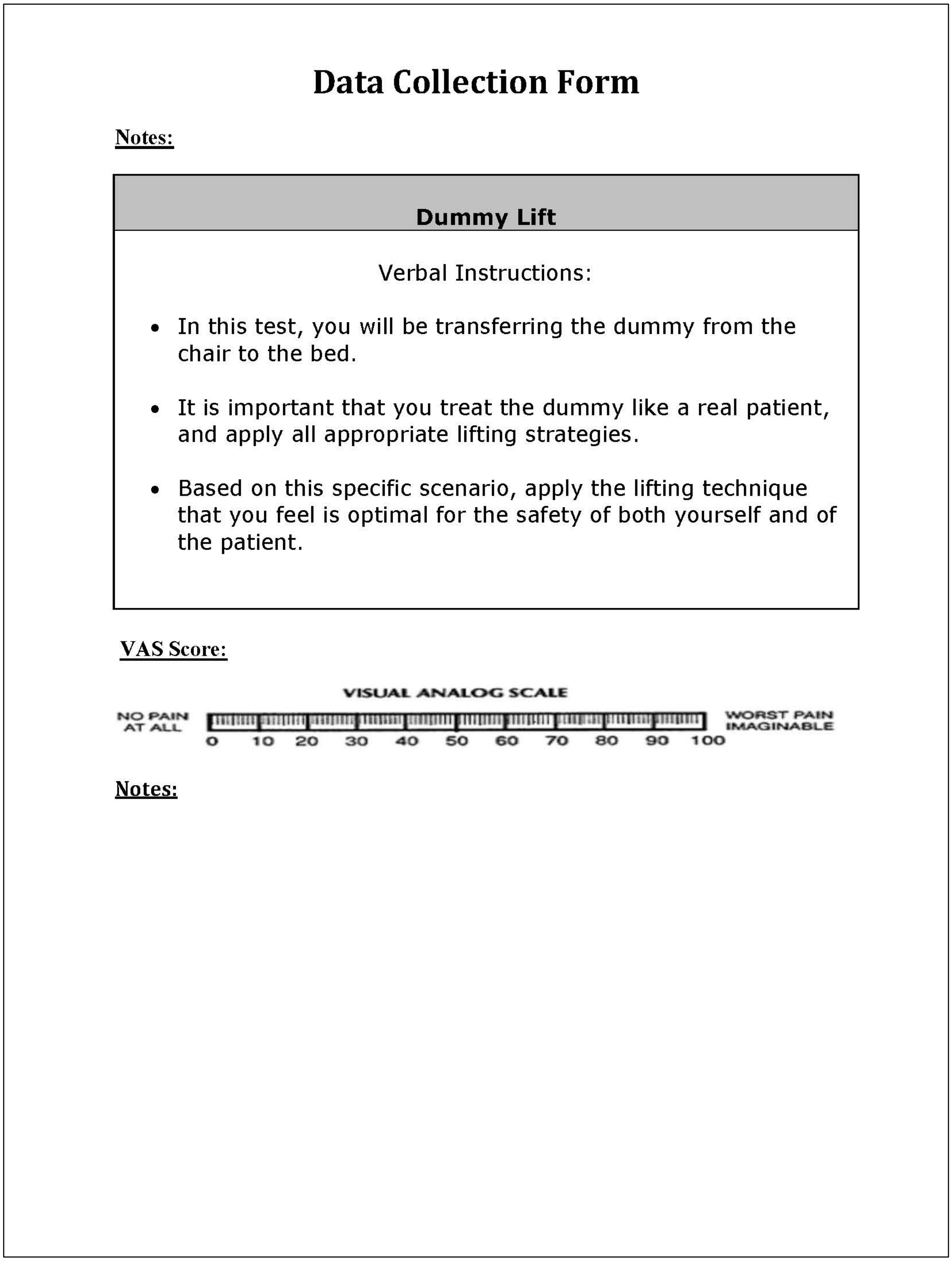
**Notes:**

| Muscular Strength | |
|---|---|
| Grip Strength | R1: _________kg R2: _________kg<br>L1: _________kg L2: _________kg<br>**Combined (R+L):** _____kg |

**VAS Score:**



## Appendix A: Collection Protocol Form - Page 6 of 6



# Data Collection Form

**Notes:**

| **Dummy Lift** |
|---|
| Verbal Instructions:<br>• In this test, you will be transferring the dummy from the chair to the bed.<br>• It is important that you treat the dummy like a real patient, and apply all appropriate lifting strategies.<br>• Based on this specific scenario, apply the lifting technique that you feel is optimal for the safety of both yourself and of the patient. |

**VAS Score:**

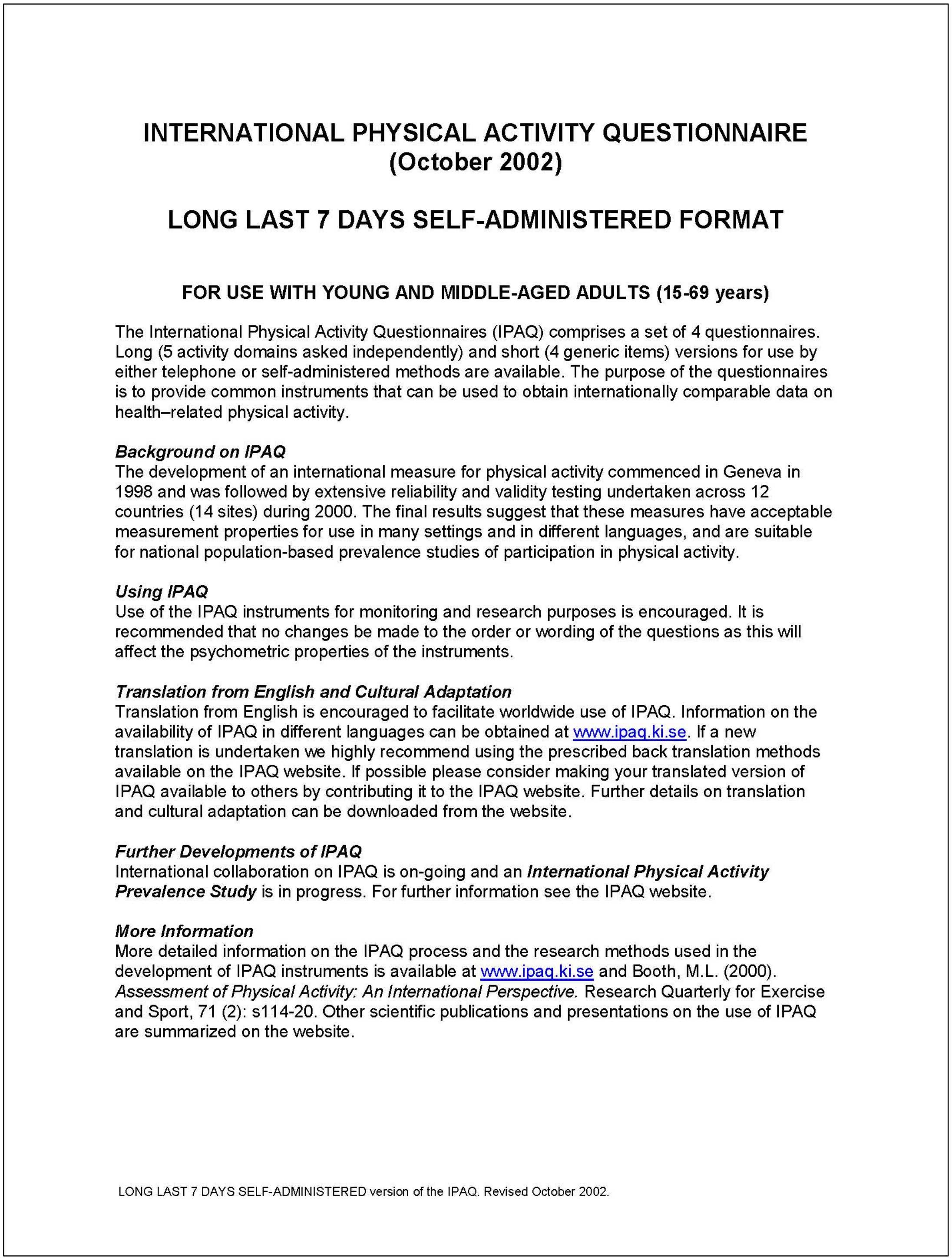
VISUAL ANALOG SCALE

NO PAIN AT ALL 0 10 20 30 40 50 60 70 80 90 100 WORST PAIN IMAGINABLE

**Notes:**

## Appendix B: International Physical Activity Questionnaire - Page 1 of 6

**The International Physical Activity Questionnaire is open access, and so permission to reproduce the questionnaire was not required.**



# INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE
(October 2002)

## LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

### FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

***Background on IPAQ***
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

***Using IPAQ***
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

***Translation from English and Cultural Adaptation***
Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

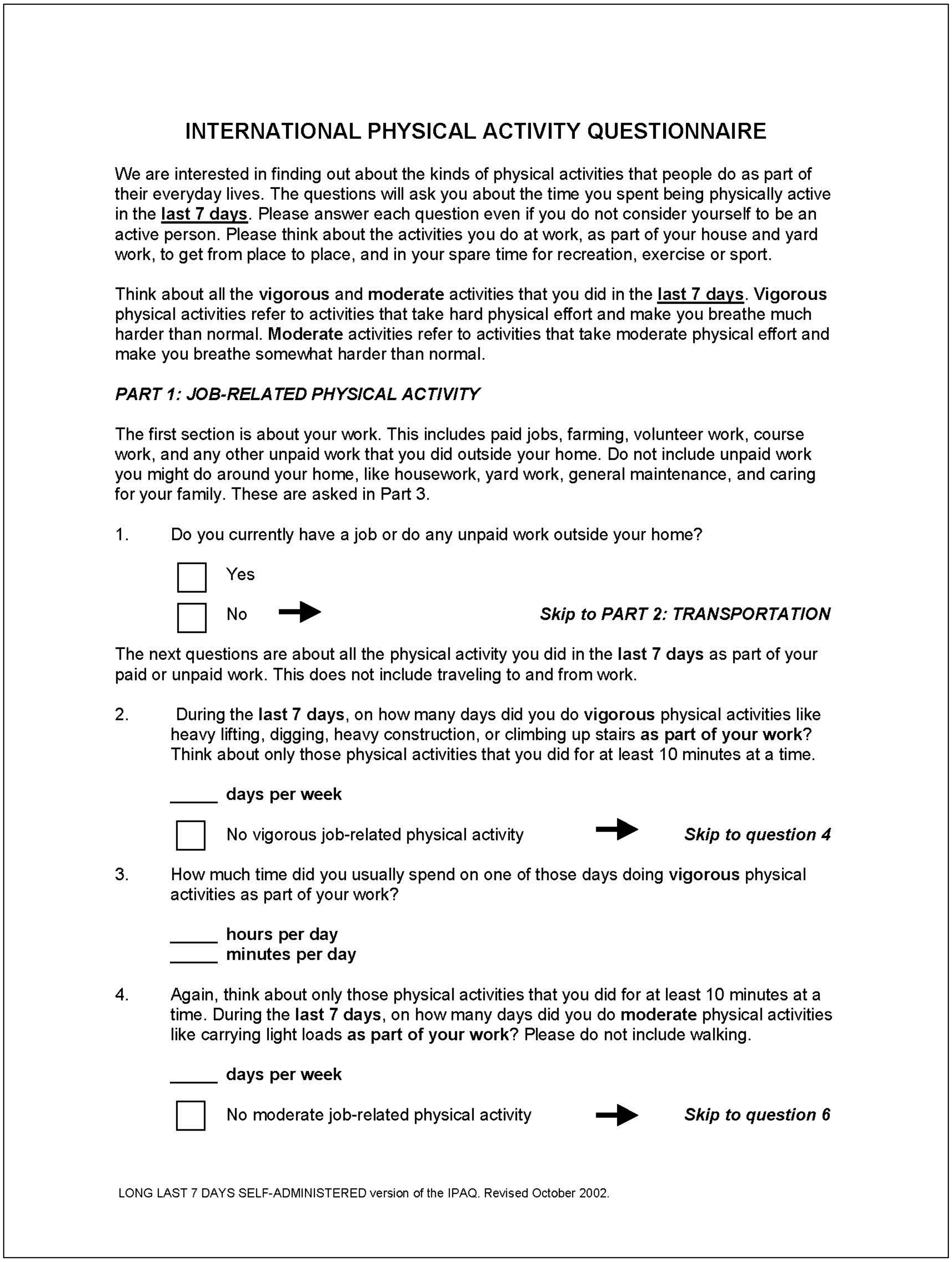
***Further Developments of IPAQ***
International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

***More Information***
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

## Appendix B: International Physical Activity Questionnaire - Page 2 of 6

**The International Physical Activity Questionnaire is open access, and so permission to reproduce the questionnaire was not required.**



### INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the <u>**last 7 days**</u>. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the <u>**last 7 days**</u>. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

***PART 1: JOB-RELATED PHYSICAL ACTIVITY***

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes
☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

## Appendix B: International Physical Activity Questionnaire - Page 3 of 6

## The International Physical Activity Questionnaire is open access, and so permission to reproduce the questionnaire was not required.

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

***PART 2: TRANSPORTATION PHYSICAL ACTIVITY***

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

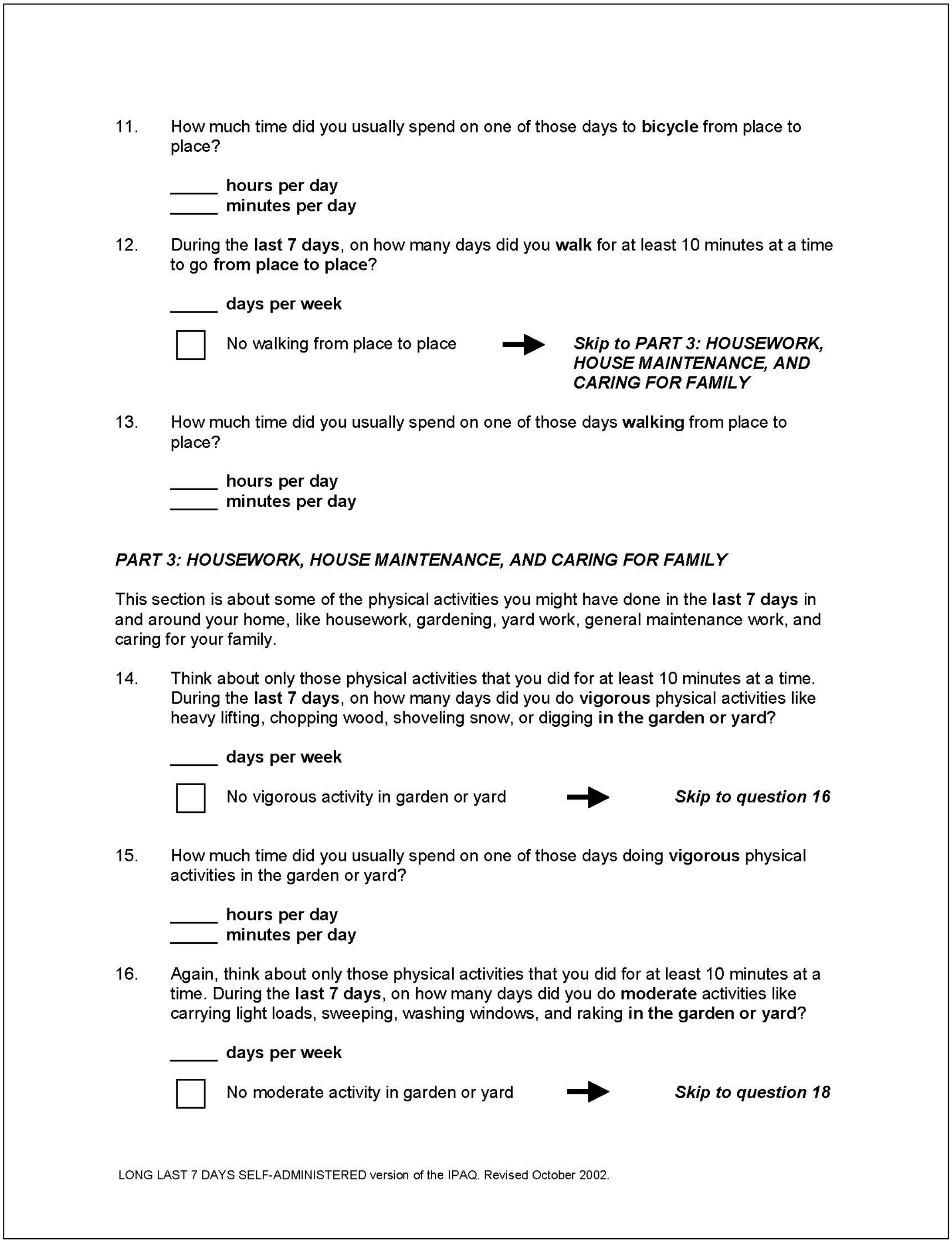
10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

## Appendix B: International Physical Activity Questionnaire - Page 4 of 6

**The International Physical Activity Questionnaire is open access, and so permission to reproduce the questionnaire was not required.**



11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

***PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

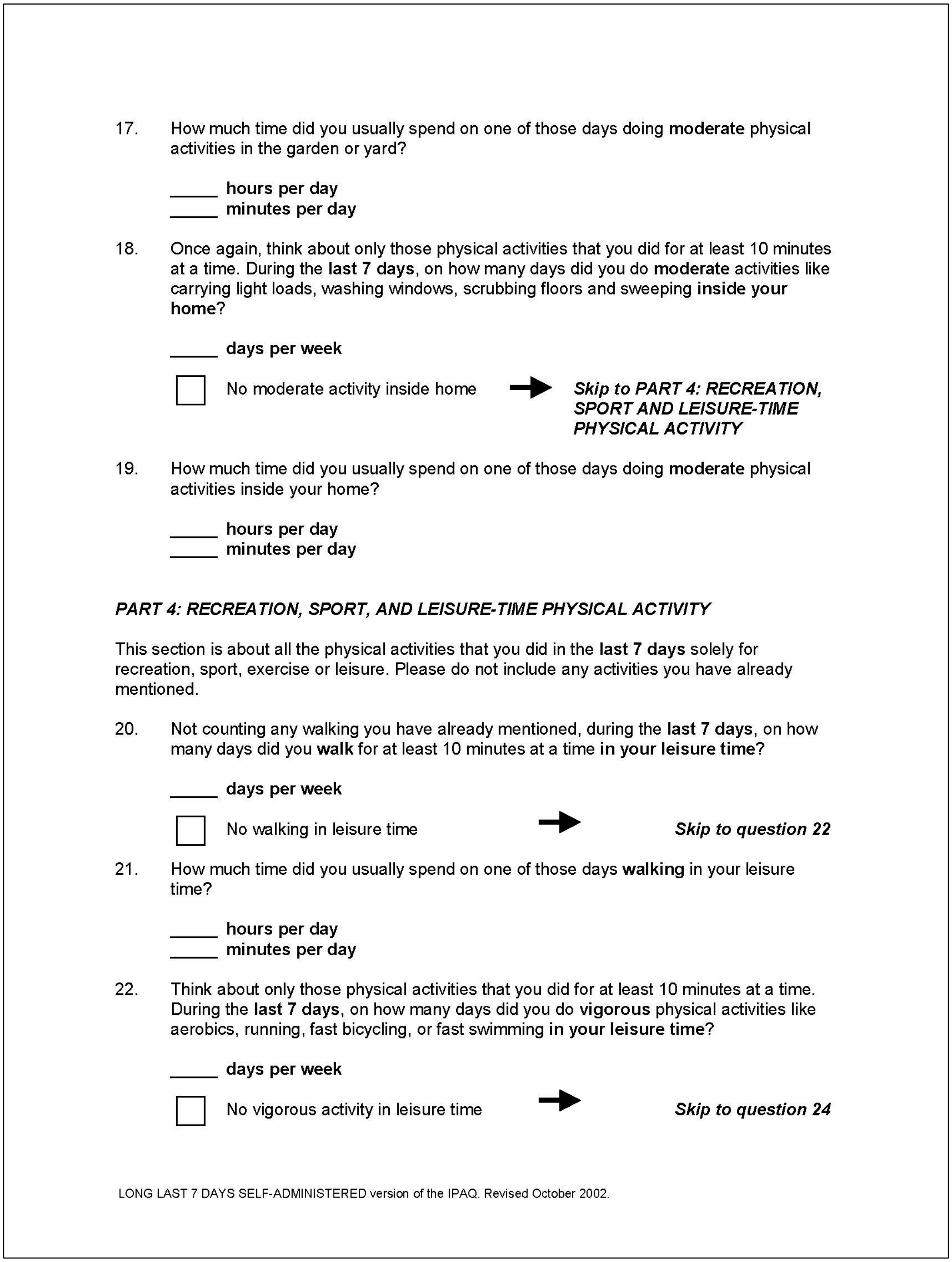
_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

## Appendix B: International Physical Activity Questionnaire - Page 5 of 6

**The International Physical Activity Questionnaire is open access, and so permission to reproduce the questionnaire was not required.**



17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

***PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY***

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

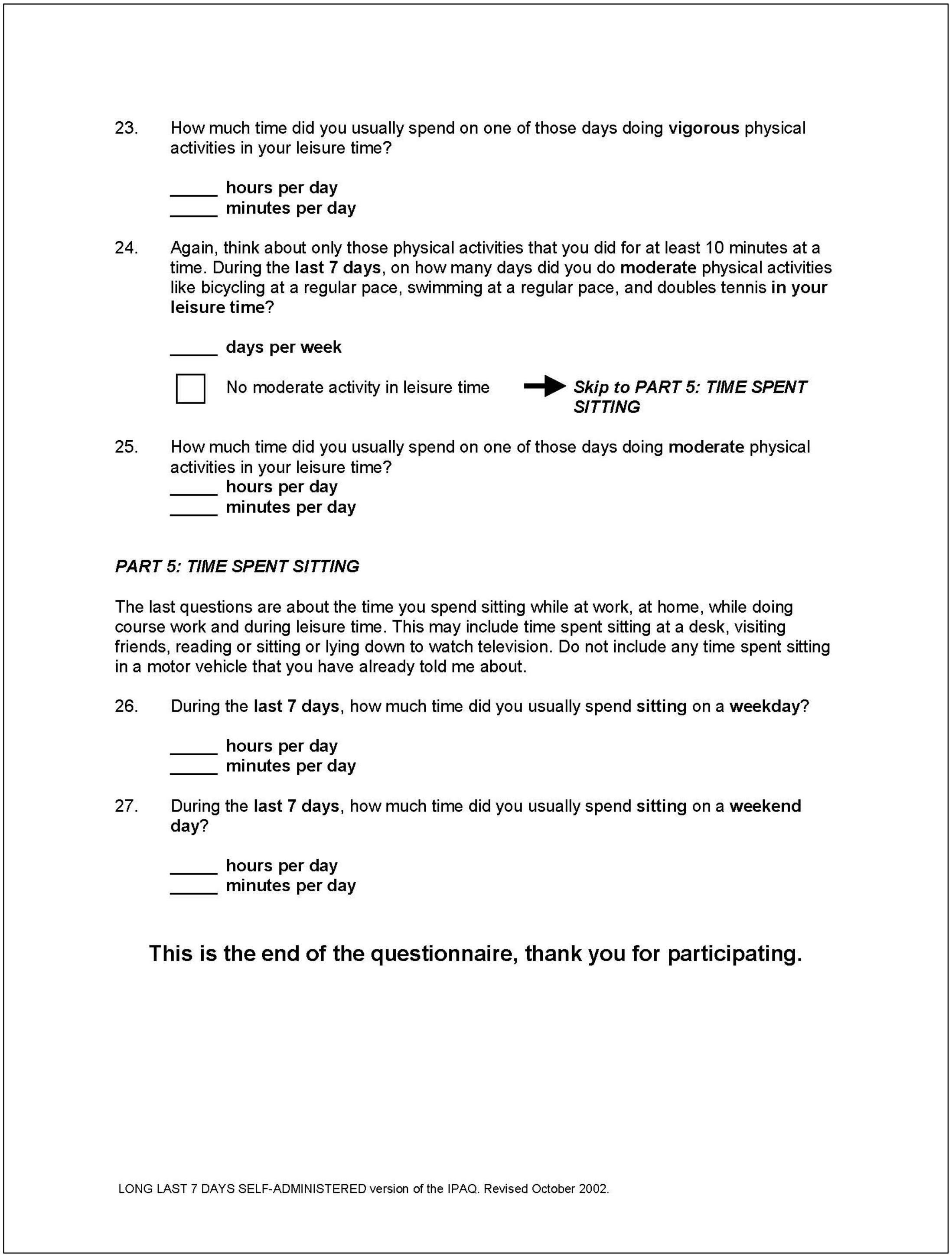
_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

## Appendix B: International Physical Activity Questionnaire - Page 6 of 6

**The International Physical Activity Questionnaire is open access, and so permission to reproduce the questionnaire was not required.**



23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

***PART 5: TIME SPENT SITTING***

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

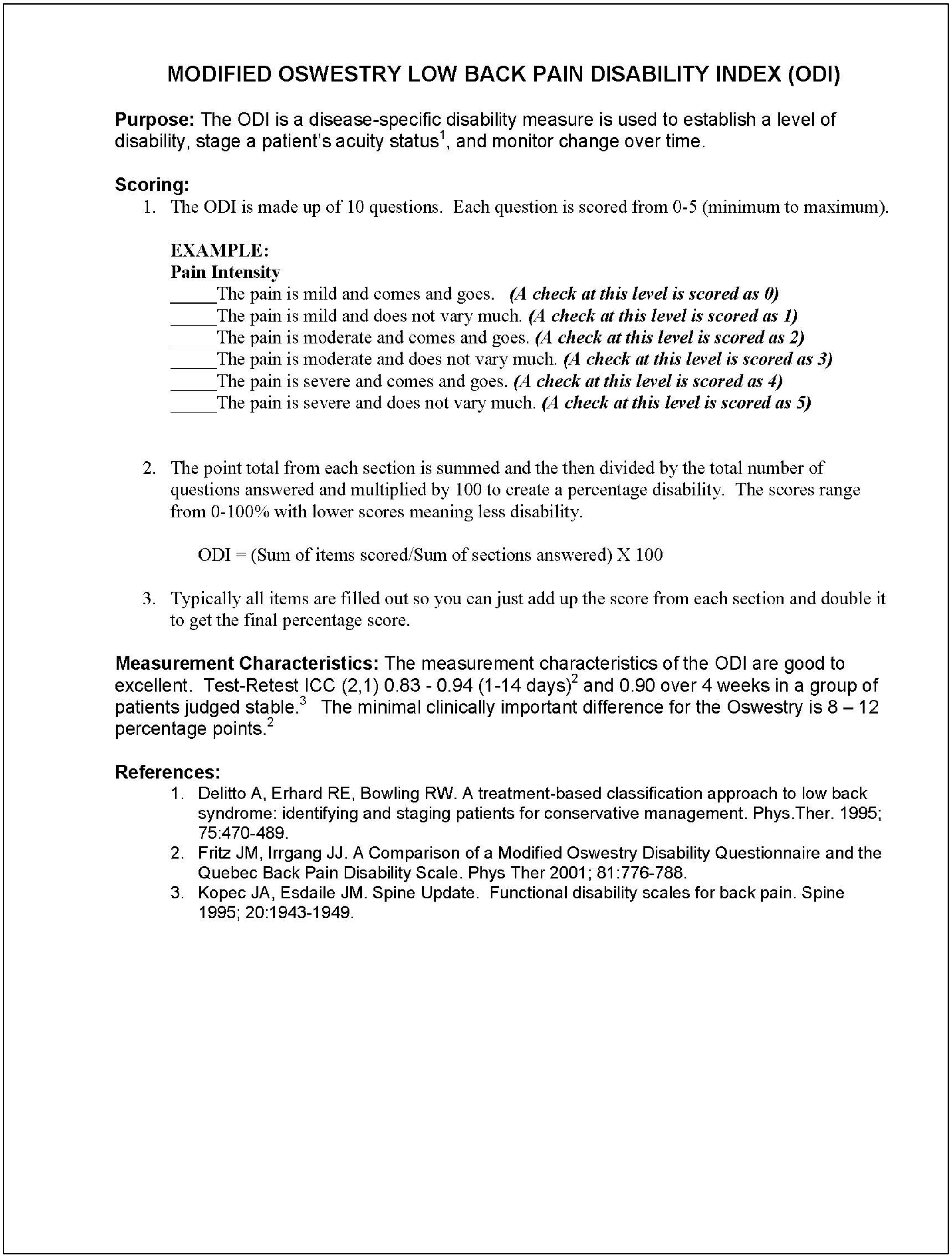
_____ **hours per day**
_____ **minutes per day**

**This is the end of the questionnaire, thank you for participating.**

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

## Appendix C: Modified Oswestry Low Back Pain Disability Index - Page 1 of 3

**Approval to reproduce the copyrighted Modified Oswestry Low Back Pain Disability Index was granted by Oxford University Press.**



### MODIFIED OSWESTRY LOW BACK PAIN DISABILITY INDEX (ODI)

**Purpose:** The ODI is a disease-specific disability measure is used to establish a level of disability, stage a patient's acuity status[1], and monitor change over time.

**Scoring:**

1. The ODI is made up of 10 questions. Each question is scored from 0-5 (minimum to maximum).

   **EXAMPLE:**
   **Pain Intensity**
   _____The pain is mild and comes and goes. ***(A check at this level is scored as 0)***
   _____The pain is mild and does not vary much. ***(A check at this level is scored as 1)***
   _____The pain is moderate and comes and goes. ***(A check at this level is scored as 2)***
   _____The pain is moderate and does not vary much. ***(A check at this level is scored as 3)***
   _____The pain is severe and comes and goes. ***(A check at this level is scored as 4)***
   _____The pain is severe and does not vary much. ***(A check at this level is scored as 5)***

2. The point total from each section is summed and the then divided by the total number of questions answered and multiplied by 100 to create a percentage disability. The scores range from 0-100% with lower scores meaning less disability.

   ODI = (Sum of items scored/Sum of sections answered) X 100

3. Typically all items are filled out so you can just add up the score from each section and double it to get the final percentage score.

**Measurement Characteristics:** The measurement characteristics of the ODI are good to excellent. Test-Retest ICC (2,1) 0.83 - 0.94 (1-14 days)[2] and 0.90 over 4 weeks in a group of patients judged stable.[3] The minimal clinically important difference for the Oswestry is 8 – 12 percentage points.[2]

**References:**

1. Delitto A, Erhard RE, Bowling RW. A treatment-based classification approach to low back syndrome: identifying and staging patients for conservative management. Phys.Ther. 1995; 75:470-489.
2. Fritz JM, Irrgang JJ. A Comparison of a Modified Oswestry Disability Questionnaire and the Quebec Back Pain Disability Scale. Phys Ther 2001; 81:776-788.
3. Kopec JA, Esdaile JM. Spine Update. Functional disability scales for back pain. Spine 1995; 20:1943-1949.

## Appendix C: Modified Oswestry Low Back Pain Disability Index - Page 2 of 3

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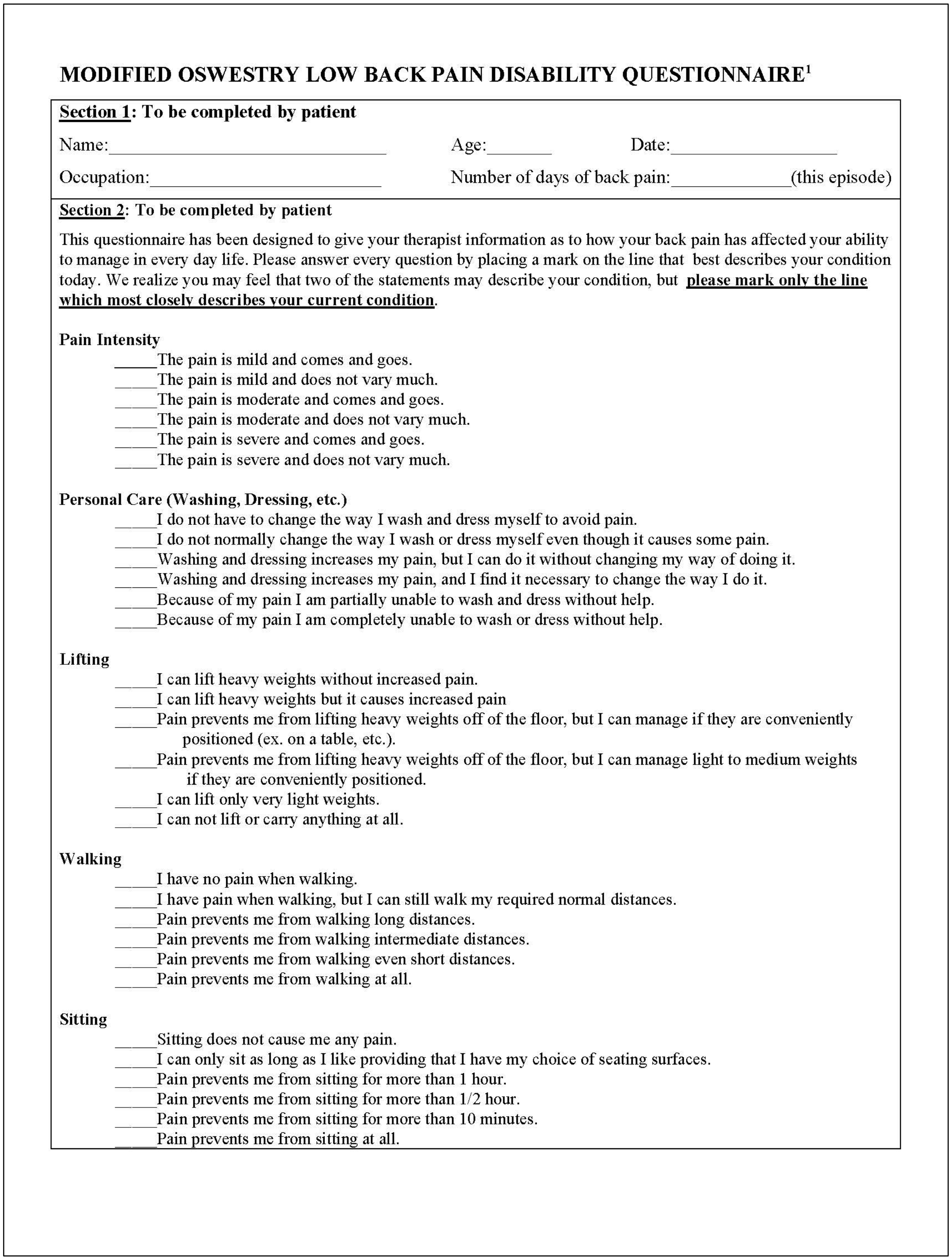


### MODIFIED OSWESTRY LOW BACK PAIN DISABILITY QUESTIONNAIRE[1]

**Section 1: To be completed by patient**

Name:______________________________ Age:_______ Date:__________________

Occupation:_________________________ Number of days of back pain:_____________(this episode)

**Section 2: To be completed by patient**

This questionnaire has been designed to give your therapist information as to how your back pain has affected your ability to manage in every day life. Please answer every question by placing a mark on the line that best describes your condition today. We realize you may feel that two of the statements may describe your condition, but **please mark only the line which most closely describes your current condition**.

**Pain Intensity**

_____The pain is mild and comes and goes.
_____The pain is mild and does not vary much.
_____The pain is moderate and comes and goes.
_____The pain is moderate and does not vary much.
_____The pain is severe and comes and goes.
_____The pain is severe and does not vary much.

**Personal Care (Washing, Dressing, etc.)**

_____I do not have to change the way I wash and dress myself to avoid pain.
_____I do not normally change the way I wash or dress myself even though it causes some pain.
_____Washing and dressing increases my pain, but I can do it without changing my way of doing it.
_____Washing and dressing increases my pain, and I find it necessary to change the way I do it.
_____Because of my pain I am partially unable to wash and dress without help.
_____Because of my pain I am completely unable to wash or dress without help.

**Lifting**

_____I can lift heavy weights without increased pain.
_____I can lift heavy weights but it causes increased pain
_____Pain prevents me from lifting heavy weights off of the floor, but I can manage if they are conveniently positioned (ex. on a table, etc.).
_____Pain prevents me from lifting heavy weights off of the floor, but I can manage light to medium weights if they are conveniently positioned.
_____I can lift only very light weights.
_____I can not lift or carry anything at all.

**Walking**

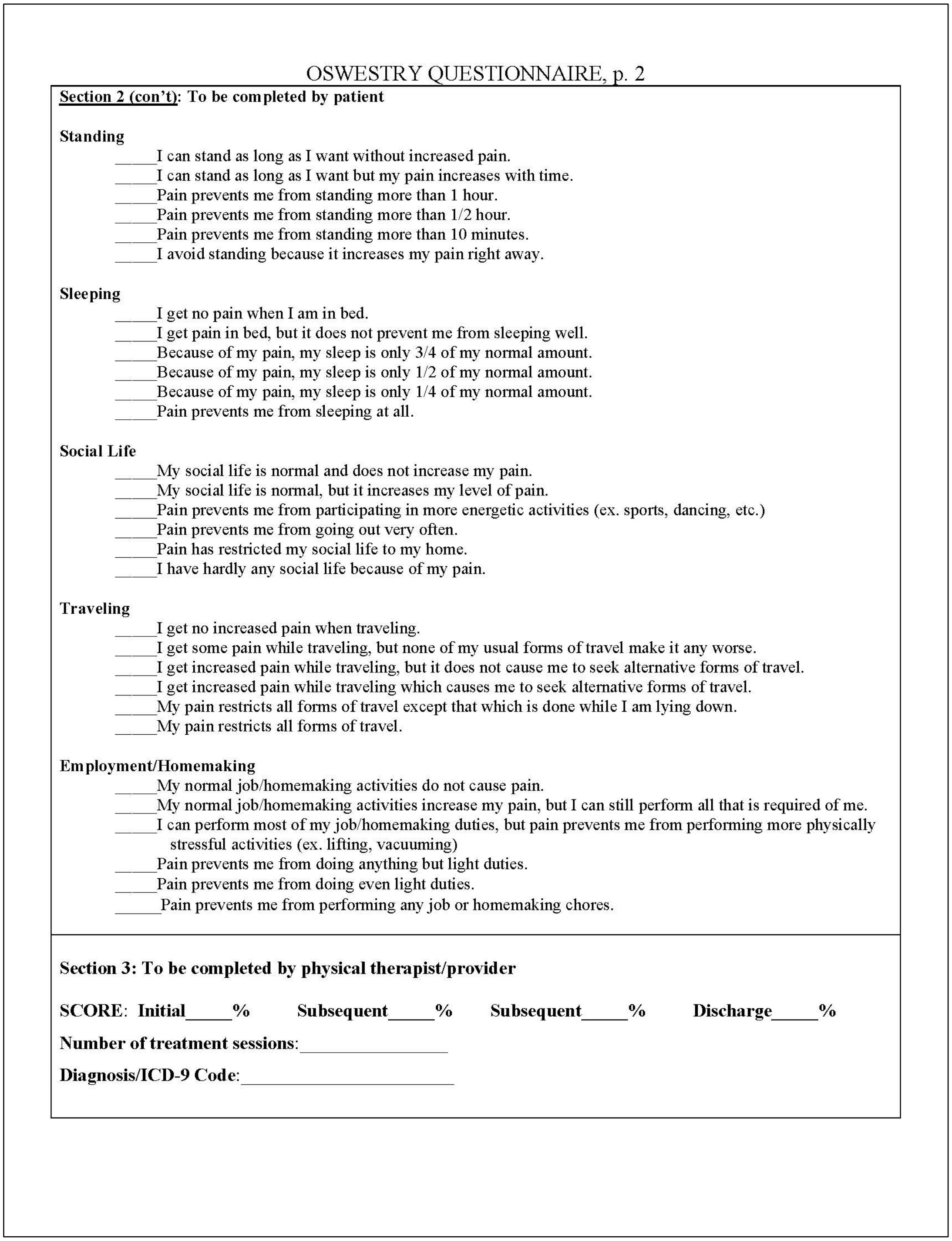
_____I have no pain when walking.
_____I have pain when walking, but I can still walk my required normal distances.
_____Pain prevents me from walking long distances.
_____Pain prevents me from walking intermediate distances.
_____Pain prevents me from walking even short distances.
_____Pain prevents me from walking at all.

**Sitting**

_____Sitting does not cause me any pain.
_____I can only sit as long as I like providing that I have my choice of seating surfaces.
_____Pain prevents me from sitting for more than 1 hour.
_____Pain prevents me from sitting for more than 1/2 hour.
_____Pain prevents me from sitting for more than 10 minutes.
_____Pain prevents me from sitting at all.

## Appendix C: Modified Oswestry Low Back Pain Disability Index - Page 3 of 3

**Approval to reproduce the copyrighted Modified Oswestry Low Back Pain Disability Index was granted by Oxford University Press.**



OSWESTRY QUESTIONNAIRE, p. 2

**Section 2 (con't): To be completed by patient**

**Standing**
_____I can stand as long as I want without increased pain.
_____I can stand as long as I want but my pain increases with time.
_____Pain prevents me from standing more than 1 hour.
_____Pain prevents me from standing more than 1/2 hour.
_____Pain prevents me from standing more than 10 minutes.
_____I avoid standing because it increases my pain right away.

**Sleeping**
_____I get no pain when I am in bed.
_____I get pain in bed, but it does not prevent me from sleeping well.
_____Because of my pain, my sleep is only 3/4 of my normal amount.
_____Because of my pain, my sleep is only 1/2 of my normal amount.
_____Because of my pain, my sleep is only 1/4 of my normal amount.
_____Pain prevents me from sleeping at all.

**Social Life**
_____My social life is normal and does not increase my pain.
_____My social life is normal, but it increases my level of pain.
_____Pain prevents me from participating in more energetic activities (ex. sports, dancing, etc.)
_____Pain prevents me from going out very often.
_____Pain has restricted my social life to my home.
_____I have hardly any social life because of my pain.

**Traveling**
_____I get no increased pain when traveling.
_____I get some pain while traveling, but none of my usual forms of travel make it any worse.
_____I get increased pain while traveling, but it does not cause me to seek alternative forms of travel.
_____I get increased pain while traveling which causes me to seek alternative forms of travel.
_____My pain restricts all forms of travel except that which is done while I am lying down.
_____My pain restricts all forms of travel.

**Employment/Homemaking**
_____My normal job/homemaking activities do not cause pain.
_____My normal job/homemaking activities increase my pain, but I can still perform all that is required of me.
_____I can perform most of my job/homemaking duties, but pain prevents me from performing more physically stressful activities (ex. lifting, vacuuming)
_____Pain prevents me from doing anything but light duties.
_____Pain prevents me from doing even light duties.
______Pain prevents me from performing any job or homemaking chores.

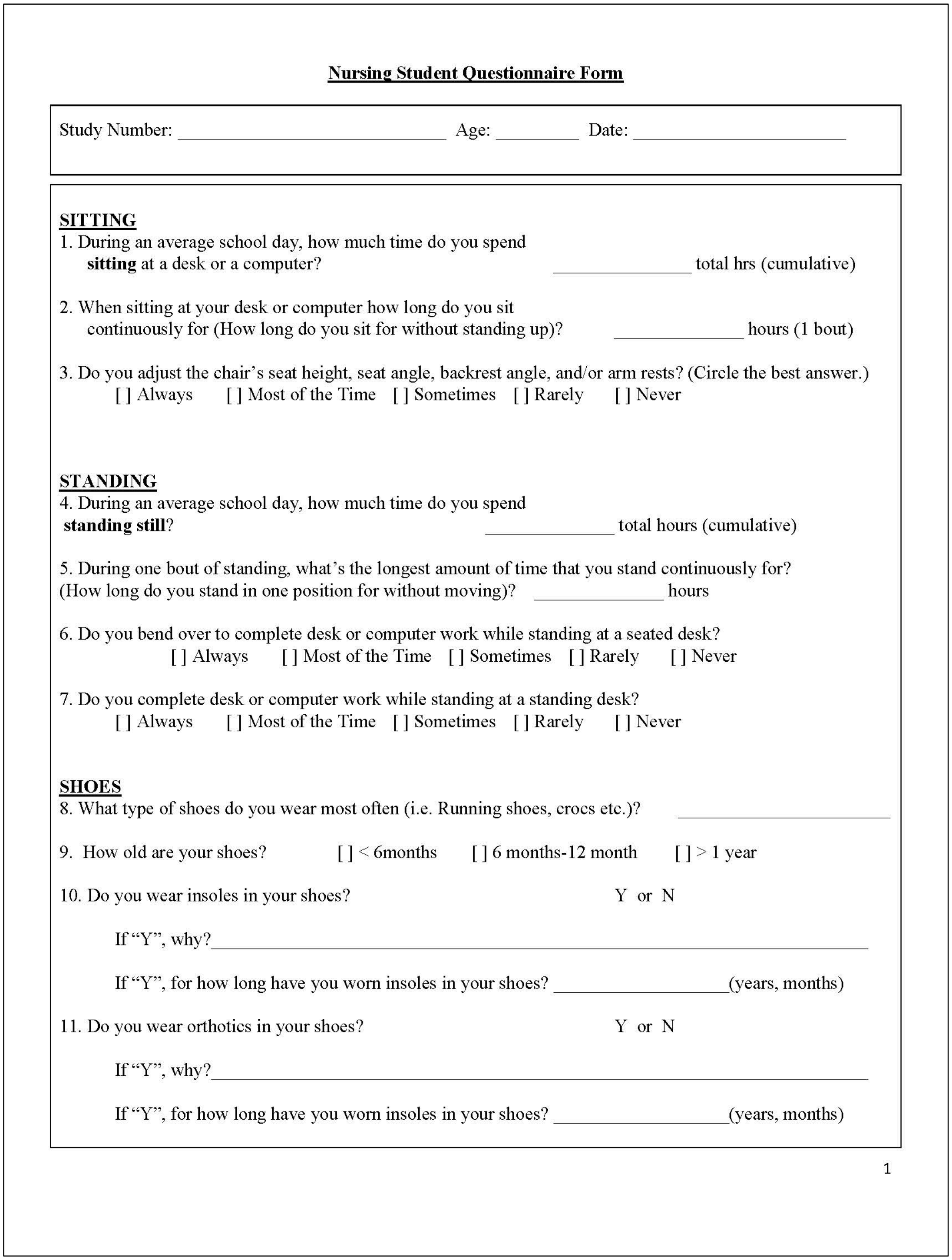
**Section 3: To be completed by physical therapist/provider**

SCORE: **Initial_____%** **Subsequent_____%** **Subsequent_____%** **Discharge_____%**

**Number of treatment sessions**:________________

**Diagnosis/ICD-9 Code**:_______________________

## Appendix D: Nursing Student Questionnaire - Page 1 of 2



**Nursing Student Questionnaire Form**

Study Number: ______________________________ Age: _________ Date: _______________________

**SITTING**

1. During an average school day, how much time do you spend **sitting** at a desk or a computer? _______________ total hrs (cumulative)

2. When sitting at your desk or computer how long do you sit continuously for (How long do you sit for without standing up)? ______________ hours (1 bout)

3. Do you adjust the chair's seat height, seat angle, backrest angle, and/or arm rests? (Circle the best answer.)
☐ Always ☐ Most of the Time ☐ Sometimes ☐ Rarely ☐ Never

**STANDING**

4. During an average school day, how much time do you spend **standing still**? ______________ total hours (cumulative)

5. During one bout of standing, what's the longest amount of time that you stand continuously for? (How long do you stand in one position for without moving)? ______________ hours

6. Do you bend over to complete desk or computer work while standing at a seated desk?
☐ Always ☐ Most of the Time ☐ Sometimes ☐ Rarely ☐ Never

7. Do you complete desk or computer work while standing at a standing desk?
☐ Always ☐ Most of the Time ☐ Sometimes ☐ Rarely ☐ Never

**SHOES**

8. What type of shoes do you wear most often (i.e. Running shoes, crocs etc.)? _______________________

9. How old are your shoes? ☐ < 6months ☐ 6 months-12 month ☐ > 1 year

10. Do you wear insoles in your shoes? Y or N

If "Y", why?______________________________________________________________________

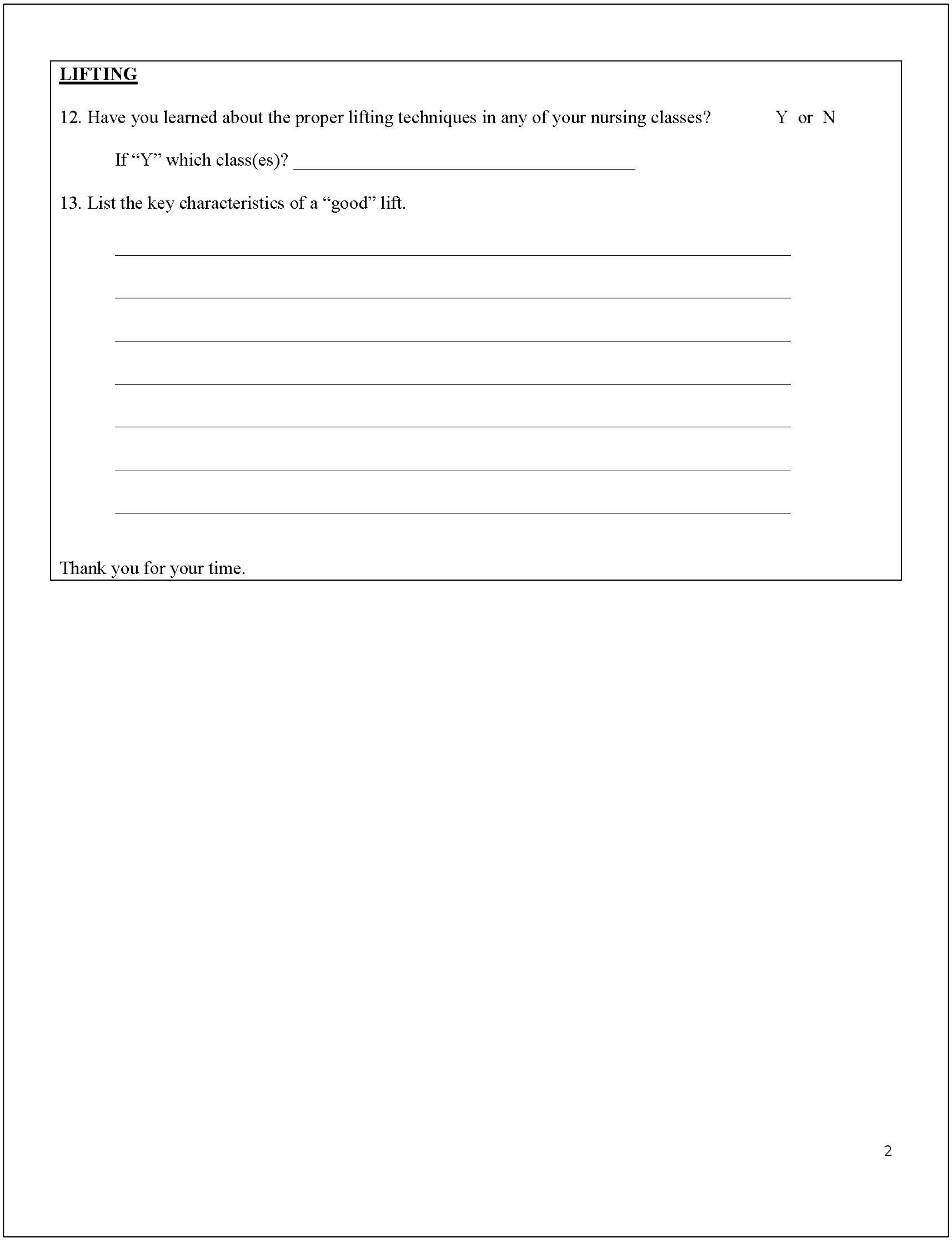
If "Y", for how long have you worn insoles in your shoes? ___________________(years, months)

11. Do you wear orthotics in your shoes? Y or N

If "Y", why?______________________________________________________________________

If "Y", for how long have you worn insoles in your shoes? ___________________(years, months)

## Appendix D: Nursing Student Questionnaire - Page 2 of 2



**LIFTING**

12. Have you learned about the proper lifting techniques in any of your nursing classes? Y or N

If "Y" which class(es)? ______________________________

13. List the key characteristics of a "good" lift.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

Thank you for your time.

2