School of Physiotherapy

Towards the identification of modifiable personal predictors of low back pain in nursing students

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Statement of Originality

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for an award of any other degree or diploma in any university.

Tim Mitchell

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Abstract

Low back pain (LBP) remains one of the most common and challenging primary care issues in the developed world. Manual occupations such as nursing are known to involve a high risk of occupational LBP, which is associated with enormous health care expenditure as well as indirect work and disability-related costs. Despite extensive efforts to reduce LBP in nurses, evidence supporting the efficacy of any specific intervention to prevent LBP is limited.

The majority of LBP prevention strategies are directed at occupational risk factors in working nurses. However, as there is some evidence that LBP is already a significant problem in nurses prior to commencing full time employment, it is proposed that nursing students should be the focus of prevention interventions. This would require prevention interventions targeting personal rather than occupational LBP risk factors. As the best personal predictor of future LBP is currently a previous history of LBP, further investigation of *modifiable* personal LBP risk factors is required. Consequently, the aim of this doctoral research was to identify modifiable personal characteristics that predict LBP in nursing students.

Firstly, a large survey was conducted on undergraduate nursing students and recently graduated nurses to determine patterns of LBP prevalence. Results from this study indicated that LBP prevalence was very high at the commencement of undergraduate training. Prevalence of LBP did not significantly change during nursing training, but did increase further in the first year of commencing work as a nurse. This increase may be partly explained by the reported increase in occupational exposure to bending and lifting. Age was consistent across the undergraduate year groups and did not influence these findings. It was concluded that nursing students would provide a sufficient number of new-onset LBP episodes (and thus sufficient statistical power) for a prospective study design. Further, as these nursing students were not yet exposed to the occupational LBP risk factors of working nurses, a clearer indication of the influence of modifiable personal factors on the development of LBP could be determined by examining a student cohort.

A cross-sectional study investigating the influence of personal physical, psychological and social/lifestyle factors was then conducted on nursing students. Preliminary analysis revealed clear gender differences across multiple domains. Therefore, the focus of further analysis was on the larger female sample.

In Part 1 of the cross-sectional study, an investigation of regional differences in lumbar spine posture and movement was undertaken. Analysis of spinal kinematics in this study supported and extended previous literature that has found global lumbar spine kinematics do not accurately reflect the kinematics of the upper lumbar or lower lumbar spinal regions in common postures and movements. Rather, these two regions have a degree of functional independence. This finding has implications for interpretation of measures of spinal posture, motion and loading. Further, body mass index influenced regional lumbar posture and movement, possibly representing adaptation due to load. It was concluded that regional rather than global lumbar spine measures needed to be investigated in further analyses of this doctoral research.

In Part 2 of the cross-sectional study, personal characteristics associated with LBP were investigated. Approximately one third of all subjects reported significant LBP in the 12-months preceding the study. Analysis of factors associated with LBP supported the biopsychosocial nature of LBP. Higher stress levels and use of passive coping strategies, increased physical activity levels, holding the lower lumbar spine further from end-range flexion during functional tasks and increased age, all contributed independently to the presence of LBP. These findings supported the hypothesis that modifiable personal characteristics were associated with LBP.

The importance of identifying sub-groups of LBP patients has become widely accepted. In Part 3, further exploratory analysis was conducted on this cross-sectional data to determine if differences in physical and psychological characteristics were evident in two defined sub-groups of female nursing students with LBP. These sub-groups were based on O'Sullivan's mechanism based classification system. Results indicated that two sub-groups of LBP subjects had differing physical and psychological characteristics associated with their LBP. Further, control subjects could be distinguished from each of these two sub-groups by different factors. These findings add validity to O'Sullivan's LBP classification system. Further, the findings may suggest that different combinations of psychological and physical factors are linked to LBP in different sub-groups in this population, and therefore may require different intervention approaches based on these factors.

In the final stage of this doctoral research, the cohort of female nursing students was followed prospectively for 12-months. The focus of further analysis was on identifying modifiable personal predictors in a sub-group of subjects with new-onset

LBP. The results of this study strongly supported that personal factors from multiple domains are predictors of new-onset LBP. After controlling for previous LBP, age and body weight, regression analysis identified that smoking, increased physical activity levels (both exercise and spinal loading), higher stress levels, reduced back muscle endurance, greater posterior pelvic tilt in slump sitting and more accurate spinal repositioning in sitting were all independent predictors of new-onset LBP. These findings have implications for the development of prevention and management interventions for LBP in nurses.

Results from this doctoral investigation support the multi-factorial and biopsychosocial nature of LBP. The important distinction of this research when compared to previous work is the selection of a cohort at the beginning of their working life, with a focus on modifiable personal, rather than occupational factors, associated with LBP. Factors from physical, psychological and social/lifestyle domains were all independently associated with significant new-onset LBP in female nursing students. Interventions utilising a prevention approach that targets modifiable characteristics, such as those identified in this cohort of nursing students, may have the potential to reduce the impact of occupational LBP in this group. These preliminary findings have important implications for future LBP research and clinical interventions.

Contents

Publications in peer reviewed journals

- Mitchell T, O'Sullivan PB, Burnett AF, Straker L, Rudd C. Low back pain characteristics from undergraduate student to working nurse in Australia: A cross-sectional survey. Int J Nurs Stud 2008. 45(11): 1636-44.

- Mitchell T, O'Sullivan PB, Burnett AF, Straker L, Smith A. Regional differences in lumbar spinal posture and the influence of low back pain. BMC Musculoskelet Disord. 2008. (In press).

- Mitchell T, O'Sullivan PB, Burnett AF, Straker L, Smith A, Thornton J, Rudd C. Biopsychosocial factors are associated with low back pain in female nursing students: a cross sectional study. Int J Nurs Stud. (Accepted for publication).

- Mitchell T, O'Sullivan PB, Burnett AF, Straker L, Smith A, Thornton J, Rudd C. Factors associated with low back pain in female nursing students: Influence of sub-classification. Submitted for publication in Spine.

- Mitchell T, O'Sullivan PB, Burnett AF, Straker L, Smith A, Thornton J, Rudd C. Identification of modifiable personal factors that predict new-onset low back pain: A prospective study of female nursing students. Submitted for publication in Clin. J. Pain.

Conference presentations

- Mitchell T, O'Sullivan P, Smith A, Burnett A, Straker L, Thornton J, Rudd C. "Predicting low back pain in nurses: Towards injury prevention." 2008 Australian Society of Medical Research Symposium. Perth, Australia.

- Mitchell T, O'Sullivan P, Burnett A, Straker L, Smith A, Thornton J, Rudd C. "Towards low back pain prevention in nurses." 2008. 28th Australian Pain Society Conference. Perth, Australia.

- Mitchell T, O'Sullivan P, Burnett A, Straker L, Smith A, Thornton J, Rudd C. "When to implement low back pain prevention in nurses." 2007 Biannual Musculoskeletal Physiotherapy Australia Conference. Cairns, Australia.

- Mitchell T, O'Sullivan P, Burnett A, Straker L, Smith A, Thornton J, Rudd C. "Posture and low back pain in nursing students." 2007 Biannual Musculoskeletal Physiotherapy Australia Conference. Cairns, Australia.

- Mitchell T, O'Sullivan P, Burnett A, Straker L, Smith A, Thornton J, Rudd C. "The relationship between spinal kinematics, psychosocial factors and low back pain in female nursing students." 2007. Biannual Musculoskeletal Physiotherapy Australia Conference. Cairns, Australia.

- Mitchell T, O'Sullivan P, Burnett A, Straker L. "The pattern of low back pain in nursing students and graduate nurses in Western Australia." 2007. Arthritis Foundation of W.A. Annual Research Update. Perth, Australia.

List of Abbreviations

BMI	Body Mass Index
EP	Extension Pattern
FP	Flexion Pattern
GN	Graduate Nurse
LBP	Low back pain
LLx	Lower Lumbar
NS	Nursing Student
ODI	Oswestry Disability Index
TLx	Total Lumbar
ULx	Upper Lumbar
VAS	Visual Analogue Scale

CHAPTER 1 - Introduction

1.1. Background: The LBP problem

Low back pain (LBP) remains one of the most common and challenging primary care issues in the developed world, with occupational LBP being associated with enormous health care expenditure as well as indirect work and disability-related costs (Borkan et al. 2002). Over recent decades significant resources have been allocated to reducing the impact of LBP in the workplace, however this has proven difficult to achieve (Andersson 1999).

In 2002 in Australia, it was estimated that direct and indirect costs associated with LBP exceeded nine billion dollars (Walker et al. 2003). Recent statistics from Western Australia revealed that 19% of workers compensation LBP claims consumed 83% of direct costs. Further, average costs for LBP claims resulting in four or more months off work exceeded $110 000 per claim (Hawkes 2007). Direct and indirect economic costs of LBP are also an increasing financial burden in other countries (Dagenais et al. 2008).

To date, there is no consensus regarding how to manage the LBP problem (Waddell 2004c). Evidence for injury prevention is limited (Dawson et al. 2007) and it is unclear which treatment is most effective for acute or chronic LBP (Assendelft et al. 2004; Hayden et al. 2005). Research strategies to deal with the LBP problem have included: identification of factors predicting new LBP episodes and LBP chronicity; injury prevention programs; and identification of optimal treatment strategies. Possible reasons for the inconclusive research findings in these areas include: variable LBP definitions (Dionne et al. 2008); methodological issues (such as validity of measures) (Bouter et al. 1998); the lack of sub-grouping of LBP characteristics despite increasing evidence that LBP sufferers are a non-homogeneous group which require sub-classification (Borkan et al. 2002; Ford et al. 2007); and the complexity of LBP disorders suggesting examination from multiple domains within a biopsychosocial framework is required (Waddell 2004b).

As LBP prevention can result in a reduction of the enormous costs associated with chronic LBP management (Hawkes 2007), improvement in injury prevention is an important goal. It has been recognised that LBP is a biopsychosocial problem (Waddell 2004b; Gatchel et al. 2007), therefore multifactorial interventions are likely to be most effective (Dawson et al. 2007). Figure 1.1 outlines the complex interactions between factors associated with LBP in the biopsychosocial model. In order to implement a multifactorial intervention, first the factors contributing to the development of LBP must be determined. Identification of modifiable LBP risk factors across multiple domains (eg. physical, psychological, social/lifestyle) is a priority. As highlighted by the biopsychosocial model, it must also be considered that other non-modifiable factors such as genetics may also be important LBP risk factors (Chan et al. 2006; Battie et al. 2007). Further, there is also evidence to suggest that environmental factors such as interpersonal conflict may also strongly contribute to, and/or influence future LBP episodes (Fejer et al. 2006; El-Metwally et al. 2008).

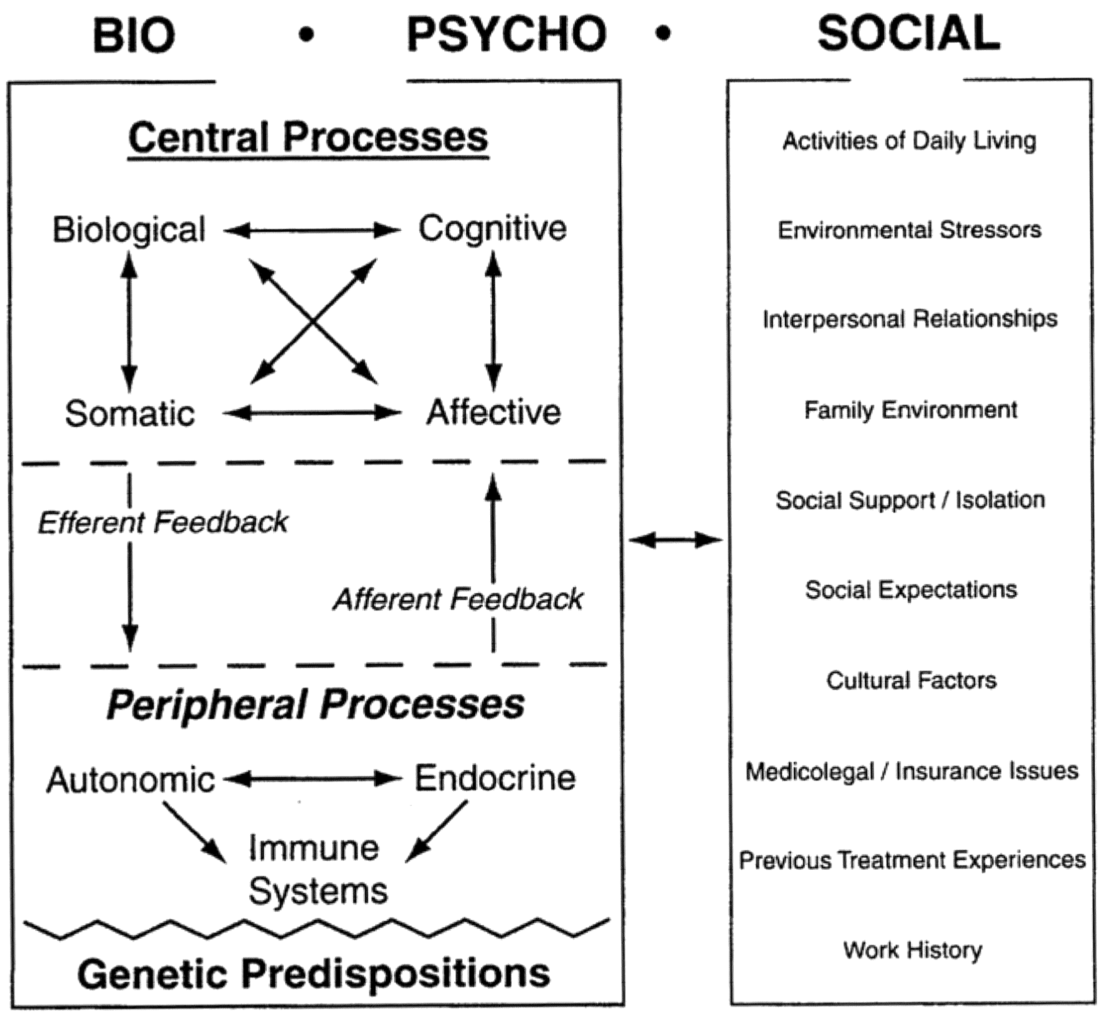

Figure 1.1. The biopsychosocial model of LBP (Gatchel 2004).

A review paper by Turk (Turk 2005) proposed the importance of matching treatment to specific sub-groups of chronic pain patients. This concept is supported by recent evidence demonstrating that sub-grouping non-chronic, non-specific LBP patients significantly improves treatment outcome (Brennan et al. 2006). If different treatments are effective for different LBP groups, it is also likely that different factors are associated with the development of LBP within these groups. There remains a lack of research into modifiable personal characteristics associated with and predictive of LBP. Further research is also required into these characteristics in different sub-groups of non-specific LBP patients (no patho-anatomical diagnosis).

A recent review by Ford et al. investigating classification systems for chronic LBP highlighted that most classification systems are uni-dimensional in nature (Ford et al. 2007). This finding reflects that there is a mismatch between the widely accepted biopsychosocial model of pain and classification systems that are applied to the management of LBP disorders. This reinforces the need to develop a system that is a truly multi-dimensional classification system. In order to do this, it is necessary to identify the underlying factors that drive LBP disorders, which may assist in the validation of a classification system that reflects the risk factors associated with the disorder.

Key Points

- LBP is a common problem, with significant personal costs and societal costs.
- Despite extensive research, clear effective injury prevention and treatment strategies have not been identified.
- As LBP is a biopsychosocial problem, injury prevention strategies are likely to require a multifactorial approach.
- Very few current LBP classification systems reflect a biopsychosocial model.
- It is recognised that identification of sub-groups of LBP patients is a key factor to improve intervention outcomes and may therefore be important in prevention.
- To advance LBP prevention and intervention research, identification of modifiable personal characteristics that are associated with the development of LBP is required, as are interventions designed that are directed specifically at these factors.

1.2. Nurses: A high-risk population

Nurses are an integral occupational group within the health care system, often working in an environment of high physical and psychological stress (Yip 2004). Work tasks of nurses are variable and can include physically active components such as transferring patients, bedside care and showering, as well as sedentary components such as attending to documentation and meetings. The Australian nursing population is ageing and a critical shortage of nurses has been predicted (Stein-Parbury 2000). This shortage is likely to be exacerbated if nurses are unable to work due to LBP. Therefore, minimising the loss of nurses due to LBP is an important priority (Dawson et al. 2007).

Annual LBP prevalence estimates in the general population range from 15-70%, with point prevalence averaging around 30% (Adams et al. 2002b) whilst the lifetime recurrence rate of LBP is up to 80% (Hides et al. 2001; Haldorsen et al. 2002). In specific nursing populations however, an annual prevalence of 76-86% (Maul et al. 2003; Corona et al. 2005) and a point prevalence as high as 40-59% (Smith and Leggat 2004; Violante et al. 2004; Yip 2004) have been reported, suggesting a higher risk of LBP among nurses.

Staffing shortages in the nursing profession have resulted in a changing nature of the workforce in Australia. Between 1995 and 2002, the average age of working nurses increased by 3 years, and there was a reduction in the number of nurses per 100,000 people in the population (Chrisopoulos and Waters 2003). There has been a subsequent government campaign to increase the number of qualified nursing staff in Australia. As a result, some nurses are returning to the workforce following extended absences, and others are opting for nursing as a career change later in life. These and other factors are having a relative aging effect on both the qualified and student nursing populations (Stein-Parbury 2000). Given LBP is more recurrent (multiple episodes with periods of no pain in between) and persistent (slow to settle) in older adults (Cassidy et al. 2005), this workforce change may further influence the related LBP issues in nurses.

The higher prevalence of LBP among manual occupations such as nursing is thought to be associated with increased spinal loads during lifting tasks (Smedley et al. 1997; Eriksen et al. 2004). However, the significant proportion of nurses' work time spent in forward bending postures (Baty and Stubbs 1987; Lee and Chiou 1995) may also contribute to their LBP. Further, there is evidence of increased LBP risk associated with more sedentary activities such as prolonged computer use (Hakala et al. 2006; Spyropoulos et al. 2007). Given prevention strategies such as manual handling training and lifting devices have not consistently changed back pain injury statistics (Dawson et al. 2007), clearly other factors than heavy or repetitive manual load are important in the development of LBP.

For example, “no lift” policies are now common in many hospitals (Nelson et al. 2006) however, manual handling remains the primary cause attributed to LBP episodes in nurses (Mohseni-Bandpei et al. 2006; Feng et al. 2007). Either this reflects a failure of the policy, or other factors associated with LBP may also need to be considered. Reducing the lifting component of manual handling may only reduce exposure to high load tasks, leaving other risk factors unchanged.

In support of this, Western Australian health care workers’ compensation statistics highlight a change from single traumatic event back injuries to more cumulative mechanical stress related LBP (Stansbury and Lim 2004). This may reflect the need to consider the importance of sustained and repetitive non-lifting manual nursing tasks (such as bending and sitting) in the prevention of LBP. Alternatively, the direct link to specific incident injuries made by nurses may be attributed to beliefs of nurses, rather than actual injury cause (Smedley et al. 2005). The causes of LBP identified by nurses has previously been shown to differ from actual work tasks performed (Harber et al. 1988).

In line with LBP being considered within a biopsychosocial framework, the growing evidence of psychological factors contributing to LBP in nursing staff must also be taken into consideration (Sherehiy et al. 2004). For example, poor job satisfaction (Ready et al. 1993), psychological distress (Feyer et al. 2000) and perceived low co-worker support (Eriksen et al. 2004) have all been identified as factors associated with LBP in nurses. Whether these factors independently contribute to LBP, or have a cumulative effect when combined with other factors (such as increased physical load), is not yet clear. Further, as certain personality traits are more susceptible to increased spine loading and suspected LBP risk (Marras et al. 2000), personality types among nursing personnel (Bean and Holcombe 1993) may contribute to this complex LBP picture. The scheduling of work in the nursing profession may also have an influence on occupational LBP in this group, as fatigue from long work shifts (particularly night shifts) is thought to influence LBP episodes (Eriksen et al. 2004).

Key points

- Nurses are a high-risk group for occupational LBP.
- In Australia, nursing shortages have resulted in an ageing nursing population.
- Current injury prevention strategies in nurses have not proven to be consistently effective.
- Consistent with LBP in the general population, LBP in nurses appears to be a multifactorial problem, with influences including occupational physical and psychological stressors.

1.3. When does LBP become a problem in nurses?

In the general population, LBP prevalence rates are known to increase over the adolescent / early adulthood period (McMeeken et al. 2001; Sjolie 2004). By around 15 years of age, 45-60% of adolescents have already had their first experience of LBP (Kovacs et al. 2003; O'Sullivan et al. 2008) and recent evidence suggests patterns for LBP recurrence may be established as early as pre-teenage years (Stanford et al. 2008). Cumulative LBP prevalence tends to plateau by the age of 22 (Hestbaek et al. 2006), however LBP recurrence and severity are thought to increase with age (Dionne et al. 2006).

As age appears to be a strong contributor to increasing LBP prevalence rates, consideration should be given to the timing of LBP prevention (Hestbaek et al. 2006). Although targeting LBP when prevalence rates first increase (during adolescence) appears logical, the likely success of intervening in such target populations must also be taken into account. For example, exercise program adherence in children and adolescents is a recognised problem (Feldman et al. 2007; van Sluijs et al. 2008), whereas compliance with an injury prevention program in a nursing population has been shown to be high (Nelson et al. 2006). Therefore, efforts to identify risk factors associated with the development of LBP should perhaps be best concentrated at a time of both increasing LBP prevalence as well as when potential for success of intervention is higher.

In working nurses, younger nurses are thought to be at greatest risk for LBP (Sherehiy et al. 2004). Therefore, targeting prevention interventions at nursing students before they reach the hospital wards may prove beneficial (Hellsing et al. 1993). Studies examining student nurses (Feyer et al. 2000; Smith and Leggat 2004) have found a high prevalence of LBP prior to commencing full time nursing employment, but exactly how long before commencing employment this should occur remains unclear. A recent longitudinal study reported that the greatest increase in LBP prevalence was during the theoretical component of undergraduate study, rather than during increased clinical exposure or the transition to full time nursing employment (Videman et al. 2005). Further, some studies report a peak rise in LBP prevalence during nursing training (Hellsing et al. 1993; Klaber-Moffett et al. 1993), whilst others report no change in LBP prevalence across the duration of nursing training (Smith and Leggat 2004). Although recent research has considered the pattern of LBP from undergraduate nursing study and during the transition to full time employment (Videman et al. 2005), the contributions of age (Harreby et al. 1996; McMeeken et al. 2001; Sjolie 2004) and occupational exposure due to course content (Smedley et al. 1997; Eriksen et al. 2004) remains unclear.

Key points

- The timing of LBP interventions in nurses appears to be a critical issue.
- As LBP is already a problem in nursing students, evidence suggests interventions should be targeted prior to commencing full time employment.
- Whether LBP increases during undergraduate training, or on commencement of nursing employment is unclear and requires further investigation.

1.4. Risk factors for LBP

Risk factors for LBP are thought to be multidimensional and include physical and psychological attributes, socioeconomic factors, occupational environmental factors and genetic factors (Shelerud 2006; Rubin 2007). Adams and co-workers have considered various LBP risk factors and proposed possible relationships between them (Adams et al. 2002b) (Figure 1.2). Some of these risk factors are not modifiable, such as genetics, anthropometry, gender and cultural issues. Other factors, such as occupational, physical and psychological are thought to be modifiable and have been the focus of occupational injury prevention strategies. However, such strategies have largely been directed at a single factor rather than utilising a multi-dimensional approach (Dawson et al. 2007). Occupational factors addressed in injury prevention programs include workplace ergonomics, manual handling training, physical conditioning or psychological components such as stress management (Burton et al. 1996; Jensen et al. 2006; Waters et al. 2006). Most of these interventions have shown only modest effect (Lahad et al. 1994; Dawson et al. 2007), and are often conducted in a large group format within the workplace (Lahad et al. 1994).

Given the complex multifactorial nature of LBP, it is likely that LBP prevention strategies will need to target LBP management strategies, where sub-groups of LBP are recognised and interventions targeted at the specific characteristics of each sub-group is provided (Fritz et al. 2007). Therefore, identification of personal LBP risk factors that are present prior to the commencement of employment may be important. In the case of nurses, the literature suggests the target population should be nursing students (Hellsing et al. 1993), which necessitates a shift in focus from occupational LBP risk factors to modifiable personal LBP risk factors.

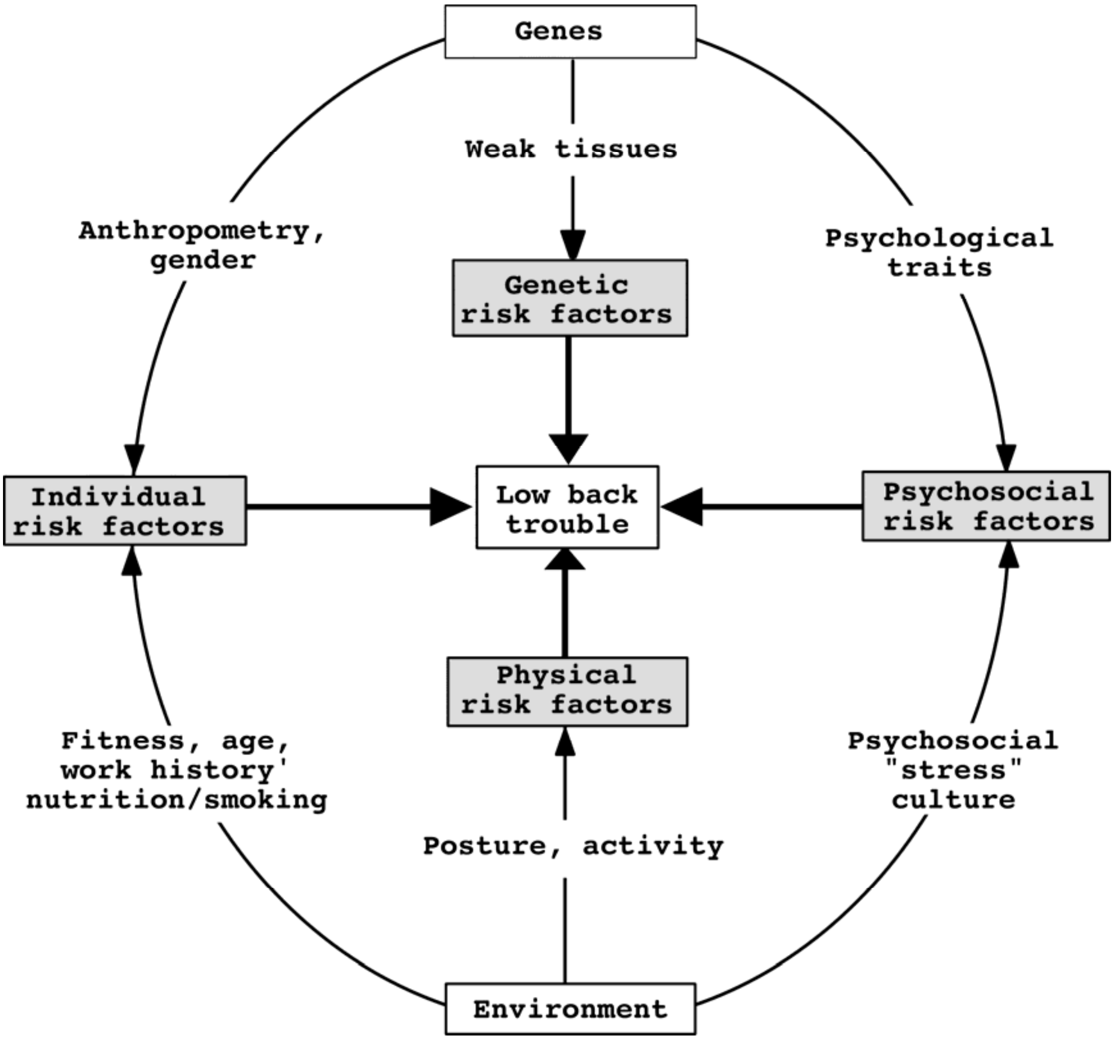

Figure 1.2. Risk factors for LBP and the relationships between them (Adams et al. 2002b).

1.5. Potential personal causes of LBP: Physical factors

While physical characteristics form a strong component of LBP management (Ferreira et al. 2007) and prevention interventions (Dawson et al. 2007), there is only limited prospective evidence of physical factors (outlined below) being predictive of future LBP. Physical and biomechanical interventions including workplace design, manual handling training, lumbar supports and lifting devices are examples of common physical approaches to back injury prevention. A recent systematic review of injury prevention in nurses found that there is little evidence to support the efficacy of any single physical intervention (Dawson et al. 2007).

While there is no shortage of evidence linking biomechanical factors and physical characteristics with back pain in workers (Andersson 1981; Burdorf and

Sorock 1997; Adams et al. 2002a), determining whether these factors are present prior to, or as a result of, the injury has proven more difficult. In a cohort study of health care workers by Adams and co-workers, less than 7% of new LBP variance was explained by personal physical characteristics (Adams et al. 1999). It is hypothesized that both methodological issues such as lack of population-specific measures, and lack of identification of LBP sub-groups may account for the current lack of evidence in the literature regarding physical predictors of LBP. For example, measures of physical performance (such as cardiovascular fitness) may only be relevant to LBP in high-demand physical populations. Conversely, measures of spinal kinematics may be different across occupations when the different functional demands and exposures to different body postures relevant to each occupation is considered.

1.5.1 Physical performance factors

One physical characteristic that has been reported as a risk factor for future LBP across a number of studies is **reduced back muscle endurance** (Biering-Sorensen 1984; Alaranta et al. 1995; Stroyer and Jensen 2008). However, a recent systematic review of prospective LBP studies did not support these findings (Hamberg-van Reenen et al. 2007), possibly due to the review not considering the relevance of different physical capacities of the different sample populations. It may be that reduced muscle endurance is only a relevant risk factor for certain populations such as manual workers exposed to sustained and repeated bending activities, or perhaps only certain sub-groups of individuals at risk of LBP such as those who also habitually adopt passive, end range spinal postures. It is hypothesised that poor back muscle endurance may render the spine vulnerable to tissue strain (O'Sullivan et al. 2006a), however it is unclear why or how this reduced muscle endurance initially occurs. Possible causes of reduced back muscle endurance might include their disuse through inactivity (Moffroid et al. 1994), altered motor control patterns (O'Sullivan et al. 1997), prolonged habitual positioning of the spine in postures associated with reduced activity of spinal muscles (O'Sullivan et al. 2002), or decreased central drive secondary to sleep deprivation, stress and fatigue (Lentz et al. 1999; Thomas et al. 2000).

Reduced lower limb muscle endurance has also been identified prior to low back injury in some populations including nurses and adolescent female rowers

(Klaber-Moffett et al. 1993; Stevenson et al. 2001; Perich et al. 2006) and a link between reduced back muscle endurance and quadriceps inhibition has been reported in male golfers with LBP (Suter and Lindsay 2001). Evidence of leg muscle fatigue contributing to a change in lifting posture (from semi-squat to stoop) during a repetitive lifting task (Sparto et al. 1997) is thought to occur because stoop lifting is less physiologically demanding on the lower limb muscles (Welbergen et al. 1991; Hagen et al. 1993). It is hypothesised that stoop lifting and bending postures, if habitually adopted due to poor endurance of the lower limb muscles, may be a factor contributing to increased end range flexion and shear tissue loading on the lumbar spine during manual tasks. Repeated end range tissue loading has been linked with LBP (Cholewicki and McGill 1996). Given the repetitive demands of some nursing tasks, determining whether lower limb muscle endurance is associated with LBP development could help guide LBP prevention interventions in nurses.

Poor cardiovascular fitness is often related with LBP (Cakmak et al. 2004; Kuster 2004), however the literature is not conclusive as to its validity as a predictor of low back injury (Biering-Sorensen 1984; Adams et al. 1999; Feldman et al. 2001). This may be because as a measure in isolation, its predictive ability may be poor. Physical performance measures including cardiovascular fitness have previously been shown to fail to discriminate between LBP and control subjects from different occupations (Schenk et al. 2007). When considered in conjunction with other physical characteristics however, cardiovascular fitness may be a measure of importance. Further, physical performance measures such as muscle endurance and cardiovascular fitness may only be relevant to specific populations where such measures are integral to the occupational demands. For example, it has been found that fitness and lifestyle parameters did not effectively predict back injury in a nursing cohort (Ready et al. 1993), whereas cardiovascular fitness was predictive of LBP in firefighters (Cady et al. 1979).

1.5.2. Spinal kinematics

Numerous cross-sectional studies have attributed reduced lumbar **sagittal range of motion** in LBP subjects compared with healthy controls to the presence of pain (Burton 1987; Wong and Lee 2004; Shum et al. 2005). However, a recent study using dynamic MRI measurement found segmental lower lumbar sagittal hypermobility in LBP subjects, during both a therapist lumbar mobilisation technique and a self extension movement while prone (Kulig et al. 2007). Another study using lateral radiographs found both segmental hypermobility and segmental rigidity were evident in different sub-groups of LBP patients (Abbott et al. 2006). The cause or effect relationship between lumbar mobility and subsequent LBP can only be determined prospectively.

In terms of prospective evidence, decreased sagittal spinal mobility measured during clinical examination was a predictor of the presence of LBP in one study (Biering-Sorensen 1984), but in another study reduced lateral bending measured with an electromagnetic tracking device was a predictor (Adams et al. 1999). A recent systematic review of prospective studies found conflicting evidence for a relationship between spinal mobility and LBP (Hamberg-van Reenen et al. 2007). Methods of spinal mobility measurement, the population under investigation, variable definitions of LBP and lack of patient sub-classification may account for conflicting findings in previous prospective research.

Epidemiological studies on manual workers have identified **sustained habitual postures** such as sitting (Biering-Sorensen 1983; Furber et al. 1992) and standing (Mohseni-Bandpei et al. 2006; Andersen et al. 2007) as physical factors that typically exacerbate LBP. However, a systematic review of sitting posture and occupational LBP did not support any link between these two factors (Lis et al. 2007). These findings must be interpreted with caution, as they are based on self-reported activities to which individuals attributed their LBP (Harber et al. 1988), rather than measured spinal posture. There is some evidence of a direct link between spinal posture and LBP (Dankaerts et al. 2006; Smith et al. 2008) but currently there is a lack of prospective evidence for posture being a predictor of LBP.

One adolescent cohort study using a manual spinal posture measure did not support a relationship between posture and LBP (Widhe 2001). However, a number of the cross-sectional in-vivo studies which report a relationship between posture and LBP examined specific sub-groups of LBP patients (Dankaerts et al. 2006; O'Sullivan et al. 2006a). The causal relationship is yet to be explored in prospective studies. Further, it has been proposed that posture needs to be considered across a number of positions rather than a single measure (Smith et al. 2008), and may be particularly relevant if considered across common functional or pain provocative tasks.

Recent research has established a relationship between the level of trunk muscle activity and different types of standing and sitting posture (O'Sullivan et al. 2002). Adopting passive postures, such as sway standing (the thorax displaced posterior to the pelvis with resultant increased low lumbar extension with thoracic flexion), and slump sitting (increased lumbo-pelvic flexion), results in reduced muscle activity in the transverse abdominal wall and back muscles, when compared to more upright standing and sitting postures. This consistently reported reduced electromyographic (EMG) activity of the trunk muscles is described as a 'relaxation' response, where load is shifted from the motor system to the passive spinal structures (Dolan et al. 1988; Andersson et al. 1996). It has been hypothesised on the basis of this research that subjects who habitually adopt passive spinal postures may de-condition their lumbar stabilising muscles through their consistent inactivity (O'Sullivan et al. 2002), leading to increased passive system loading, injury and subsequent pain (Cholewicki and McGill 1996). This is supported by evidence of correlations between slump sitting, increased time spent sitting and reduced back muscle endurance in manual workers with LBP (O'Sullivan et al. 2006a).

Conversely, those who maintain hyper-extended spinal postures with high levels of muscle activity may overload spinal structures, causing pain via increased compressive spinal load and an inability to relax spinal muscles (Dankaerts et al. 2006). Dankaerts and co-workers have recently shown that both habitual passive flexed lumbar sitting posture and hyper-lordic lumbar sitting postures in different individuals are associated with LBP (Dankaerts et al. 2006), supporting a link between posture and LBP in certain individuals. Further, results of a recent large *in-vivo* study on adolescents showed an increased risk of LBP with non-neutral standing postures (Smith et al. 2008). Whether these findings represent a cause or effect of this relationship requires prospective investigation.

It has been reported that manual workers with LBP adopt **bending and lifting kinematics** which may make them more vulnerable to injury (McGill et al. 2003). For example, when performing forward bending activities it has been shown that specific groups with LBP preferentially adopt movement patterns that expose regions of their spine to increased flexion / shear strain (Dankaerts 2005). This may expose these spinal segments to increased end range tissue stress for longer periods, and possibly increase risk of injury (Cholewicki and McGill 1996).

Furthermore, Gill and associates recently identified the importance of considering the lumbar spine as consisting of separate regions, rather than viewing it as a rigid body, when measuring spinal movement and function (Gill et al. 2007). Their study examining healthy subjects has shown a lack of variation of lower lumbar (LLx) spine posture when commencing lifting, irrespective of both the lifting technique used, or the distance the load is away from subject's feet (Gill et al. 2007). Further, movement variation when lifting was found to occur in the upper lumbar (ULx) and mid thoracic spine rather than the LLx spine, supporting the idea that regional differences within the lumbar spine may be important to consider when investigating spinal kinematics.

Clinically, LBP patients report more pain in the lower lumbar (LLx) spinal segments than upper lumbar (ULx) segments (Biering-Sorensen 1983; Beattie et al. 2000). This is consistent with a greater degree of degeneration being evident in the LLx spinal segments with increasing age (Twomey and Taylor 1987), which is thought to be due to the greater mechanical stress through these segments (Adams et al. 2002a). Given some individual lumbar spinal segments show greater degenerative changes than other lumbar segments (Adams et al. 2002a), the notion of the lumbar spine as a homogenous region may not provide a true reflection of pain and function in this region.

When considering the possible lack of LLx variation in lifting tasks, the specific regional spinal postures that an individual holds may be important in the development or maintenance of LBP. This may help explain why previous research has been unable to identify an optimal lifting style for reducing LBP (Straker 2003), as regional lumbar posture rather than whole lumbar spine or body position (eg. stoop v squat lift technique), may be a more important factor. While sustained postures and performing certain manual tasks are predictors of LBP in some prospective occupational studies (Harkness et al. 2003; Eriksen et al. 2004; Andersen et al. 2007), there have been varying findings as to which postures / tasks are thought to actually increase risk. This is likely to vary between different occupations.

It is logical that as various occupations have different inherent associated physical LBP risk, the postural and kinematic analysis of tasks needs to be specific to the occupational population being investigated. Further, it is proposed that spinal kinematics, when considered in relation to pain provocative movements and postures, is more likely to identify differences between those who do, or do not, experience LBP. For example, differences between LBP and control subjects' sitting posture were identified in a group of industrial workers with flexion-related LBP (O'Sullivan et al. 2006a). Based on previous research (Jackson and McManus 1994; Dvorak et al. 1995; O'Sullivan et al. 2006b), it is unclear whether the influence of gender on spinal posture or mobility may further confound kinematic findings.

Specific back muscle dysfunction (Hides et al. 1994; Hodges and Richardson 1996) and **impaired spinal proprioception** (Brumagne et al. 2000; Newcomer et al. 2000; O'Sullivan et al. 2003) have been reported in LBP populations. It has been hypothesised that these findings may represent a motor control deficit, occurring secondary to pain and motor dysfunction of the spinal stabilising muscles, which in turn may result in increased passive system loading from repeated end range stress to the spine (O'Sullivan et al. 2003). While impaired motor control of the lumbar spine has also recently been associated with the development of LBP (Cholewicki et al. 2005), impaired trunk proprioception was not found to predispose college athletes to LBP (Silfies et al. 2007), but was a predictor of knee injuries (Zazulak et al. 2007). There is also some preliminary evidence of different motor control strategies for spinal repositioning within different sub-groups of LBP patients (Descarreaux et al. 2005). Further, evidence that spinal proprioception is impaired in a pain free population following a period of back muscle fatigue (Taimela et al. 1999) suggests a complex interaction between spinal proprioception, LBP and other factors.

Key points

- There is limited prospective evidence supporting muscle endurance, cardiovascular fitness and spinal kinematics as physical LBP risk factors.
- Measures of physical performance may only be relevant when considered in conjunction with other factors, or alternatively may only be important in high physical demand occupations.
- Spinal kinematic measurement methods, particularly consideration of the lumbar spine in separate regions may be a key methodological issue.

- Consideration of sub-groups with different spinal kinematic characteristics may also help identify physical LBP risk factors.
- Further targeted prospective research considering the above methodological issues is required.

1.6. Potential personal causes of LBP: Psychological factors

Whilst physical mechanisms may explain LBP provocation in some individuals, psychological factors may play a more important role for others (Turk 2005). Given pain and illness are subjective experiences, with recognised interrelationships between biological changes, psychological status and socio-cultural factors (Gatchel et al. 2007), it is not surprising the literature commonly reports that the strongest modifiable predictors of LBP chronicity are in the psychological domain (Boersma and Linton 2005; Boersma and Linton 2006). It is unclear whether this dominance of psychological risk factors is a true reflection of risk factor importance or if it may be partly explained by methodological limitations in the measurement of physical risk factors, as described above. However, in spite of this, psychological factors only explained 16% of new LBP episodes in a general population study (Croft et al. 1995). Further, when considered in conjunction with physical risk factors, modifiable personal characteristics did not account for a large proportion of variance in new episodes of LBP (Adams et al. 1999).

Despite the current lack of evidence supporting personal psychological risk factors as explaining a large proportion of the variance for LBP, recent clinical literature supports a multidimensional approach to LBP management, with consideration of matching physical and psychosocial characteristics to specific LBP sub-groups (Turk 2005). There is evidence that some pain conditions (such as Fibromyalgia) are phasic and “episodes” are thought to be more influenced by the psychological status of the patient (Gatchel et al. 2007). It is possible that psychological triggers may therefore be an important predictor for some individuals with recurrent LBP. For example psychological factors have been reported to be linked to the insidious onset of LBP episodes (McBeth et al. 2007). In terms of predicting new-onset LBP, the strength of relationship between psychological characteristics and LBP is currently weaker than in chronic LBP research, and predictive factors vary between studies (Klaber-Moffett et al. 1993; Adams et al. 1999; Feyer et al. 2000).

Regarding individual psychological risk factors, prospective research has repeatedly identified psychological distress (**stress, depression and anxiety**) as a factor that may play a role in the development of LBP (Croft et al. 1995; Papagerorgiou et al. 1997; Power et al. 2001). There is prospective evidence for depression predicting the development of new LBP, more strongly than clinical or anatomic risk factors (Jarvik et al. 2005). As pain is an emotional experience (IASP. Task Force on Taxonomy 1994) with a neuro-biological basis, one could expect negative emotions play a key role in its modulation or maintenance. Increased psychological distress may predispose people to experience pain and may be a modulating factor for amplifying pain severity (Gatchel et al. 2007). Direct influences of emotions on the autonomic nervous system (such as via the hypothalamic-pituitary-adrenal (HPA) axis) could result in altered tissue sensitivity in some individuals (Martinez-Lavin 2007). Further, descending inhibitory pain modulation systems are known to be influenced by forebrain activity including emotional responses (Zusman 2002) and longer term stress may weaken central descending tonic pain inhibition (Ashkinazi and Vershinina 1999).

Higher psychological distress may also contribute to pain via increased mechanical spinal loading due to higher levels of muscle tension. Marras and co-workers have shown that psychologically stressful environments produced higher trunk muscle co-activation responses, but only in certain individuals (Marras et al. 2000). They hypothesized that this muscle co-activation could make them more susceptible to increased spinal loading and subsequent LBP risk. Alternatively, evidence in a nursing population of high levels of psychological distress preceding LBP episodes was hypothesized to be a reflection of the somatic component of acute distress (Feyer et al. 2000). It has been proposed that this somatisation involves physical symptoms which cannot be attributed to organic disease, but rather are the result of an emotional disorder (Craig et al. 1993). However, this concept is not supported by evidence in other studies showing an interaction between physical and psychological factors in LBP patients (Moseley et al. 2004).

Aspects of psychological distress have been associated with LBP both within the workplace and / or individual social situation (Bigos et al. 1991; Papagerorgiou et al. 1997; Feyer et al. 2000). Recent literature specific to nursing populations describe stress at work (Elfering et al. 2002), low daily mood (Smedley et al. 1997), and poor co-worker relationships (Eriksen et al. 2004; Yip 2004), as important components of the overall perception of job satisfaction. Whilst low job satisfaction has long been considered a potential LBP predictor (Bigos et al. 1991), and has also been supported by recent prospective evidence (Ghaffari et al. 2008), other research has not detected this relationship (Feyer et al. 2000). Further, there is also some evidence of higher, rather than lower job satisfaction being associated with LBP (Kerr et al. 2001). These contradictory findings may be indicative of varying effects across different populations or study settings (Bigos et al. 1991), with the psychological impact of work environment being likely to vary between individuals (Marras et al. 2000).

As psychological distress during childhood is predictive of future LBP (Stanford et al. 2008), and coping styles influence levels of psychological stress (Wang and Yeh 2005), it seems logical that coping strategies could play a role in development or recurrence of LBP, in some individuals. The strategies individuals adopt to cope with painful or stressful situations may also influence the long-term outcome of their disorder. Passive **coping strategies** have been linked with LBP chronicity (Mercado et al. 2005; Koleck et al. 2006), whilst "adaptive copers" tend to have lower levels of disability associated with their LBP episodes (Turk 2005). Poor coping has been found to be predictive of future LBP in military recruits (Larsen and Leboeuf-Yde 2006), but not in an adolescent cohort (Viikari-Juntura et al. 1991). Although considerable research has been devoted to psychological predictors of LBP chronicity (Pincus et al. 2002), there is otherwise little prospective research into the influence of coping strategies on recurrence or new-onset LBP. Temperament and personality can be vulnerability factors that predisposes towards negative pain interpretation and maladaptive beliefs, or they can be a resilience factor protecting against such cognitions and beliefs (Gatchel et al. 2007). In terms of resilience to chronicity, positive coping strategies such as optimism have been associated with better general health and adaptation to chronic disease (Scheier and Bridges 1995).

The role of pain-related fear and anxiety in chronic LBP is well described by the fear-avoidance model (Vlaeyen and Linton 2000). Fear and anticipation of pain can significantly impact on the level of function and pain tolerance (Vlaeyen and Linton 2000). Resultant avoidance behaviours can lead to activity limitation and other physical and psychological consequences that may further contribute to pain persistence and disability (Gatchel et al. 2007). This is evidenced by the ability of fear avoidant beliefs to predict LBP chronicity (Linton and Hallden 1998), as well as predict development of LBP in young workers (Van Nieuwenhuyse et al. 2006). Cognitive responses are influenced by factors including an individual’s beliefs regarding LBP (Cedraschi and Allaz 2005). Fear avoidant behaviours resulting in abnormal movement patterns and inappropriate restriction of general activity levels are examples of how ill-informed beliefs can increase risk of progression to LBP chronicity (Al-Obaidi et al. 2005; Brox et al. 2005). Positive advice regarding LBP can improve LBP beliefs and reduce fear-avoidance related to activity and LBP (Buchbinder et al. 2001). Whether these beliefs regarding LBP have an influence on the onset of first episode LBP, or the recurrence of LBP, is yet to be shown conclusively.

Catastrophising (a cognitive component associated with pain-related fear), is consistently associated with pain-related disability (Peters et al. 2005; Sullivan et al. 2005). Catastrophising is linked with pain avoidant coping strategies, which are more common in specific sub-groups of personality profiles. Of the three main profiles identified by Turk and Rudy, “dysfunctional” patients are most likely to rely on catastrophising as a coping strategy (Turk and Rudy 1988), and commonly have higher LBP and disability levels (Klapow et al. 1995). However the influence of catastrophising in LBP development is unclear and requires further research.

Although relationships between psychological factors and early LBP development are not currently well defined, clearly the contribution of psychological factors cannot be ignored. Given the powerful modulation effect psychological factors can have on the central nervous system (Zusman 2002), and neuro-biological factors such as the HPA axis influencing the experience of LBP (McBeth et al. 2007), it is likely that methodological issues, rather than lack of relationships, would account for conflicting research findings (Macfarlane et al. 2008). The vast array of psychological measurement instruments, and the varying psychological influences on different populations, make consensus amongst studies difficult. However, it should also be considered that psychological factors may only be important to the development of LBP in certain individuals (Marras et al. 2000; Boersma and Linton 2005). It may also be that these psychological factors are genetically predisoposed, with certain individuals being predisposed to resilience or vulnerability (Kendler et al. 1993; Derijk and de Kloet 2008). Further, emotions such as depression, anxiety and anger are not distinct, and may interact and augment each other in the pain experience (Gatchel et al. 2007).

Key points

- Current research supports psychological distress as the strongest modifiable predictor of future LBP**.** There is preliminary evidence for mechanisms behind psychological distress contributing to new-onset LBP however, further validation studies are required.
- There is evidence for other psychological factors (catastrophising, back pain beliefs and coping strategies) being linked with LBP risk, but primarily chronicity rather than new-onset LBP.
- Personal psychological risk factors do not account for a large proportion of new-onset LBP variance.

1.7. Potential causes of LBP: Social / Lifestyle factors

Social and lifestyle factors have been identified as further potential contributors to LBP risk. These risk factors tend to vary depending on the population under investigation. For example, pain related disability and medication consumption are higher in American than Japanese populations, suggesting that cultural and socio-economic differences can affect the presentation of LBP (Billis et al. 2007). Similarly, musculoskeletal symptom reporting and disability levels have been shown to differ in both office and manual workers from different cultures (Madan et al. 2008). These differences make comparisons of LBP risk across studies involving different cultures difficult.

Individual personal social and lifestyle factors within a population are also thought to influence LBP risk. Increased risk of occupational LBP chronicity is linked with previous history of compensation as well as socio-econonic status, medical comorbidities and education levels (Abenhaim et al. 2000; Gross and Battie 2005; Alexopoulos et al. 2008). A review by Dempsey and co-workers, on personal factors associated with industrial LBP, report other personal factors such as smoking and alcohol consumption that are known to be associated with LBP chronicity (Dempsey et al. 1997). Causal mechanisms behind such risk factors are not yet certain (Leino-Arjas et al. 2006; Uei et al. 2006; Mikkonen et al. 2008), but clearly these factors need to be considered in prospective LBP risk studies.

In terms of future LBP risk, a study examining the predictive capacity of pre-employment screening by Lucey and co-workers (Lucey 2008) identified factors including age and smoking which subsequently predicted above average sickness absence. However, the best model using these and other identified risk factors only predicted around 10% of the variation in sickness absence. In other prospective studies, poor general health was associated with increased LBP risk in females (Croft et al. 1999), while smoking has also been shown to be a predictor of LBP in adolescents (Feldman et al. 2001). While the mechanism/s behind this increased risk are unclear, they are probably best explained by the biopsychosocial model of pain, which proposes a complex interaction of variables from biological, psychological and social domains (Waddell 2004b).

Many studies have examined the relationship between **physical inactivity** and LBP, with mixed findings (Hildebrandt et al. 2000). A positive correlation has been shown between the presence of LBP and time spent watching television in adolescents. Balague proposed this association may be partly explained by physical inactivity (Balagué et al. 1994). Recent research supports this in a specific population, with an observed relationship between prolonged sitting, inactivity and poor back muscle endurance (O'Sullivan et al. 2006a). Further, leisure time inactivity has been found to be both associated with (Bergstrom et al. 2007) and not associated with (Yip 2004; Van Nieuwenhuyse et al. 2006) increased risk of LBP.

Other research has examined the relationship between **higher levels of moderate / vigorous activity** and LBP. One proposed explanation for this relationship is that there is a link between physical activity and back muscle endurance, which is supported by Moffroid and colleagues who found that subjects who were reportedly more active achieved significantly higher scores on the Biering-Sorensen test (lumbar extensor muscle endurance) (Moffroid et al. 1994). In contrast, previous research in nurses has shown that subjects with LBP did not show signs of physical deconditioning compared with healthy controls (Schenk et al. 2007). Prospective literature provides inconsistent conclusions regarding higher activity and LBP, with findings that higher levels of physical activity in young populations may either be protective of (Wedderkopp et al. 2008), or increase the risk of LBP (Kujala et al. 1999; Mattila et al. 2008). As being both higher educated and female has been previously associated with higher levels of physical activity (Salmon et al. 2000), links between physical activity and LBP may be highly dependent on a number of factors, not least the population sample under investigation.

Key points

- Social and lifestyle factors have been linked to LBP chronicity and there is some evidence supporting their role in the development of LBP.
- Physical activity is the most widely investigated lifestyle risk factor, but again prospective evidence is mixed regarding its influence on LBP risk.
- Mechanisms behind the possible link between LBP and social and lifestyle factors are likely to be complex and fit within a biopsychosocial model of LBP.
- Social and lifestyle factors warrant consideration in future studies investigating LBP risk, but their importance may be dependent on the specific population under investigation.

1.8. Potential personal causes of LBP: Other factors

A number of non-modifiable personal characteristics have also been associated with the development of LBP. Patho-anatomical spinal abnormalities formed the basis of early LBP classification systems and diagnostic models (Bernard and Kirkaldy-Willis 1987; van den Hoogen et al. 1995). Patho-anatomical abnormalities including spondylolisthesis, spinal stenosis and herniated discs can be clinically significant diagnoses which require surgical intervention in some individuals (Yeung and Yeung 2006). However, at best, 20% of LBP can be directly attributed to a patho-anatomical cause (Albert et al. 2008). Preliminary research has also identified “modic changes” on MRI as another potential patho-anatomical factor, that correlates with LBP in a small sub-group of patients. (Albert et al. 2008; Leboeuf-Yde et al. 2008). In spite of this, where patho-anatomical diagnosis is reached, it correlates poorly with levels of pain and disability, suggesting that other factors are involved in the pain disorder (Waddell 2004a). The majority of LBP disorders have no know patho-anatomical diagnosis, highlighting the need to identify other factors that underlie the LBP disorder.

The strongest predictor of LBP recurrence and chronicity, across a range of occupational groups including nursing, has consistently been shown to be a **previous history of LBP** (Smedley et al. 1997; Maul et al. 2003; Hestbaek et al. 2006). Unfortunately, as the majority of people experience some LBP in their life (Walker 2000) and commonly have their first episode during adolescence (Kovacs et al. 2003), having a known history of LBP does not help guide prevention strategies. However, a previous LBP history should be taken into account when considering other factors that may predict future LBP episodes. Similarly, age and body weight appear to have some influence on LBP (Croft et al. 1999; Cassidy et al. 2005; Leboeuf-Yde et al. 2006) and also should be accounted for when investigating factors that may predict future LBP episodes.

1.8.1. Gender

Despite generally living healthier lifestyles, having lower body mass index (BMI) and less stressful occupations than males, it is widely reported that females experience more LBP than men (Schneider et al. 2006). There is evidence of increased pain prevalence in females for pelvic pain, LBP, neck pain and pain syndromes such as fibromyalgia (Kovacs et al. 2003; Bunketorp et al. 2005; Giamberadino 2008; Vleeming et al. 2008).

Gender differences have also been reported across a number of other factors associated with LBP. A recent study on sitting posture in healthy individuals showed males sat with more spinal flexion than females, regardless of the chair type (Dunk and Callaghan 2005). Gender differences in standing lumbar curvature (greater lordosis in females) as well as LBP diagnosis have been shown in one clinical study (Norton et al. 2004), while standing spinal posture was also shown to differ between genders in a large adolescent sample (Smith et al. 2008). In terms of back muscle endurance, although some conflicting evidence exists, clear gender differences are commonly reported (Demoulin et al. 2006). Female subjects have repeatedly been shown to have greater lumbar erector spinae muscle endurance compared to the males (Kankaanpaa et al. 1998; Suuden et al. 2008). Furthermore, there is some evidence to suggest that females with LBP have greater endurance in the Sorensen test compared with healthy controls, which is in contrast to males (Biering-Sorensen 1984).

Gender differences are also recognised in relation to a range of psychological factors and LBP (Gatchel et al. 2007). There is evidence of gender differences in depression (Hyde et al. 2008), pain related anxiety (Robinson et al. 2005), pain behaviours (Dickens et al. 2002) and pain coping strategies (Inman et al. 2004). There is also evidence of gender differences in mechanical spinal loading in response to psychological stress (Marras et al. 2000). Further, gender differences in biochemical factors, such as stress biomarkers and their association with LBP development (Schell et al. 2008), supports the concept of the complex multifactorial nature of LBP.

1.8.2. Genetics

In terms of accounting for differences between LBP and pain free individuals, **genetic factors** should also be considered. For example, family history has been shown to be associated with LBP in large samples of adolescents (Masiero et al. 2008; O'Sullivan et al. 2008). Genetic factors have also been shown to explain a large proportion of LBP variance, associated with degenerative disc changes (Battie et al. 2007). However, a recent large twin study of children rather than adolescents found that environmental rather than genetic factors explained the greatest proportion of LBP variance (El-Metwally et al. 2008). As described earlier, evidence for genetic predisposition to psychological characteristics suggests that mechanical factors such as degenerative disc changes may not be the only pathway behind genetic influences on LBP development (Battie et al. 2007).

Key points

- A number on non-modifiable personal factors are potentially associated with increased risk of LBP. These include patho-anatomical factors, gender and genetic factors.
- Gender differences are consistently reported in both physical and psychological factors associated with LBP.
- Gender differences need to be considered in future studies investigating LBP.
- Genetic factors are also thought to play a role in LBP development, which likely involve physical as well as psychological pathways.

1.9. Why is predicting LBP so difficult?

Despite thousands of studies into LBP risk and management, we are not much closer to controlling LBP risk (Marras 2005). As described above, there are multiple factors from a number of domains, which may be associated with the development of LBP. Clearly no single factor is responsible, and perhaps the combination of factors vary within different populations, or possibly even from person to person. Therefore, predicting LBP in any population appears a very difficult task. Not surprisingly, previous studies investigating LBP predictors utilising a uni-dimensional approach have had little success.

Even studies examining multi-dimensional factors have not identified consistent personal risk factors associated with LBP (Feyer et al. 2000), with less than 12% of variance being explained by personal physical and psychosocial characteristics in one comprehensive multifactorial study (Adams et al. 1999). A greater proportion of variance has been explained when unmodifiable predictors such as previous LBP history (Denis et al. 2007) and genetics (Battie et al. 2007) are considered. However, as such variables are not modifiable, they do not assist the development of LBP prevention strategies.

The best method of identifying LBP risk factors is via prospective research (Macfarlane et al. 2008). However, there is a range of methodological issues that may impact on prospective findings. Firstly, definitions of an episode of LBP vary greatly (de Vet et al. 2002). Marras and co-workers found that both LBP prevalence and factors associated with LBP vary when different definitions of LBP were applied to a cohort of workers with recurrent LBP (Marras et al. 2007). Definitions can be based on a range of factors including pain intensity, frequency and duration of symptoms, length of time between episodes, the need for treatment or time off work, or disability levels. Varying definitions also make comparisons between studies difficult (Dionne et al. 2008).

Secondly, selection and recruitment of subjects is a potential source of bias in any study. Of particular concern with prospective studies is limiting the number of potential confounding variables. As many of the factors described above including age, gender, occupation, leisure time activity, socio-economic status and history of LBP are all thought to have some direct or indirect influence on LBP development, they all need to be taken into consideration during recruitment and data analysis.

Other issues with subject recruitment and study design including sample size, length of follow up and subjects lost to follow up have the potential to limit results (Adams et al. 1999).

Thirdly, selection of characteristics that may be predictive of LBP is problematic. Measuring all factors from previous studies would not be possible for logistical reasons. One approach to selecting valid LBP risk factors is to identify a relatively homogenous population at risk of LBP (such as by occupation and gender) and then consider the most important / likely hypothesised risk factors specific for that population. This should apply across multiple domains (physical, psychological and social/lifestyle). For example, different psychological and physical risk factors would be expected to be associated with sedentary white collar workers when compared to manual labourers, necessitating different measurement tools for different groups (Spyropoulos et al. 2007).

Another issue to consider here is the operationalisation of important constructs. Examples include regional versus global lumbar spine angles described earlier (Section 1.5.2), as well the complexities involved in measuring factors such as volitional movement (Cholewicki et al. 2005). Further, the cost of complex, non-functional measurement devices may be prohibitive, and inclusion of too many lengthy test procedures may hamper subject recruitment.

Finally but perhaps most importantly, the lack of homoegeneity in the non-specific LBP population and the recent recognition of the need to identify LBP sub-groups must be considered (Borkan et al. 1998; Fritz et al. 2007). There is preliminary evidence that intervention based on specific syndromes or diagnoses within the non-specific LBP group is more effective than treatment provided to a general non-specific LBP patient sample (Fritz et al. 2003). Further, sub-grouping acute LBP patients based on psychological characteristics has been shown to have validity in prediction of LBP chronicity (Shaw et al. 2007) and may assist in matching patients to appropriate treatment groups (Boersma and Linton 2005). One could also expect the same logic would apply to identification of factors predicting onset of LBP.

Selecting sub-groups for predicting LBP could be applied across different sub-group definitions including occupation, gender and age, or more specific individual characteristics such as psychological characteristics or spinal posture type. For example, with sitting posture, differences between LBP and control subjects were only found to be evident when subjects were sub-grouped according to directional pain provocation and exposure to this activity or posture in their daily life (Dankaerts et al. 2006).

To date, over 40 LBP classification systems have been documented (Billis et al. 2007), with only a small number of these following a biopsychosocial approach (Ford et al. 2007). Classification systems should consider the multiple dimensions that are likely to be involved in the presentation of LBP episodes (Ford et al. 2007). O’Sullivan’s mechanism based classification system sub-groups patients according to specific motor control impairments directly related to LBP provocative postures and movements whilst also considering lifestyle and psycho-social factors (O'Sullivan 2000; O'Sullivan 2005), and there is preliminary evidence for it’s efficacy (Dankaerts et al. 2007). If such a classification system is successful in selecting different factors important to management of LBP in different sub-groups, its basis may also have application in selecting sub-groups of individuals with different LBP risk factors.

Key points

- Identifying the combination of factors associated with LBP development is difficult and requires a focussed multifactorial approach.
- LBP definition, subject recruitment, selection of variables and methods of measurement all require careful consideration in studies investigating personal LBP risk factors.
- Failure to identify different sub-groups with different LBP risk factors may explain the lack of success in previous prospective studies.
- Given the large proportion of LBP variance explained by non-modifiable personal factors such as LBP history and genetics, it is unclear what proportion of LBP variance could be explained by modifiable personal characteristics.

1.10. A hypothesized model of relationships between modifiable personal factors and LBP risk.

A range of possible models for LBP development have been proposed, including biomechanical load (McGill 1997), disuse and deconditioning (Verbunt et al. 2003), psychological factors (Truchon et al. 2008), pathophysiology (Langevin and Sherman 2007) and pain of non-organic origin (Maigne 2004). Any model of pain which focuses on a single dimension is thought to be inadequate and incomplete (Gatchel et al. 2007). A recent review paper by Marras proposed that different professions are focussing on a common injury causality process, but from different perspectives (Marras 2005). Unfortunately, rather that adopting a multi-dimensional approach, these uni-dimensional perspectives result in limited advances in LBP management. Current literature widely supports the notion of a biopsychosocial model of LBP, which recognises the complex interaction of a range of factors across multiple domains (Borkan et al. 2002; Gatchel et al. 2007). Although such a model recognises complex interactions, it does not explicitly recognise the possibility that different groups of individuals may be primarily affected by different components of this model, such as specific physical and/or psychological factors (O'Sullivan 2006). This may help explain why generic multi-dimensional biopsychosocial interventions are not necessarily more effective for managing non-specific LBP patients (Johnson et al. 2007).

In terms of identifying predictors of LBP, it is proposed that personal rather than occupational factors may be more important for the development of successful LBP prevention interventions. For example, in a comparison of LBP and control subjects in an industrial population, differences in sitting posture, back muscle endurance and amount of time spent sitting were evident between the groups (O'Sullivan et al. 2006a). This is despite all LBP subjects performing their pre-injury duties three months prior to testing and all workers being exposed to the same occupational workplace safety initiatives. It is proposed that consideration of physical, psychological, social / lifestyle and other personal characteristics (such as age and gender) with relevance to a specific high-risk population may explain a greater proportion of LBP variance than previous prospective studies.

A proposed model for research into modifiable personal risk factors for LBP in nurses is outlined in Figure 1.3. This model has been developed based on previous research into LBP risk factors, evidence of proposed mechanisms for the development of LBP, and clinical observations of the research team. It focuses on the modifiable personal component of LBP risk. Although important, occupational risk factors have been widely explored (Feyer et al. 2000; Hoogendoorn et al. 2002; Jang et al. 2007) and are not the focus of this thesis. The model proposes that modifiable personal characteristics from physical, psychological and social / lifestyle domains all have the potential to influence future LBP risk. The factors from each of these domains comprise the battery of screening tests that form the basis of this doctoral research.

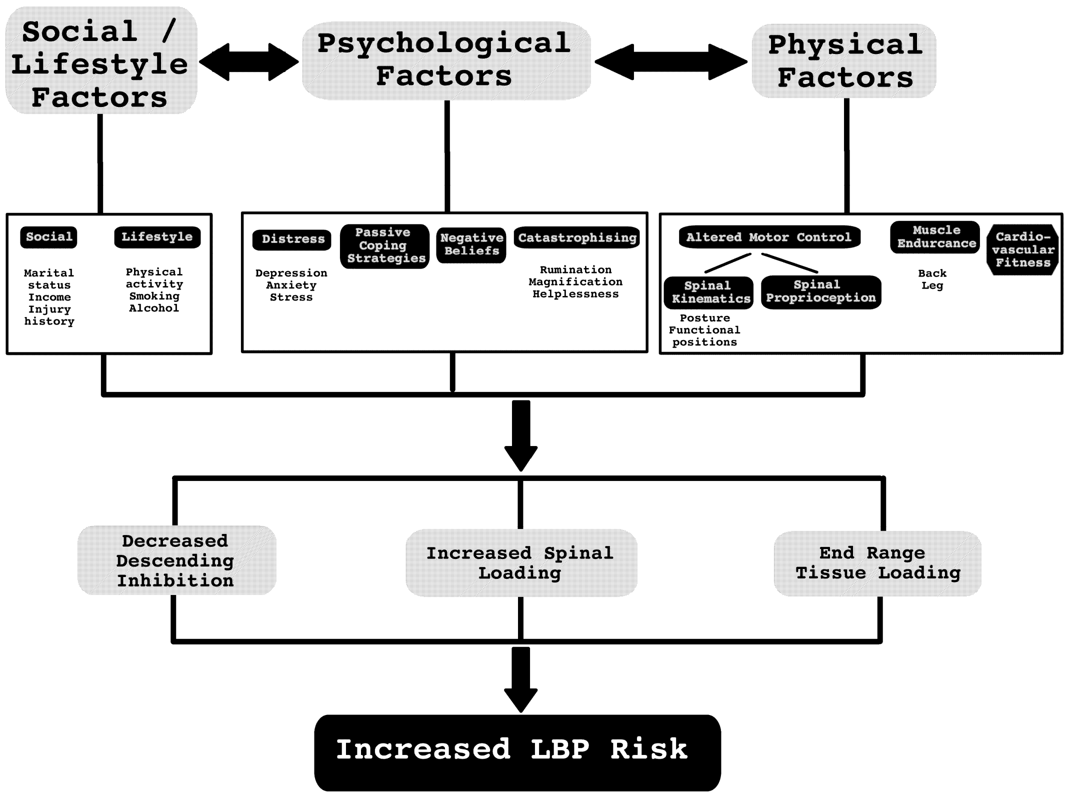

Figure 1.3. Hypothesized model of relationships between modifiable personal characteristics and LBP risk.

Figure 1.3 outlines the three domains (physical, psychological and social / lifestyle) and proposes that individual factors within these domains are likely to involve complex interactions that contribute to the development of LBP. The strength of the relationships between factors is also likely to vary between individuals. Previously proposed mechanisms for LBP development or amplification are provided as examples of mechanisms of LBP development in this model: forebrain mediated decreased descending pain inhibition (Zusman 2002); increased spinal loading from both physical and psychological influences (Marras et al. 2000); and repeated end range mechanical tissue loading (Cholewicki and McGill 1996).

Whilst the mechanism of pain development for each potential risk factor in the proposed model is not clear, the biopsychosocial model of pain has assisted in the understanding of the possible interaction of multifactiorial pain mechanisms, particularly for chronic pain. For example, conditions such as fibromyalgia which were considered to have a significant underlying psychological component have been recently shown to also have a neurobiological basis (McBeth et al. 2007). It has been proposed on this basis that childhood stress, sleep disturbance, genetic factors, decreased serotonin and increased substance P availability directly influence hypothalamic-pituitary-adrenal (HPA) axis functioning, which results in increased vulnerability to physical symptoms with subsequent trigger events (McBeth et al. 2007).

Altered processing of pain could arise from a number of neuroendocrine, neurotransmitter and neurosensory disturbances, with environmental stressors being a potential triggering factor (Giamberadino 2008). Other recent developments in understanding chronic pain mechanisms include dynamic modulation of the immune and central nervous systems (Watkins and Maier 2005), and the concept that cellular biological function is dependent on genetic expression, and either over-expression or elimination of a gene is known to result in functional changes which can influence modulation of pain sensitivity (Gatchel et al. 2007). It is possible that these factors play a role in recurrent LBP, but their involvement in new-onset LBP is unclear.

The risk of LBP with mechanical load such as high volumes of bending and lifting has been described in Section 1.5. Physical mechanisms for LBP including repeated end range tissue loading (Cholewicki and McGill 1996) and high levels of compressive spinal load (Marras et al. 2000; Bakker et al. 2007), have been identified. However, recent research into “modic changes” on MRI scans suggests higher volumes of physical load in combination with other personal factors such as smoking and obesity may further increase the risk of LBP (Leboeuf-Yde et al. 2008). These findings further support the multi-factorial nature of LBP.

Key points

- Although LBP is best explained by the biopsychosocial model, current generic biopsychosocial interventions are not more effective than uni-dimensional interventions for managing non-specific LBP.

- Further evidence is required regarding the individual influence personal characteristics from multiple domains have on the development of LBP.
- A proposed model of personal LBP risk factors in nurses has been developed. It considers factors from physical, psychological and social / lifestyle domains which may contribute to the development of LBP.

1.11. Developing thesis rationale and research questions

From the preceding review, it is clear that LBP is a multifactorial problem, with contribution from factors across a range of domains. It is unclear which factors are more important, or indeed if factors affect different populations to varying degrees. Consequently, the *general aim* of this doctoral research was:

- To investigate the influence of physical, psychological and social / lifestyle factors on LBP in a high-risk occupational population (nurses).

A series of studies that investigated different aspects of this general aim were conducted. Figure 1.4 provides a schematic overview of the studies involved.

1.12. Development and specific aims of the series of studies

1.12.1. Investigation of when LBP becomes a problem for nurses.

As LBP prevalence is already high in adolescence, targeting LBP preventative strategies at working nurses may not be the ideal time to intervene. Evidence suggests that LBP is also a significant problem among nursing students, however whether LBP prevalence peaks across undergraduate training or once commencing employment as a nurse is not clear. Further, whether increased LBP prevalence is a consequence of increasing age or linked with changing occupational exposures (such as bending/lifting) is also unclear. This study examined the prevalence of LBP among nursing students and recently graduated nurses and volume of occupational exposure associated with this LBP. The specific aims were:

- To determine LBP prevalence in undergraduate nursing students and recently graduated nurses and whether LBP prevalence significantly alters across university training or once full-time employment commences.
- To examine the relative contributions of age and occupational exposure on the duration and severity of LBP episodes (Chapter 2).

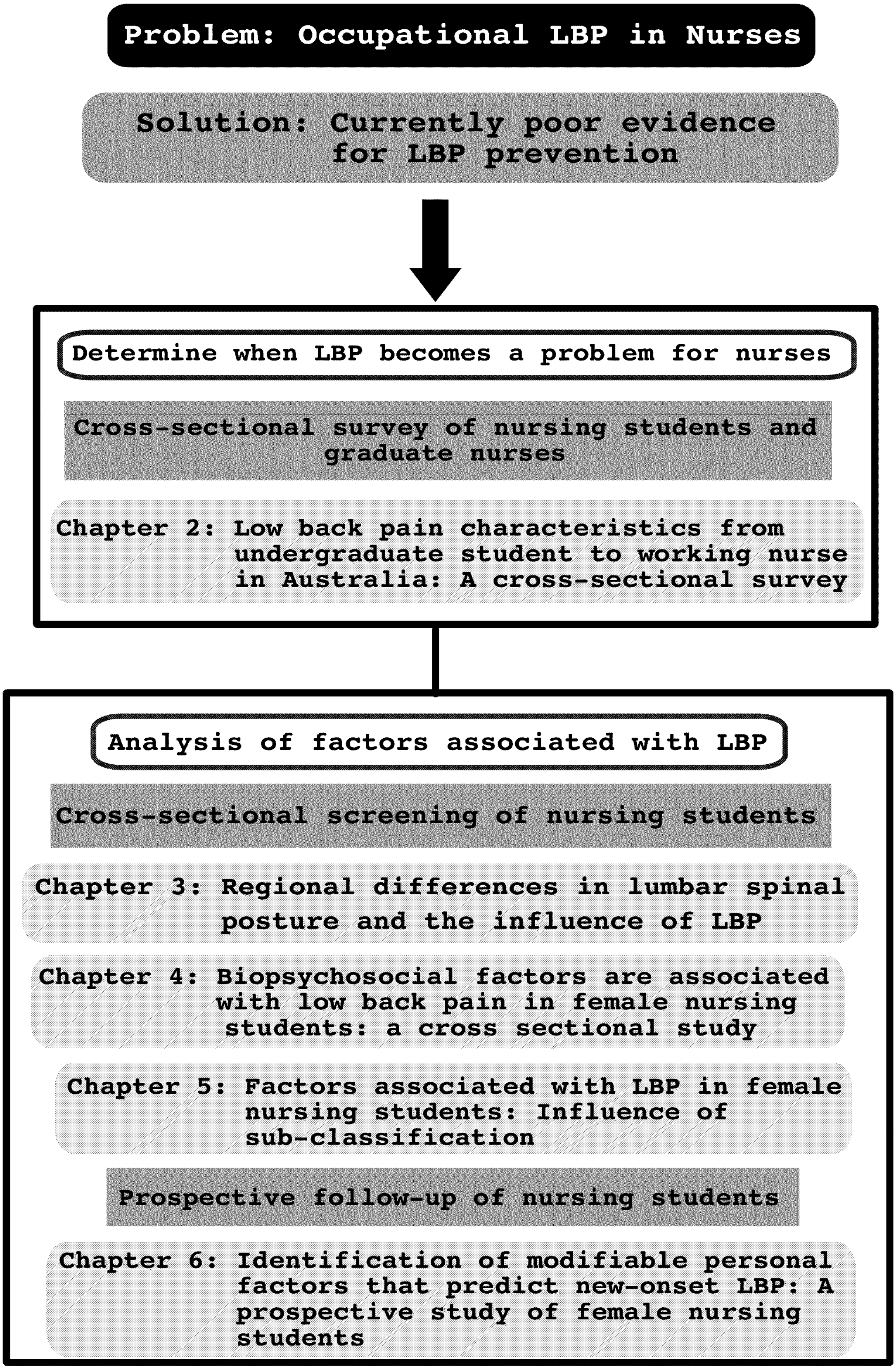

Figure 1.4. Overview of the thesis and steps involved in the investigation of

modifiable personal LBP risk factors in nurses.

1.12.2. Regional differences in lumbar spinal posture and the influence of low back pain.

Recent research has shown that regional lumbar kinematics may differ from global lumbar kinematics in a lifting task (Gill et al. 2007). The lack of consideration of regional lumbar spine kinematics in previous studies was proposed as a reason for limited evidence supporting the influence of spinal kinematics on LBP. Investigation of this concept of regional spinal differences in general movement and postures, as well as nursing specific tasks, was considered necessary prior to prospective investigation of kinematic LBP risk factors. The specific aims were:

- To determine whether regional (upper/lower) differences exist in lumbar; static posture angles, range of motion and dynamic spinal angles during functional tasks.
- To determine if the nature of any regional differences are similar in subjects with and without a history of LBP (Chapter 3).

1.12.3. Cross-sectional investigation of personal factors associated with LBP in nursing students.

As LBP is a multifactorial problem, factors from a range of domains that may be associated with LBP need to be considered. There is limited knowledge regarding the influence of modifiable personal characteristics on LBP outside of occupational environments. However, selection of personal factors also needs to be relevant to the target population under investigation. In terms of nurses, significant factors (physical, psychological and social/lifestyle) identified in previous studies were considered. Further, kinematic measures specific to tasks and postures commonly associated with LBP aggravation in nurses were developed.

Following the identification of a cohort of nursing students with high LBP prevalence, the proposed personal LBP risk factors (Figure 3) required investigation. An initial cross-sectional investigation of the relationship of these factors in nursing students with and without significant LBP was conducted. The specific aims were:

- To comprehensively evaluate the influence on LBP of modifiable personal factors, including task-specific individual physical factors, relevant to pain provocation in female nursing students (Chapter 4).

1.12.4. Investigation of the influence of sub-groups on personal factors associated with LBP in nursing students.

There is growing evidence that supports the concept of different LBP sub-groups with different factors associated with their LBP. O'Sullivan's mechanism based classification system is one which considers both physical and psychological influences (O'Sullivan 2005). Although this system has some validity (Dankaerts 2005), evidence of the influence of physical and psychological characteristics on these different sub-groups is required. The specific aims were:

- To determine whether differences in psychological characteristics and physical factors are evident in two defined sub-groups of female nursing students with LBP, and whether different factors discriminate between different LBP sub-groups and controls (Chapter 5).

1.12.5. Prospective investigation of factors predicting LBP in nursing students.

Following the identification of personal physical, psychological and social / lifestyle characteristics that were associated with LBP at baseline, subjects were followed prospectively for 12-months. This study was designed to identify which baseline characteristics were associated with future episodes of LBP. The specific aims were:

- To identify psychological, physical and social / lifestyle characteristics which predicted new episodes of LBP in nursing students (Chapter 6).
- To identify psychological, physical and social / lifestyle characteristics which predicted recurrence or protection from recurrence of LBP in nursing students (Appendix VI).

1.13. Summary and significance

Despite enormous research efforts, prevention of LBP is generally unsuccessful, and identification of factors that predict LBP is mainly limited to non-modifiable variables such as previous history of LBP. The important distinction with the proposed study is the selection of a combination of modifiable physical, psychological and social/lifestyle characteristics in a specific high-risk population (nurses), which are potentially inter-related in their impact on spinal function and thus LBP. By incorporating measures of personal characteristics which directly influence each other, and considering the combined impact of these factors in a specific high-risk population, the prediction of LBP may be more successful. Further, consideration of different LBP sub-groups may be important. LBP risk factors may not be identifiable without consideration of sub-groups, or different factors may be relevant to LBP risk in these different groups. This study has potential to increase the evidence of modifiable characteristics associated low back injury, which may lead to early intervention or prevention programs for at-risk workers and help reduce LBP recurrence and chronicity.

Key points

- LBP in nurses remains a significant problem despite extensive research.
- Timing of LBP preventative strategies may be a key factor.
- To date, uni-dimensional approaches to LBP prevention have not proven successful and whilst a multifactorial biopsychosocial approach has become widely accepted, conclusive evidence for the effectiveness of this approach is also limited.
- Identification of modifiable personal LBP risk factors could assist the development of successful prevention interventions.
- There is currently limited evidence as to what modifiable characteristics cause LBP.
- The process of identifying modifiable personal characteristics is complex, possibly requiring consideration of factors across multiple domains that are specific to individual populations.
- Physical risk factors may need to consider pain provocative movements and tasks specific to the population under investigation.
- Sub-groups within specific populations may also need to be considered.
- Based on current literature and contemporary clinical practice, a hypothetical model – identifying likely risk factors from multiple domains (physical, psychological, social / lifestyle) has been developed. This has included specific reference to factors specific to the target group (nurses).

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CHAPTER 2 – Study I

There is conflicting evidence regarding whether LBP prevalence increases before, during or after undergraduate nursing training. Current LBP prevention strategies have failed to produce significant improvements in low back injury statistics among health care populations, possibly due to the timing of these interventions. In order to select an appropriate target nursing population for LBP prevention strategies, more information regarding low back pain prevalence rates across undergraduate nursing training and on the commencement of nursing employment is required.

The *general aim* of this study was to determine LBP prevalence in undergraduate nursing students and recently graduated nurses. The specific aims and its overall place in this doctoral research are shown in figure 2.0.

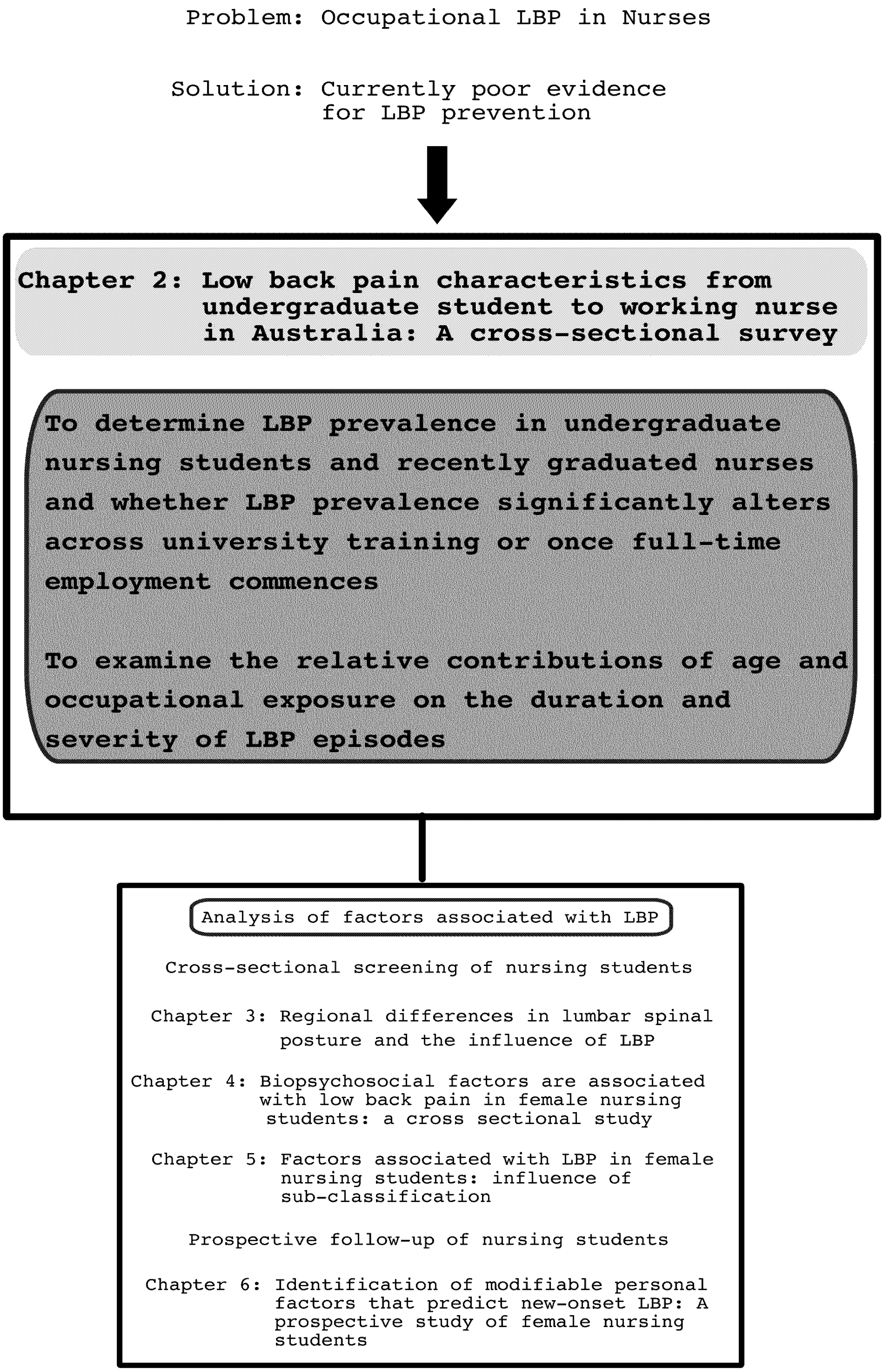

Figure 2.0. Schematic representation of Study I within the thesis.

Low back pain characteristics from undergraduate student to working nurse in Australia: A cross-sectional survey.

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Int J Nurs Stud. 2008. 45(11): 1636-44.

2.0. Abstract

Background: Nurses are known to be a high risk group for occupational low back pain. The periods of greatest risk for developing low back pain in this population are not well defined. Recent literature suggests current preventative strategies are not consistently effective in improving low back injury statistics among health care populations. The objectives of this study were to identify the relative contributions of age and occupational exposure on the prevalence, duration and severity of low back pain episodes among undergraduate nursing students and recently graduated nurses.

Methods: A cross-sectional survey was conducted on two undergraduate nursing schools and one public teaching hospital graduate nurse training program in Western Australia. A total of 897 undergraduate nursing students (years 1, 2 and 3) and 111 graduate nurses recruited by personal invitation during lectures. Using a modified version of the Nordic Low Back Questionnaire, information regarding low back pain episode prevalence, impact, duration, frequency and causes was obtained.

Results: Mean age was consistent across all groups (26.7 ± 9.0 years) and had no significant effect on lifetime low back pain prevalence ($p = 0.30$). Very high lifetime (79%), 12 month (71%) and 7 day (31%) low back pain prevalence rates were consistent across all 3 year groups of undergraduate nursing students, but were significantly higher after 12 months of full-time employment [Lifetime (95.5%), 12 month (90%) and 7 day (39%)]. Around 60% of all respondents with low back pain utilised at least one of (a) treatment, (b) medication, or (c) a reduction in activity. Nursing students and graduate nurses attributed the majority of their low back pain to bending or lifting despite recent efforts to reduce manual workplace demands (lifting) on nurses. Strategies for managing low back pain differed between nursing students and graduate nurses.

Conclusions: These results may suggest a rise in occupational exposure from student to working nurse is the primary cause of the increase in low back pain. Increased exposure may be to physical as well as psychological stressors. Given that

prevalence rates are very high prior to commencing work, nursing student populations should be a target group for low back pain preventative strategies.

2.1. Introduction

Manual occupations including nursing are thought to be at particularly high risk of low back pain (LBP). The 12 month prevalence of LBP in nursing populations has been reported to range between 66% and 76% (Smedley et al. 1997; Maul et al. 2003), with point prevalence reported to be as high as 40-59% (Smith and Leggat 2004; Violante et al. 2004; Yip 2004). The impact of LBP for nurses includes time off work, increased risk of chronicity, as well as associated personal and economic costs.

Over recent decades, significant resources have been allocated to reducing the prevalence of LBP in the workplace. However, this has proven to be difficult to achieve (Andersson 1999). Evidence for the effectiveness of injury prevention strategies appears mixed, with a recent systematic review finding no strong evidence for the efficacy for any specific intervention (Fanello et al. 2002; Smedley et al. 2003; Jensen et al. 2006; Dawson et al. 2007). One possible explanation is that specific interventions are not consistently being effectively targeted in different studies.

The strongest predictor of LBP recurrence and chronicity, across a range of occupational groups including nursing, has consistently been shown to be a previous history of LBP (Smedley et al. 1997; Maul et al. 2003; Hestbaek et al. 2006). In the general population LBP prevalence rates are known to increase over the adolescent / early adulthood period (McMeeken et al. 2001; Sjolie 2004). Cumulative LBP prevalence tends to plateau by the age of 22 (Hestbaek et al. 2006), however LBP recurrence and severity are thought to continue to increase with increasing age (Dionne et al. 2006). As age appears to be a strong contributor to increasing LBP prevalence rates, consideration should be given to the timing of LBP preventative strategies (Hestbaek et al. 2006).

Studies examining student nurses (Feyer et al. 2000; Smith and Leggat 2004) have found a high LBP prevalence rate already existing prior to commencing full time nursing employment. These findings suggest that LBP prevention should be considered *before* the commencement of full time nursing duties (Hellsing et al. 1993). How long before commencing employment this should occur remains unclear. A recent longitudinal study reported that the greatest increase in LBP prevalence was during the theoretical component of undergraduate study, rather than during increased clinical exposure or the transition to full time nursing employment

(Videman et al. 2005). Some studies report a peak rise LBP prevalence during nursing training (Hellsing et al. 1993; Klaber-Moffett et al. 1993), whilst others report no change in LBP prevalence across the duration of nursing training (Smith and Leggat 2004). The most probable reason for these conflicting results is the use of different measurement tools and different definitions of LBP. Further, the failure to consistently separate the effects of increasing age (Harreby et al. 1996; McMeeken et al. 2001; Sjolie 2004) and changes in occupational exposure due to course content (Smedley et al. 1997; Eriksen et al. 2004) may have influenced results. Although recent research has considered the pattern of LBP from undergraduate nursing study and during the transition to full time employment (Videman et al. 2005), the contributions of age and occupational exposure remains unclear.

The purpose of this study was to examine the relative contributions of age and occupational exposure on the prevalence, duration and severity of low back pain episodes among undergraduate nursing students and recently graduated nurses.

2.2. Methods

This cross sectional survey collected information on LBP characteristics, gender, age and clinical exposure of both undergraduate nursing students (NS) and recently graduated nurses (GN).

2.2.1. Sample

This convenience sample was derived from a total of 1668 NS from the two major Western Australian undergraduate nursing courses who were eligible to participate in the study. GN enrolled in the Graduate Training Program at a major metropolitan teaching hospital were also invited to participate (n=134). These GN had been working for approximately12 months at the time of the survey.

2.2.2. Protocol

The NS were surveyed once, at a year group lecture at the beginning of their university semester. Participation rates were therefore highly dependent on lecture attendance rates for each year group. GN were surveyed during lectures at a continuing education session as part of their hospital Graduate Training Program.

Subjects needed to be aged between 18-50 years to be included in the study. An information sheet was distributed with the questionnaire and informed consent was indicated by completion of the questionnaire. Ethical approval was obtained through the relevant university and hospital ethics committees (Appendix 1).

2.2.3. Questionnaire

LBP prevalence and impact data was obtained using a modified version of the Nordic Low Back Questionnaire (Kuornika et al. 1987). LBP was defined as any "ache, pain or discomfort", and the location was defined by the shaded area of a body diagram (T12 to gluteal folds). A total of ten questions were asked requiring checking a yes / no or multiple response answer choice. Lifetime, 12 month and 7 day LBP prevalence rates and total 12 month LBP duration were obtained. Impact of LBP was determined with questions on medication consumption, requiring treatment and modification of work/home duties due to LBP in the preceding 12 months. LBP was defined as "clinically significant" if subjects reported that their LBP necessitated either the use of medication, if they sought treatment, or if it necessitated a reduction in activity levels. Basic demographic data of age, gender and professional exposure (year of study/months of work) were also obtained.

In addition to the above standardised questions, novel questions regarding annual LBP recurrence, LBP aggravating factors and worsening of LBP were added. LBP recurrence was determined by the number of episodes (distinct period of LBP of any duration or severity) of LBP in the preceding 12 months. Participants were also asked which postures / activities (Bending/lifting, sitting/driving, standing/walking, sudden movements or non-specific) they felt aggravated their LBP. GN were also asked whether they felt their LBP occurred more frequently or was more severe since commencing full time employment. These novel questions were pilot tested on 10 general population subjects and 10 undergraduate NS. Specific duties and time breakdown data were beyond the scope of this survey. The survey was completed and collected in class at the time of distribution, as it only took approximately three minutes to complete.

2.2.4. Nursing course content

The content and timing of content in both undergraduate courses was determined by examining course curricula. For both universities, the undergraduate nursing curriculum content included components of theoretical study comprised of lectures, laboratory sessions and tutorials, and clinical placement experience across primary, secondary and tertiary health care sectors. Workplace safety and basic manual handling training was a first year component of both courses. Further manual handling training was provided on clinical placements according to the patient-handling load of individual clinical settings. Although course content was generally similar, Curtin University of Technology's course was run over seven semesters (3.5 years), and the Edith Cowan University (ECU) course over six semesters (3 years). Relative contact time for lectures / tutorials and clinical placements was similar across semesters of study at each university. The majority of clinical hours were completed during the final three semesters of the Curtin course and the final two semesters of the ECU course. For direct comparison between students from both universities, we defined semester five, six and seven Curtin University students as the third year group for comparison to the third year group (semester five and six) at ECU.

2.2.5. Data analysis

All data were coded and entered into SPSS v12 for analysis. Descriptive statistics, Chi Square and Independent t-test analyses were used to test for significant differences in responses between year groups, using 95% confidence intervals and a critical alpha of $p < 0.05$. Logistic regression was used to analyse LBP prevalence by year group, controlling for age.

2.3. Results

A total of 897 NS from Curtin University (n=427) and ECU (n=470) participated in the study, with the overall response rate being 54%. The response rate for the GN group was 83% (n=111). An average of 96% of subjects who actually attended the lecture where the survey was distributed completed the questionnaire. The response rates produced adequate power for all NS year groups and GN based on finite population sample size calculations (95% confidence / 50% proportion / 5% error margin).

2.3.1. Age, gender and occupational exposure of sample

The majority of subjects were female (91%), and this did not differ significantly across NS year groups or GN ($\chi^2 = 1.62$, df = 3, p = 0.65) (See Table 2.1). The average NS age was 26.7 years (±8.9). This was consistent across NS year groups, and did not increase in the GN group (F=0.41; df=3; p = 0.74).

In the first year of each course, around three quarters of the program was in a non-clinical setting. NS undertook between 900-1000 hours of clinical experience during their studies. Clinical experience commenced in first year of study and increased steadily as the course progressed (Table 2.1). The remainder of contact time for each year group included lectures, tutorials, laboratory sessions, and computer based learning. The non-clinical component of the course predominantly involved sitting. GN were employed full time and worked an average of 38 hours per week, with scheduled educational study days reducing their clinical contact slightly. Normal nursing duties constituted over 90% of GN's hours worked.

Table 2.1. Gender [n(%)], age (mean + standard deviation) and hours of clinical exposure as a proportion (%) of total program contact hours of nursing students (NS) and graduate nurses (GN)

	NS				GN
	1st Year	2nd Year	3rd Year	All NS	
Female	312 (90.7%)	234 (89.7%)	252 (92.3%)	798 (90.9%)	98 (88.3%)
Male	32 (9.3%)	27 (10.3%)	21 (7.7%)	80 (9.1%)	13 (11.7%)
Age (yrs)	26.6 ± 9.1	27.1 ± 9.6	26.6 ± 8.4	26.7 ± 9.0	26.0 ±7.5
Clinical exposure	25%	50%	> 60%	N/A	> 90%

2.3.2. LBP prevalence

The total NS population LBP prevalence rates were very high; lifetime (79%), 12 month (71%) and 7 day (30%). Although there was a slight upward trend for lifetime and annual prevalence, these results were consistent across the 3 years of undergraduate nursing study (Figure 2.1), with no significant difference evident in lifetime (χ^2 = 4.52, df = 2, p = 0.104), 12 month (χ^2 = 0.87, df = 2, p = 0.65), or 7 day (χ^2 = 0.80, df = 2, p = 0.67) prevalence rates between year groups. GN LBP prevalence rates: lifetime (95.5%), 12 month (90%) and 7 day (39%) were comparatively higher. There were significant increases in LBP prevalence from 3rd year NS to GN in lifetime prevalence ($\chi^2 = 12.87$, df = 1, $p < 0.001$), 12 month prevalence ($\chi^2 = 9.43$, df = 1, $p = 0.002$) and 7 day prevalence ($\chi^2 = 4.13$, df = 1, $p = 0.042$). Only 12 month LBP prevalence differed significantly between the genders. Across all subjects surveyed, 12 month prevalence was 13% lower in males compared to females ($\chi^2 = 6.17$, df = 1, $p = 0.013$).

2.3.3. Influence of age on LBP prevalence

Across the 3 years of undergraduate NS, the effect of age adjusted for year group was not significant for lifetime (p = 0.23, 95% CI: 0.99 - 1.03), 12 month (p = 0.08, 95% CI: 0.97 - 1.00) or 7 day prevalence (p = 0.94, 95% CI: 0.98 - 1.02). As the largest increase in LBP prevalence was from 3rd year NS to GN, the effect for age was also examined across these two groups. Again the effect of age adjusted for year group was not significant for lifetime (p = 0.16, 95% CI: 0.99 - 1.07), 12 month (p = 0.27, 95% CI: 0.96 - 1.01) or 7 day LBP prevalence (p = 0.65, 95% CI: 0.97 - 1.02).

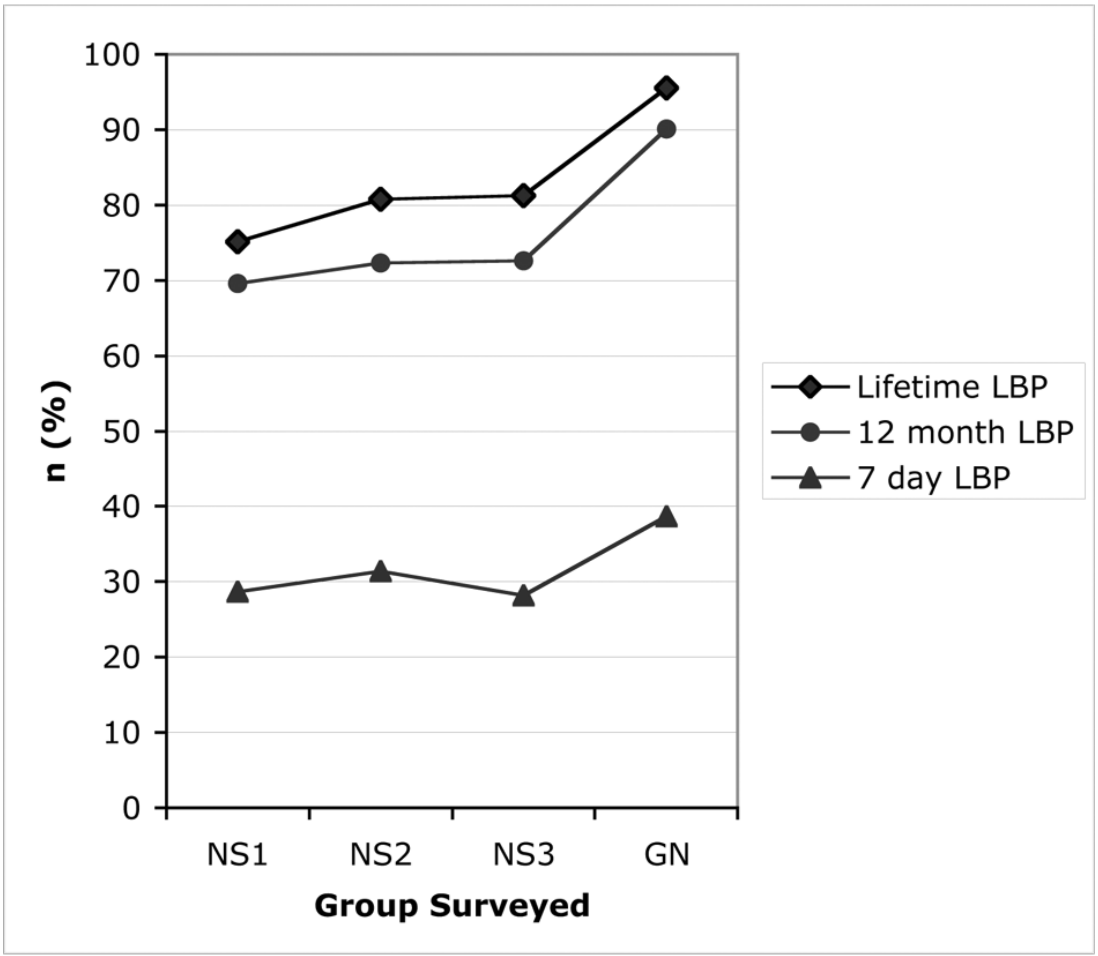

Figure 2.1. Lifetime, 12 month and 7 day prevalence of LBP in nursing students (NS year 1, 2 and 3) and graduate nurses (GN).

2.3.4. LBP duration and recurrence

Over 60% of all subjects with LBP in the previous 12 months reported an annual duration of 1-7 days (Table 2.2). Only a small proportion of NS and GN had more than 30 days of LBP in the previous 12 months. LBP duration did not differ significantly between NS year groups or GN ($\chi^2 = 8.73$, df = 9, p = 0.463).

Over three quarters of all subjects with LBP in the previous 12 months experienced two or more episodes of LBP in that time frame (Table 2.2). There were no significant differences between NS year groups or GN for annual number of LBP episodes ($\chi^2 = 7.19$, df = 9, p = 0.618).

Table 2.2. Details of the LBP total duration and the number of LBP episodes over a 12 month period in nursing students (NS Year 1, 2 and 3) and graduate nurses (GN)

	NS			GN
	1st Year	2nd Year	3rd Year	
	n (%)	n (%)	n (%)	n (%)
Duration LBP in 12mths				
1-7 Days	159 (65.4%)	118 (60.2%)	134 (66.7%)	60 (61.2%)
8-30 Days	39 (16.0%)	31 (15.8%)	32 (15.9%)	21 (21.4%)
>30 Days	31 (12.8%)	38 (19.4%)	25 (12.4%)	15 (15.3%)
Every Day	14 (5.8%)	9 (4.6%)	10 (5.0%)	2 (2.2%)
LBP episodes in 12mths				
1	59 (24.3%)	39 (19.4%)	48 (23.3%)	19 (19.0%)
2-3	78 (32.1%)	74 (36.8%)	79 (38.3%)	40 (40.0%)
>3	106 (43.6%)	88 (43.8%)	79 (38.3%)	41 (41.0%)

Note. *[n(%)] = subjects reporting LBP in the previous 12 months*

2.3.5. Impact of LBP

Although a greater proportion of GN had LBP in the previous 12 months, the proportions (60%) of NS and GN that had LBP in that time which was “clinically significant” LBP were similar (Table 2.3). There was a decline in reports of needing to reduce activity due to LBP from 1st year NS to GN (44% v 23%) (χ^2 = 12.65, df = 3, p = 0.005). Conversely, medication consumption among LBP subjects increased across the years of undergraduate training and was highest among GN (χ^2 = 10.11, df = 3, p = 0.018) (Table 2.3). Treatment utilisation for managing LBP was consistent across all groups. Since commencing full time employment as a nurse, 65% of GN felt their back pain was occurring more frequently, and 39% felt their LBP was more severe. Further, 35% felt their LBP was both more frequent and more severe.

Table 2.3. Impact of LBP over previous 12 months of nursing students (NS) and graduate nurses (GN).

	NS			GN
	1st Year	2nd Year	3rd Year	
	n (%)	n (%)	n (%)	n (%)
Any impact**	157 (64.6%)	122 (60.4%)	118 (57.0%)	60 (59.4%)
Reduced activity	108 (44.4%)	74 (36.6%)	71 (34.3%)	23 (22.8%)
Treatment	91 (37.4%)	79 (39.1%)	64 (30.9%)	34 (33.7%)
Medication	68 (28.0%)	76 (37.6%)	68 (32.9%)	43 (42.6%)

Note. ** = Nurses who reported at least one of the 3 impact measures. *[n(%)] = subjects reporting LBP in the previous 12 months*

2.3.6. LBP aggravating factors

Across all NS year groups and GN, bending / lifting was by far the most frequently reported LBP aggravating factor (Table 2.4). Approximately 66% of all NS selected bending / lifting as the greatest aggravating factor but this increased to 75% for GN (χ^2 = 3.63, df = 1, p = 0.057). When comparing across NS year groups and GN, the proportion of subjects associating pain with sitting / driving reduced between second and third year NS by around 14%, and a further 8% in GN (χ^2 = 16.61, df = 3, p = 0.001). LBP associated with other postures or activities did not differ significantly between groups

Table 2.4. Association between postures / activities and LBP of nursing students (NS) and graduate nurses (GN)

	NS			GN
Aggravating Factor	1st Year	2nd Year	3rd Year	Grad
	n (%)	n (%)	n (%)	Nurse
Bending / Lifting	177 (67.6%)	149 (68.0%)	144 (64.0%)	79 (74.5%)
Sitting / Driving	110 (42.0%)	106 (48.4%)	78 (34.7%)	29 (27.4%)
Standing / Walking	73 (27.9%)	59 (26.9%)	58 (25.8%)	26 (24.5%)
Sudden Movement	80 (30.5%)	72 (32.9%)	68 (30.2%)	40 (37.7%)
Non-Specific	50 (19.1%)	35 (16.0%)	52 (23.1%)	17 (16.0%)

Note. *[n(%)] = subjects reporting previous history of LBP*

2.4. Discussion

The cross-sectional lifetime, 12 month and 7 day prevalence rates of LBP across these NS and GN populations were found to be very high. Perhaps more importantly, over 60% of all NS with LBP reported LBP that could be classified clinically significant, ie. resulting in reduced activity, seeking treatment or taking medication. The high prevalence and impact rates for even the first year NS supports the importance of implementing preventative LBP strategies prior to the commencement of full time nursing employment.

After approximately 12 months of working full-time as a nurse, lifetime, 12 month and 7 day LBP prevalence rates were significantly higher than those of 3rd year NS. This trend of increased LBP prevalence once commencing full time nursing duties was consistent, although somewhat higher, when compared with a recent prospective study of LBP in NS and GN (Videman et al. 2005). Other studies report a large range of lifetime LBP prevalence (66% - 81%), among working nurses (Buckle 1987; Smedley et al. 1997; Maul et al. 2003; Videman et al. 2005). The lifetime and 12 month NS prevalence rates reported here are in line with general population prevalence rates among adult Australians (Walker et al. 2004), but are higher than other studies on LBP in NS (Klaber-Moffett et al. 1993; Feyer et al. 2000; Kim et al. 2000; Smith and Leggat 2004; Videman et al. 2005). These prevalence rates are also slightly higher than a survey of Australian undergraduate physiotherapy students (Nyland and Grimmer 2003).

2.4.1. Age and LBP prevalence

Lifetime LBP prevalence increases rapidly over the period from 12 to 22 years of age, with only relatively minor increases thereafter (Hestbaek et al. 2006). This may explain why the lifetime LBP prevalence of our sample was already high before commencing their nursing studies (mean age of 1st year NS 26.6 ± 9.1) and did not change significantly across the three NS year groups. This trend was also reported in a recent study on rural Australian NS with similar mean age (25.5 years) (Smith and Leggat 2004). However, this result is at odds with the findings of the prospective study by Videman et al (2005) who reported that LBP prevalence increased dramatically throughout an undergraduate course. Their results among a somewhat younger cohort (mean age of 1st year NS 22.6 years) found LBP prevalence increased most during the early, theoretical part of the course. It is possible that these results reflect the age of the cohort, as NS clinical contact hours did not increase greatly during the period of increasing LBP prevalence.

Examining our results and results of prior studies suggests age may be as strong a determinant of LBP prevalence across adolescent and young adult populations as physical load exposure or activity levels (Harreby et al. 1996; Jones and Macfarlane 2005; Hestbaek et al. 2006). However, after this time, other factors including occupational exposure, lifestyle, psychosocial factors and back pain beliefs may explain the majority of LBP episodes. The increase in LBP prevalence rates from NS to GN in this study can be attributed to factors such as occupational exposure once commencing nursing employment, rather than age, as age was clearly shown to have no influence over LBP prevalence rates.

The older student population in this study may reflect the recent Australian nursing staff undersupply and a resultant changing nature of the workforce in Australia. Between 1995 and 2002 in Australia the average age of working nurses rose by 3 years, and there was a reduction in nurses per 100,000 population (Chrisopoulos and Waters 2003). There has been a subsequent government campaign to increase the numbers of qualified nursing staff in Australia. As a result, some nurses are returning to the workforce following extended absence, and others are opting for nursing as a career change later in life. This is having a relative aging effect on both the qualified and student nursing populations (Stein-Parbury 2000).

2.3.2. LBP characteristics

Most LBP reports for undergraduate NS and GN appear to be recurrent in nature, with symptoms lasting only a few days. Only a small proportion of respondents had LBP lasting more than one month in the previous year. These results suggest that the majority of reported episodes of LBP were pain of short duration and, given the high lifetime LBP prevalence among 1st year NS, first time LBP occurred prior to the commencement of nursing studies. This is in line with findings of high LBP prevalence rates in adolescent populations (McMeeken et al. 2001; Sjolie 2004). Given the best predictor of future LBP is a previous history of LBP (Smedley et al. 1997; Jones and Macfarlane 2005; Videman et al. 2005), targeting preventative strategies at younger populations where LBP prevalence is already high should be considered.

Around 60% of all NS and GN had what could be classified as clinically significant LBP in the preceding 12-month period, in that they required at least one of either medication, treatment or activity modification due to their LBP. Although these figures do not indicate the related levels of disability and the fact that most LBP episodes are relatively short, this statistic is significant given the strong predictive factor previous LBP has on future LBP recurrence and chronicity (Jones and Macfarlane 2005).

Activity reduction as a means of dealing with LBP steadily declined from 1st year NS to GN (44% v 23%). Conversely, medication consumption was less with first year students than other year groups. GN were even more reliant on medication (43% compared with 33% of 3rd year NS). It appears medication consumption, compared to activity reduction is a preferred management option for dealing with LBP among this nursing population. Previous reports indicate that the one month prevalence of pain medication consumption in nurses to be as high as 88% (Trinkoff et al. 2001). The increased medication consumption of GN compared with NS, without a concurrent reduction in activity levels may reflect the difference in pain coping strategies among these groups.

2.4.3. LBP aggravating factors

Across all NS and GN, bending / lifting was the most frequently reported LBP aggravating factor. Over 65% of all NS selected ‘bending / lifting’ as the predominant aggravating factor, but this increased to 75% of GN. The lack of increase in report of bending or lifting aggravating NS LBP over the duration of the nursing training fails to reflect the different task demands and clinical exposure of the different year groups. This result may be influenced by leisure time activities (O'Sullivan et al. 2006) or may denote a reduction in bending and lifting now present in nursing training, even in the latter half of the course where clinical exposure increases (Felstead and Angrave 2005). Sitting / driving was also a frequently reported LBP aggravating factor. The difference in reported levels of LBP associated with sitting / driving between second and third year students (14% decline) was significant. This may reflect a reduction in sitting exposure for these students with the change in weighting of course content from more lectures / tutorials in second year, to increased clinical contact in third year.

Also of note is that after approximately 12 months of full time employment as a nurse, 65% of GN felt their back pain was occurring more frequently, and 39% felt their LBP was more severe. Further, 35% felt their LBP was both more frequent and more severe. Although this could be interpreted as a significant worsening of LBP once commencing full time employment, the proportion of subjects with constant, or almost constant LBP, did not change between NS to GN. This reported increase in LBP severity and episode duration once commencing full time employment is more likely to be a reflection of increased occupational exposure to tasks such as bending and lifting, given age was constant among our sample year groups. This is reflected in the 10% increase in reports of LBP being aggravated by bending / lifting from 3rd year NS to GN.

Despite GN working in a “no lift policy” environment, as is now common in many hospitals (Nelson et al. 2006), pain aggravated by bending or lifting sharply increased after commencing full time employment. If this reflects an increase in occupational exposure to bending tasks, the effect of hospital “no lift policies” on reducing LBP may be questionable (Jensen et al. 2006). Reducing the lifting component of manual handling may reduce exposure only to high load tasks. Although LBP is often attributed to bending and lifting, with workplace reports of gradual onset LBP being more common, a direct link to specific incident injuries may be attributed to beliefs of nurses rather than actual injury cause (Smedley et al. 2005). Causes of LBP identified by nurses has previously been shown to differ from actual work tasks performed (Harber et al. 1988).

Worker’s compensation statistics in Western Australia highlight a changing trend for health care workers from single traumatic event back injuries, to more cumulative mechanical stress related LBP in the workplace (Stansbury and Lim 2004). This may reflect the need to consider the importance of sustained and repetitive non-lifting manual nursing tasks such as bending and sitting in the prevention of LBP. Furthermore identifying the risk factors related to back pain aggravation with bending and lifting, and developing preventative programs to deal with these issues before NS reach the hospital wards may also prove beneficial.

The results of this study indicate that the majority of first LBP episodes are occurring prior to commencing full time employment, and probably even before commencing nursing studies. Given the focus on reducing injuries in nursing populations in the workplace have been relatively ineffective (Fanello et al. 2002;

Smedley et al. 2003) and the best predictor of previous LBP is a history of LBP (Smedley et al. 1997), perhaps the emphasis should shift towards identifying factors associated with LBP in younger populations, and developing targeted early interventions, rather than addressing patterns of LBP recurrence and chronicity which are well established in working nurses.

2.4.4. Limitations

Whilst 83% of GN completed the survey, only 54% of eligible NS completed the survey. NS were sampled in lectures, with only approximately 60% of NS attending. Of those who attended, 96% responded. Thus although response rates were above the minimum required a potential bias remains if there are different back pain characteristics in those who did not attend the lectures. There are also limitations in cross sectional survey data, specifically the potential for survey responders to overestimate their LBP symptoms (Papageorgiou et al. 1995). Response bias should have been minimised by the brief, anonymous, cross-sectional nature of the survey. It should also be considered that one difficulty in comparing LBP prevalence results between studies is the range of definitions of what constitutes LBP (de-Vet et al. 2002). The Nordic LBP Questionnaire, as used in this study, does not stipulate pain severity or symptom duration, so is likely to yield a higher LBP prevalence rate than other questionnaires which may consider these factors (Buckle 1987). The novel questions added to the survey were not specifically assessed for reliability or validity, however they were based on commonly used questions of LBP patients in the clinical setting.

The high average age of NS in this study suggests nursing may not have been the first career for some subjects. LBP statistics may therefore include subjects with LBP associated with their careers prior to commencing nursing studies. Although this makes determining LBP causes more complex, this sample may be reflective of changing nursing populations around the world. Given the international shortage of qualified nursing staff, future NS populations are unlikely to consist primarily of young adults commencing their first careers.

This study considered age and increased occupational exposure, however other additional information regarding more specific causes of LBP, such as working with orthopaedic or geriatric patients, and activity levels outside study / work, was not collected. Considering more individual personal characteristics may warrant investigation in a prospective study of young NS. Clear differentiation also needs to be made in future studies between bending and lifting exposures, as repetitive bending may well be as important as heavy lifting in the development or recurrence of LBP. These results pertain to a specific population, therefore further research is required to determine whether these findings also relate to other populations with high levels of manual handling exposure.

2.5. Conclusions

LBP prevalence rates were very high among NS and GN, but there were no differences between the three year groups of NS surveyed. GN compared with NS reported increased LBP prevalence, recurrence and severity. The NS and GN continue to report the majority of their LBP was aggravated by bending or lifting despite recent attempts to reduce manual workplace demands (lifting) on nurses. Occupational exposure appears to be an important factor associated with the development of LBP. Age had no effect on LBP in this group of NS and GN. The majority of first episodes of LBP are occurring prior to commencing undergraduate studies. Further prospective studies are required to identify factors associated with LBP recurrence in order to develop appropriately targeted early intervention programs.

2.6. Acknowledgements

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CHAPTER 3 – Study II

Spinal posture is commonly a focus in the assessment and clinical management of LBP patients. However, the link between spinal posture and LBP is not fully understood. Further, current literature does not consistently support the relationship between spinal posture and LBP. It is proposed this may be partly due to the methods of measurement of spinal posture. Recent evidence suggests that considering regional, rather than total lumbar spine posture is important.

The *general aim* of this study was to investigate if there are regional differences in habitual lumbar spine posture and movement. The specific aims and its overall place in this doctoral research are shown in Figure 3.0.

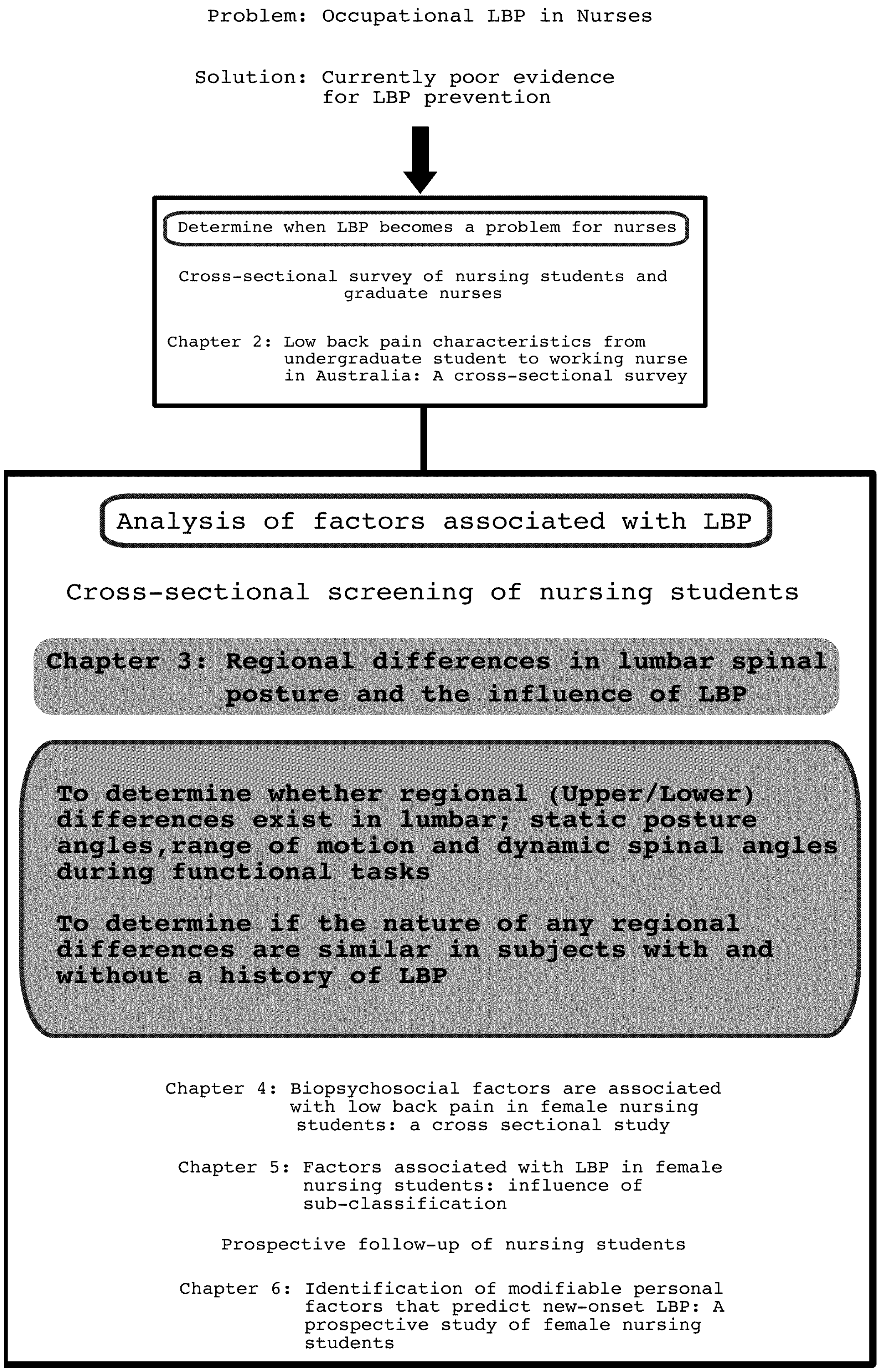

Figure 3.0. Schematic representation of Study II within the thesis.

Regional differences in lumbar spinal posture and the influence of low back pain

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3.0. Abstract

Background: Spinal posture is commonly a focus in the assessment and clinical management of low back pain (LBP) patients. However, the link between spinal posture and LBP is not fully understood. Recent evidence suggests that considering regional, rather than total lumbar spine posture is important. The purpose of this study was to determine; if there are regional differences in habitual lumbar spine posture and movement, and if these findings are influenced by LBP.

Methods: One hundred and seventy female nursing students, with and without LBP, participated in this cross-sectional study. Lower lumbar (LLx), Upper lumbar (ULx) and total lumbar (TLx) spine angles were measured using an electromagnetic tracking system in static postures and across a range of functional tasks.

Results: Regional differences in lumbar posture and movement were found. Mean LLx posture did not correlate with ULx posture in sitting ($r = 0.036$, $p = 0.638$), but showed a moderate inverse correlation with ULx posture in usual standing ($r = -0.505$, $p < 0.001$). Regional differences in range of motion from reference postures in sitting and standing were evident, with more motion occurring in the ULx spine in sitting ($F = 85.34$, $p < 0.001$) whilst there was more movement in the LLx spine in standing ($F = 4.203$, $p = 0.042$). BMI accounted for regional differences found in all sitting and some standing measures. Significant LBP was associated with decreased total lumbar extension movement compared to No Pain (-3.7^0, 95%CI: -6.3^0 to -1.0^0) or Mild Pain (-3.1^0, 95%CI: -5.3^0 to -1.0^0). However, LBP was not associated with any differences in regional lumbar spine angles or range of motion, before or after adjustment for BMI.

Conclusions: This study supports the concept of regional differences within the lumbar spine during common postures and movements. Global lumbar spine kinematics do not reflect regional lumbar spine kinematics, which has implications for interpretation of measures of spinal posture, motion and loading. BMI influenced regional lumbar posture and movement, possibly representing adaptation due to load.

3.1. Introduction

Low back pain (LBP) remains one of the most expensive medical conditions in manual workers including nurses (Stansbury and Lim 2004). Opinion remains divided regarding optimal LBP management (Waddell 2004b). Although retraining “ideal” spinal posture is a common component of the clinical management of non-specific LBP patients (Scannell and McGill 2003; O'Sullivan 2005), the direct relationship between spinal posture and LBP still remains unclear.

Evidence of both a relationship (Dankaerts et al. 2006; O'Sullivan et al. 2006a), or no relationship (Tuzun et al. 1999; Widhe 2001) between posture and LBP has been reported in previous *in-vivo* posture studies. These conflicting findings may be due to posture being relevant to LBP in some populations but not others, or alternatively may be explained by methodological differences. When investigating posture, measures need to possess sufficient discriminative validity (van Dieen et al. 1996). Clinically, LBP patients report more pain in the lower lumbar (LLx) spinal segments than upper lumbar (ULx) segments (Biering-Sorensen 1983; Beattie et al. 2000). This is consistent with a greater degree of degeneration being evident in the LLx spinal segments (Twomey and Taylor 1987; Quack et al. 2007), which is thought to be due to the greater mechanical stress through these segments (Adams et al. 2002). Given some individual lumbar spinal segments show greater degenerative changes than other lumbar segments, the notion of the lumbar spine as a homogenous region may not provide a true reflection of pain and function in this region.

To date, the concept of considering the motion and function of the lumbar spine in terms of LLx and ULx regions has been proposed (Burton 1987), but not widely investigated (van Dieen et al. 1996). The majority of studies examining LBP have not considered lumbar spinal posture in separate regions, which may help explain the consensus of no direct link between spinal posture and LBP (Raine and Twomey 1994; Lis et al. 2007). Other factors including gender (Widhe 2001) and BMI (Gilleard and Smith 2007), which are known to influence posture, may also confound this issue. However, there is emerging *in-vivo* evidence of links between posture and LBP. Dankaerts and colleagues showed differences in usual sitting posture between LBP patients and healthy controls (Dankaerts et al. 2006). Importantly, these differences were only evident when the lumbar spine was considered as separate regions (LLx and ULx), and when LBP subjects were sub-classified according to directional pain provocation patterns (Dankaerts et al. 2006).

The concept of considering regional motion and function of the lumbar spine during functional tasks has only recently been investigated. Gill and associates identified the importance of considering the lumbar spine as having separate regions, rather than viewing it as a rigid section, when measuring spinal lifting patterns (Gill et al. 2007). Their recent study examining healthy subjects has shown a lack of variation of LLx spine posture when commencing lifting, irrespective of both the lifting technique used, or the distance the load is away from subject’s feet (Gill et al. 2007). In this study, movement variation when lifting was found to occur in the ULx and mid thoracic spine, rather than the LLx spine. These findings in healthy controls are yet to be examined in a LBP population.

Further investigation of regional differences in ULx and LLx spine function across different functional tasks relevant to specific work populations is required, as many LBP patients report symptom aggravation across a number of activities or postures other than just lifting (Mohseni-Bandpei et al. 2006). The primary hypothesis of this study was that regional lumbar spine differences would be evident in standing and sitting postures, as well as for spinal angles and range of motion during functional tasks.

The aims of this study were to determine:

1. whether regional (LLx / ULx) differences exist in spinal sagittal; static posture angles, range of motion and dynamic spinal angles during functional tasks.
2. if the nature of these differences vary in subjects with and without a history of LBP.

3.2. Methods

3.2.1. Design

This cross-sectional study was part of a larger prospective study into patterns of LBP in nursing students. This current study examined the LBP characteristics and spinal kinematics across a range of static postures and functional tasks of female undergraduate nursing students.

3.2.2. Sample

Data were collected on 170 female undergraduate nursing students recruited via personal invitation from two undergraduate university nursing programs. Subjects were aged between 18 and 35 years and were in their second or third year of their programs at the time of the study. Ethical approval to conduct the study was granted from Curtin University of Technology and Edith Cowan University ethics committees, and written informed consent from subjects was obtained (Appendix 1).

3.2.3. Protocol

Subjects were excluded if they had; an inability to understand written or spoken English, presence of other conditions affecting the spine or lower limbs including inflammatory disorders, neurological diseases or metastatic disease, pregnancy or less than 6 months post-partum, or inability to assume the test postures. Subjects both with and without a history of LBP were included in the study. As acute LBP has been shown to influence spinal posture (Harrison et al. 1998) and motor control (Hodges et al. 2003), subjects who had LBP which limited their performance of the test procedures (pain greater than 3 out of 10 on a VAS at the time of testing) were excluded (1 subject).

3.2.4. LBP characteristics

Based on a previous survey of LBP in a similar nursing student sample (Mitchell et al. 2008), a range of LBP severity was expected. To investigate the influence of LBP, subjects were divided into three LBP categories; No LBP, Minor LBP and Significant LBP. Considering the multifactorial influences of LBP (Waddell 2004a), and variance in prevalence based on LBP definition (Marras et al. 2007), Significant LBP group allocation was defined by a combination of indicators across a range of domains based on previous LBP research. These indicators were:

- Lifetime LBP Severity. Subjects were asked to rate their worst ever LBP on a visual analogue pain scale (> 4/10. Based on mean episodic LBP severity data (Bolton 1999)).
- Duration of LBP in previous 12 months. Taken from Nordic LBP Questionnaire (Kuornika et al. 1987) (>1 week. To differentiate subjects with a single very short LBP episode of high severity).

- LBP requiring treatment or medication or a reduction in activity in the past 12 months (Adams et al. 1999).
- LBP disability levels at the time of testing measured by the Oswestry Disability Index (ODI) (Fairbank et al. 1980), (>20% based on mean ODI score for primary LBP of 26% (Fairbank and Pynsent 2000)).

Subjects who scored above the designated cut off score in at least three of the four categories were deemed to have Significant LBP. The remaining LBP subjects who reported some pain in the previous 12 months, but did not satisfy the criteria for Significant LBP were considered as having Minor LBP (Table 3.1).

Subjects attended a single testing session at their university. A modified version of the Nordic Low Back Pain Questionnaire (Kuornika et al. 1987) was used to determine LBP history, frequency and severity. LBP disability levels were measured using the ODI. BMI was calculated from height and weight measures to control for its known influence on spinal posture and motion (Gilleard and Smith 2007). The static spinal postures measured were usual sitting and usual standing. Sagittal spinal ranges of motion were measured as the difference between usual sitting and maximal slumped sitting and usual standing and; sway standing, maximal forward bending and maximal backward bending in standing. Peak sagittal angles were measured during a range of functional tasks chosen with consideration of likely repetitive movements and sustained postures associated with university study and nursing duties. Test postures are shown in Figure 3.1.

Table 3.1. Subject Demographics and LBP Characteristics

	No LBP (n = 36)	**Minor LBP (n = 81)**	**Significant LBP (n = 53)**
Age (mean + SD, years)	21.7 ± 3.5	22.0 ± 4.2	23.9 ± 5.1
BMI (mean + SD, kg/m$^{2)}$	21.9 ± 2.8	23.3 ± 4.3	23.1 ± 3.4
Lifetime highest VAS (mean + SD, /10)	0	3.9 ± 2.3	6.6 ± 1.6
Annual LBP Duration (range, days)	0	1-7	8-30
Requiring treatment, medication or activity reduction past 12-months (%)	0	44.4	96.2
Oswestry Disability Index (mean + SD)	0	10.4 ± 6.6	21.2 ± 9.2

BMI = body mass index. VAS = visual analogue scale.

3.2.5. Static Sitting and Standing Posture

It is acknowledged that measuring true "usual" posture is difficult in the laboratory setting. However, subjects were covertly observed when completing questionnaires prior to physical testing to gain an idea of their "usual" sitting posture, and to ensure a similar posture was adopted during testing. Further, subjects were not aware when the "usual" standing and sitting measures were being recorded, as they performed a number of tasks that involved sitting or standing as the starting position. Usual sitting and standing postures were measured as follows using a previously described protocol (Dankaerts et al. 2006):

1. Subjects were asked to sit on a stool, which was selected to allow their thighs to be parallel with the floor and knees flexed at 90°. No direction of how to sit or an indication of what was being measured was provided. This position was recorded for five seconds as their usual sitting posture (defined as the sitting posture they would usually adopt during unsupported sitting).
2. Subjects were asked to stand comfortably at a predetermined position. Whilst no specific instruction of how to stand was given, all subjects stood with their feet parallel. This position was recorded for five seconds as their usual standing posture (defined as the standing posture they would usually adopt during habitual unsupported standing).

3.2.6. Range of motion in sitting and standing

1. From the usual sitting position subjects were then assisted into their end of range lumbar flexion sitting posture for five seconds by an experienced therapist using standardised cues of asking the subject to "slouch" and using hand cues on the lateral shoulder and pelvis to guide posterior pelvic tilting.
2. Sway standing posture was defined as subject's relaxed standing posture with the pelvis translated anteriorly relative to the trunk. All subjects were guided into this position from their usual standing position for five seconds by the same experienced therapist. Excellent reliability of positioning subjects in sway posture has been shown previously (O'Sullivan et al. 2002).
3. Subjects were then asked to bend forwards as far as possible from standing, with their knees straight, and a five second recording in this position was defined as maximal forward bending.

4. Similarly, maximal backward bending was measured by asking subjects to then bend backwards as far as possible for five seconds, keeping their feet stationary.

All posture and range of motion measures were repeated three times.

3.2.7. Functional tasks

1. While in the standing position, a pen was placed in front of subjects and they were asked to pick it up. Subjects were directed to pick up the pen as if they had just dropped their own pen on the floor and needed to retrieve it. This test was performed once.
2. Subjects were then directed to pick up a moderate (5kg) load in a box with handles 20cm above floor height. No cues were given regarding how to pick up the box. This and subsequent tasks were repeated three times.
3. An adjustable bed was then set at a height 10cm above each subject's superior patella margin as a standardised height. The task involved transferring a pillow from left to right a distance of 75cm, then back to the starting position. Subjects initially stood at the mid point between the pillow and target position marked on the bed, then were asked to transfer the load, with no specific directions regarding how to lift.
4. The task involving transferring a pillow was then repeated using a 5kg box.

3.2.8. Squatting

Subjects were seated on a stool, with thighs parallel and knees flexed at 90°, and their arms folded across their chest. Subjects were then asked to adopt a squat position with their buttocks just clear of the stool, by an experienced therapist using standardised cues. This test was also used for a measure of leg muscle endurance, so only one trial was conducted. Subject's lumbar spine posture was recorded throughout the squat test, with a five second Fastrak™ data sample taken as their squat position once their position was stable after rising from the stool.

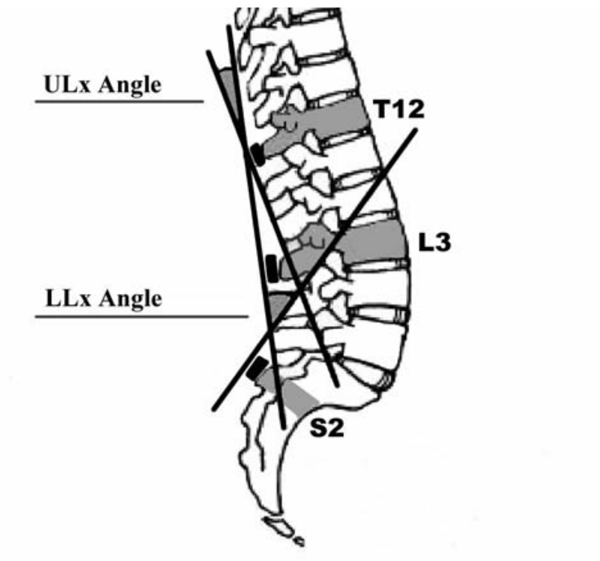
Figure 3.1. Test postures.

3.2.9. LLx, ULx and TLx angle measurement

Lumbar spine sagittal plane (flexion / extension) angles (measured in degrees) were derived from sensors placed over T12, L3 and S2 using 3-Space® Fastrak™ (Polhemus, Kaiser Aerospace, Vermont) and custom software written in LabVIEW V8 (National Instruments, Texas, USA). LLx (L3-S2), ULx (T12- L3), and total lumbar (TLx) angles (T12-S2) were calculated, as previously defined (see Figure 3.2) and shown to possess excellent inter-trial reliability in sitting (Dankaerts et al. 2006). Reliability and validity of the Fastrak™ system for measuring spinal range of motion has been demonstrated (Pearcy and Hindle 1989; Jordan et al. 2004). The Fastrak™ system is widely used in clinical research, however there are limitations of externally fixated measurement devices which have been discussed is detail elsewhere (Mannion and Troke 1999). Extension in the sagittal plane was assigned a positive value, and flexion a negative value.

For usual sitting and standing the mean angle of three trials (averaged over 5 seconds of data collection) was calculated and used for subsequent analysis. For range of motion, the mean peak angle of three trials (averaged over 5 seconds subject held position) was calculated for each of; maximal slumped sitting, sway standing and maximal forward and backward bending in standing was subtracted from the usual sitting or standing angle. The mean peak sagittal angles were calculated for the functional tasks. As there was no sustained hold during these tasks (except for the squat), the customised analysis software determined the peak sagittal flexion (or least sagittal extension) angle reached between the manually tagged start and finish of the task. Range of motion from the reference position of usual standing to the peak angle in each functional task also calculated to compare relative motion between LLx and ULx regions during these tasks.

Inter-trial reliability (from three trials for each subject) for all LLx, ULx and TLx repeated measures in this study were excellent. For the LLx spine, the mean $ICC_{(3,1)}$ was 0.97 (range: 0.93 - 0.99) and mean SEM was 2.0° (range: 0.5° - 2.5°). For the ULx spine, the mean $ICC_{(3,1)}$ was 0.94 (range: 0.87 - 0.99) and mean SEM was 2.1° (range: 0.5° - 3.1°). For the TLx spine, the mean $ICC_{(3,1)}$ was 0.95 (range: 0.87 - 0.99) and mean SEM was 2.7° (range: 0.6° - 4.7°).



LLx = lower lumbar, ULx = upper lumbar. Total lumbar angle is the angle formed between the tangents from the sensors at T12 and S2.

Figure 3.2. Spinal model used for the calculation of lumbar angles.

3.2.11. Statistical Analysis

As this study was part of a larger prospective study, sample size calculations were not specific to this study. However, calculations using Intercooled Stata 9.2 for Windows (Statacorp LP, College Station: USA) indicated over 99% power to detect half of one standard deviation difference in range of motion between ULx and LLx angles within the 170 subjects (even when assuming a strong correlation of 0.9 between ULx and LLx angles). All other statistical analyses were performed using SPSS Student Version 13.0 (SPSS, Chicago: USA). A series of repeated measures ANCOVA for each posture or task, with the within-subject contrast being lumbar region, and the between-subject contrast being pain group, adjusting for BMI were used. For each task, the partial correlation between lumbar, regions adjusted for BMI, were calculated. The criteria for statistical significance was set at $p < 0.05$.

3.3. Results

In usual sitting posture, the LLx spine was on average in an extended position, while the ULx spine was on average held in a slightly flexed (kyphotic) position. These mean LLx and ULx angles were significantly different ($F = 28.23$, $p < 0.001$). However, BMI was positively and significantly correlated with both LLx (r=0.238, p=0.002) and ULx (r=0.203, p=0.008) position. After adjusting for BMI, LLx and ULx angles were not significantly different ($F = 0.46$, $p = 0.497$). As shown in Table 3.2, the same pattern was seen with slump sitting, where ULx and LLx differences were no different after adjusting for BMI. Correlations between LLx and ULx angles are reported adjusted for BMI, however BMI had minimal effect on these correlations. In usual and slump sitting, subjects' LLx angle showed no correlation with ULx angle.

In usual standing, both the LLx and ULx angles were on average in an extended (lordotic) position. BMI was not correlated with LLx position (r=-0.023, p=0.767) but was positively and significantly correlated with ULx position (r=0.194, p=0.011). Even after adjusting for BMI, there was significantly more extension in the LLx spine than the ULx (see Table 3.2). The same pattern of more LLx extension was seen with sway standing and maximal extension in standing, but these differences were not significant after adjusting for BMI. In usual and sway standing and maximal extension, subjects' LLx angle showed a moderate inverse correlation with ULx angle.

The TLx sagittal range of motion (difference between maximal forward and backward bending angles) in standing was on average approximately 96° for all subjects, with a significantly greater proportion (58% v 42%) of this in the LLx spine compared with the ULx spine (F = 4.203, p = 0.042). BMI was positively correlated with LLx motion (r = 0.172, p = 0.025) but negatively correlated with ULx motion (r = -0.508, p < 0.001).

Table 3.2. Comparisons between ULx and LLx static and peak angles across postures and tasks. Repeated measures ANCOVA and correlations adjusted for BMI.

Posture / Activity	LLx angle (°)	ULx angle (°)	p-value	p-value adjusted for BMI	LLx / ULx correlation (p-value)
Usual sitting	4.1 ± 8.8	-1.3 ± 8.8	< **0.001**	0.497	0.036 (0.638)
Usual standing	23.4 ± 11.2	15.5 ± 9.6	< **0.001**	**0.016**	- 0.505 **(< 0.001)**
Slump sitting	1.6 ± 9.1	-8.6 ± 6.1	< **0.001**	**0.770**	- 0.111 (0.151)
Sway standing	31.2 ± 13.6	17.4 ± 11.9	< **0.001**	0.576	- 0.58 **(< 0.001)**
Maximal flexion	-11.8 ± 6.8	-15.4 ± 5.9	< **0.001**	0.026	- 0.062 (0.426)
Maximal extension	44.1 ± 19.9	25.8 ± 16.0	< **0.001**	0.183	- 0.509 **(< 0.001)**
Picking up pen	-8.1 ± 7.2	-12.5 ± 6.3	< **0.001**	0.015	0.197 **(0.012)**
Picking up box	-5.3 ± 8.3	-8.5 ± 8.5	< **0.001**	0.108	0.274 **(< 0.001)**
Transferring pillow	3.5 ± 8.5	-4.7 ± 8.3	< **0.001**	0.013	- 0.017 (0.825)
Transferring box	8.4 ± 8.9	1.7 ± 8.4	< **0.001**	0.031	- 0.147 (0.062)
Squat	-3.2 ± 9.0	-2.9 ± 9.6	0.866	0.968	0.346 **(< 0.001)**

LLx = Lower Lumbar, ULx = Upper Lumbar, BMI = Body Mass Index, Negative value = relative flexion (kyphosis) of lumbar spine.

When changing postures from both sitting and standing positions, the LLx and ULx spine displayed different patterns of movement across all subjects. With usual sitting posture as the reference angles, when moving from usual sitting to slump sitting, the majority of movement occurred at the ULx spine, with significant differences between LLx and ULx movement ($F = 85.34$, $p < 0.001$). However, BMI was negatively correlated with LLx motion ($r = -0.313$, $p < 0.001$) but not correlated with ULx motion ($r = 0.056$, $p = 466$) and after adjustment for BMI the differences between LLx and ULx movement were not significant at the critical alpha level [($F = 3.28$ $p = 0.072$) see Table 3.3]. Conversely, with usual standing posture as the reference angles and adjusting for BMI, there was significantly more LLx movement compared to ULx movement when moving from; 1. Usual standing to maximal forward bending, 2. Usual standing to maximal backward bending, and 3. Usual standing to a sway standing posture. For the 2nd and 3rd task, BMI was positively correlated with LLx motion ($r = 0.257$, $p = 0.001$ and $r = 0.327$, $p < 0.001$ respectively) but negatively correlated with ULx motion ($r = -0.343$, $p <0.001$ and $r = -0.477$, $p < 0.001$).

For the functional tasks, statistically significant differences were found between LLx and ULx peak angles for picking up a pen, picking up a box, transferring a pillow, and transferring a box, but not for squatting. However, after BMI adjustment, differences were only significant for picking up a pen and transferring a pillow and a box (Table 3.2). BMI was not correlated with these measures.

When comparing the differences in how far the LLx and ULx spine moved from the reference usual standing position to the peak angle position during functional tasks, picking up a pen, lifting a box from the floor, and squatting tasks all involved significantly more movement in the LLx spine. Only the difference in squatting remained significant after adjusting for BMI however (Table 3.3).

3.3.1. Effect of LBP

Total lumbar backward bending range of motion in standing was the only measure that was significantly different between pain groups ($F=5.18$, $p=0.007$). Significant LBP was associated with decreased backward bending movement compared to No Pain (-3.7^0, 95%CI: -6.3^0 to -1.0^0) or Mild Pain (-3.1^0, 95%CI: -5.3^0 to -1.0^0), and these estimates were unaffected by BMI. However, low back pain did not modify regional differences in any lumbar spine angle or range of motion before or after adjustment for BMI. Correlations between LLx and ULx were similar between pain groups across all tasks.

Table 3.3. Comparisons between upper lumbar and lower lumbar spine range of motion across postures and tasks. Repeated measure ANCOVA and correlations adjusted for BMI.

Posture / Activity	LLx angle (°)	ULx angle (°)	p-value	p-value adjusted for BMI	ULx / LLx correlation (p-value)
Usual to slump sitting	2.5 ± 4.0	7.3 ± 7.0	**< 0.001**	0.072	0.525 **(< 0.001)**
Usual to sway standing	8.2 ± 5.4	0.8 ± 5.4	**< 0.001**	**< 0.001**	- 0.469 **(< 0.001)**
Usual stand to full flexion	35.0 ± 10.0	30.8 ± 9.9	**0.003**	0.033	- 0.442 **(< 0.001)**
Usual stand to full extension	20.6 ± 13.3	8.9 ± 11.1	**< 0.001**	0.001	- 0.426 **(< 0.001)**
Total standing ROM	55.7 ± 18.6	39.8 ± 17.0	**< 0.001**	**0.042**	- 0.460 **(< 0.001)**
Usual stand to pick up pen	31.4 ± 9.9	28.0 ± 9.1	**0.004**	0.140	- 0.332 **(< 0.001)**
Usual stand to pick up box	28.7 ± 10.2	24.0 ± 10.1	**< 0.001**	0.069	- 0.142 (0.071)
Usual stand to transfer pillow	19.9 ± 8.2	20.3 ± 9.3	0.775	0.290	- 0.186 **(0.018)**
Usual stand to transfer box	15.0 ± 7.3	13.9 ± 8.2	0.170	0.160	- 0.041 (0.601)
Usual stand to squatting	26.5 ± 10.2	18.4 ± 11.8	**< 0.001**	**0.009**	- 0.008 (0.918)

LLx = Lower Lumbar, ULx = Upper Lumbar, BMI = Body Mass Index, ROM = Range of Motion. Angle differences are expressed as absolute values.

3.4. Discussion

This study supports and extends previous literature that found global lumbar spine kinematics do not accurately reflect kinematics of the ULx or LLx spinal regions (Burton 1987; Dankaerts et al. 2006; Gill et al. 2007). Rather the ULx and LLx spine display some functional independence and for the purposes of investigation of spinal posture, motion and loading, these regions should be considered separately.

3.4.1. Sitting

The lack of correlation between LLx and ULx angles in usual sitting is consistent with a previous investigation of sitting posture (Dankaerts et al. 2006) and supports the concept of regional differences. On average, the LLx spine in usual sitting was slightly extended, while the ULx spine was slightly flexed. When moving from a usual sitting to slump sitting position, the majority of motion occurred in the ULx spine, which also confirms the findings of Dankaerts et al using similar sitting protocol (Dankaerts et al. 2006). This movement from usual to slump sitting showed a moderate positive correlation, which is consistent with both lumbar regions moving towards their end of range flexion position.

These differences in LLx and ULx spine posture and motion in sitting were accounted for by subject's BMI, as BMI was positively correlated with LLx and ULx angles and this may be an indication that the body adapts its position in response to load. There is some evidence of BMI modifying posture and movement of the lumbar spine (Gilleard and Smith 2007), and different movement strategies from sitting to standing have been reported between obese and normal individuals (Sibella et al. 2003). Other possible examples of the body adapting its position in response to load are the reduction in sitting and standing sagittal thoraco-lumbar motion with pregnancy (Gilleard et al. 2002) and self reported improvement in spinal pain and posture following breast reduction surgery (Glatt et al. 1999; Mizgala and MacKenzie 2000).

3.4.2. Standing

In usual standing posture, there was more extension in the LLx than ULx segments. These angles showed a moderate inverse correlation, supporting their functional difference. Across all subjects, total sagittal range of motion in standing was similar to results reported in other studies (Dvorak et al. 1995; Troke et al. 2001) and the finding of a greater proportion of this motion occurring in the LLx spine is also consistent with previous findings (Pearcy et al. 1984; Tallroth et al. 1992).

Regional differences were also evident in lumbar movements from usual standing to positions of forward and backward bending as well as sway standing, with the majority of motion occurring at the LLx spine. Although previously clinically hypothesized (O'Sullivan 2000; O'Sullivan 2005), this study provides quantitative data that supports the idea that movement into the sway standing position is primarily a function of extension motion through the LLx segments, with very little motion occurring in the ULx spine. If adopted habitually, this sway standing position may result in increased load on passive spinal structures in the LLx spine due to inhibition of supporting spinal muscles (O'Sullivan et al. 2002), and may be a possible mechanism for LLx spine pain in some individuals.

Similar to sitting measures, BMI could account for some of the regional differences in static standing angles, particularly sway and maximal extension in standing. This finding is consistent with a recent study showing higher BMI was related to hyper-lordotic standing posture in adolescents (Smith et al. 2008). BMI was moderately negatively correlated with ULx measures and positively correlated with LLx measures, particularly in a number of the range of motion measures. This suggests as BMI increases, ULx motion decreases and LLx motion increases, which supports and extends the findings of Gilleard and co-workers in a study comparing obese and normal individuals (Gilleard and Smith 2007).

3.4.3. Functional Tasks

Regional lumbar spine differences are supported by Gill et al’s findings of LLx angle in healthy controls remaining consistent across different lifting techniques (Gill et al. 2007). In their study, dynamic spinal position changes occurred at the ULx and thoracic spine. The current study adds to these findings, as there was a lack of correlation between LLx and ULx peak angles in the lifting tasks at bed height. Further, LLx and ULx range of motion from the reference position of usual standing to the peak angle in each functional task was either negatively correlated or showed no correlation. There were also significant differences between LLx and ULx peak sagittal angles across all tasks except squatting. Again BMI influenced these findings. Although the role of BMI in spinal posture and function requires further investigation, the results of this study clearly support that regional lumbar posture is influenced by BMI.

3.4.4. The influence of LBP

There was a considerable prevalence of LBP reported in this relatively young sample of female undergraduate nursing students. Although not necessarily disabling, over 30% of the students had LBP that would be regarded as clinically significant. Given the supposed risk for LBP in nurses in relation to bending and lifting duties (Eriksen et al. 2004), this group of nursing students provided an interesting cohort for investigation of the influence of LBP on regional lumbar posture.

Whilst there were clear regional differences in both posture and motion observed in this study, there were no differences in these variables between subjects with and without LBP. This data suggests regional spinal angles are not important variables when subjects are sub-grouped according to LBP severity. This finding conflicts with other gender controlled evidence that individuals with LBP stand with less LLx lordosis (Jackson and McManus 1994), or greater lower lumbar lordosis than healthy controls (Korovessis et al. 1999). These conflicting results may be due to methodological differences, or alternatively may indicate that the manner by which LBP subjects are sub-grouped greatly influences whether postural differences are detected. For example regional differences in spinal posture have been shown between LBP and control subjects when patients are sub-grouped according to a mechanism based classification system (Dankaerts et al. 2006).

There is evidence for both a loss of segmental lordosis and excessive lower lumbar lordosis in different sub-groups of chronic LBP patients when classified on the basis of directional pain provocation (O'Sullivan et al. 1997; Dankaerts et al. 2006). Determining appropriate sub-classification of non-specific LBP populations appears to be a consensus in LBP research findings (Borkan et al. 1998). In the current study, sub-classification by LBP severity may have failed to adequately distinguish between LBP postural sub-groups, creating a wash-out effect (Rose 1989). Based on previous research (Jackson and McManus 1994; Dvorak et al. 1995; O'Sullivan et al. 2006b), it is unclear whether the influence of gender on spinal posture or mobility also needs to be considered when interpreting these results.

Only total lumbar sagittal extension motion differed between LBP and control subjects, possibly suggesting spinal range of motion may not be important in LBP in this population. This may mean that subjects did not have high levels of current pain at the time of testing. Previous studies have reported reduced sagittal range of motion in LBP subjects compared with healthy controls (Burton 1987; Wong and Lee 2004; Shum et al. 2005). However other studies suggest segmental hypermobility is present in LBP populations (Kulig et al. 2007), or that both segmental hypermobility and segmental rigidity are evident in different sub-groups of LBP patients (Abbott et al. 2006). Clearly, variable definitions of LBP and different methods of measuring spinal angles (MRI, X-ray, external motion analysis systems) may account for some of these conflicting findings. Alternatively, other factors such as spinal motor control (O'Sullivan 2005; Van Dillen et al. 2007), habitual posturing of the spine (Dankaerts et al. 2006; O'Sullivan et al. 2006a), patterns of spinal loading (Adams and Dolan 1991), neurophysiological (Moseley and Hodges 2006), psycho-social (Papageorgiou et al. 1997; Boersma and Linton 2005), and genetics (Battie et al. 1997) may be more important mediating factors of LBP experience than spinal range of motion, depending on the study population.

Interestingly, BMI did not influence the findings in relation to LBP in this study. This may be related to the lack of group differences in mean BMI scores and that the majority of subjects were within normal BMI range. In contrast, BMI has been associated with LBP in some studies (Leino-Arjas et al. 2006; Naidoo and Coopoo 2007), and evidence of BMI differences between standing postural alignment groups (Smith et al. 2008) may relate to compensatory patterns of loading due to body mass distribution. Given trends of increasing population obesity (Dal Grande et al. 2005), the influence of BMI on LBP may become a greater issue in the future.

3.4.5. Limitations

The results of this study of a moderate size cohort of young female nursing students cannot be generalised across other populations without further research. Particularly, the possibility of different findings between males and females across some of the measures warrants further investigation. The 3-dimensional motion analysis system is not a direct measure of spinal posture, however in a large clinical sample it is a widely accepted tool for the measurement of dynamic functional spinal angles (Mannion and Troke 1999). It also has some clinical validity as a measure of spinal posture, as Dankaerts et al (Dankaerts et al. 2006) were able to use 3-dimensional motion analysis measures to discriminate between both sub-groups of LBP as well as healthy controls.

Measurement of "usual" spinal posture in the laboratory setting is difficult. While efforts were made to blind the subjects as to when measurements of their sitting and standing posture were being recorded, this is an acknowledged weakness of the study. However, a recent study of lumbo-pelvic kinematics showed that after being asked to assume a "usual" sitting posture, subjects did not significantly alter this posture over five minutes of data collection (O'Sullivan et al. 2006b), which adds some validity for this being a measure of "usual" sitting posture.

3.5. Conclusion

This study supports the concept of separate regions of posture and movement within the lumbar spine. LLx posture is not directly related to ULx posture, and knowledge about movement in one region does not inform about movement in the other. Some regional differences in spinal angles are influenced by BMI, supporting that weight distribution has an influence over spinal posture and movement. Static posture angles, range of motion and dynamic spinal angles during functional tasks were not influenced by LBP. Regional lumbar posture and its relationship with recurrent or future LBP episodes is the subject of ongoing prospective research.

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CHAPTER 4 – Study III

Occupational LBP is a significant problem in nurses. Given LBP is already prevalent before commencing employment, there may need to be a shift in the timing and focus of these interventions. As current occupational LBP prevention strategies for nurses have not proven effective, emphasis on targeting personal characteristics within a biopsychosocial framework in prevention strategies may be indicated. Currently, the best personal predictor of LBP is previous history. Therefore, there is a need to identify other *modifiable* personal factors that contribute to LBP in nurses before they commence employment.

The *general aim* of this study was to investigate if there are modifiable personal characteristics within a biopsychosocial framework associated with low back pain in female nursing students. The specific aims and its overall place in this doctoral research are shown in Figure 4.0.

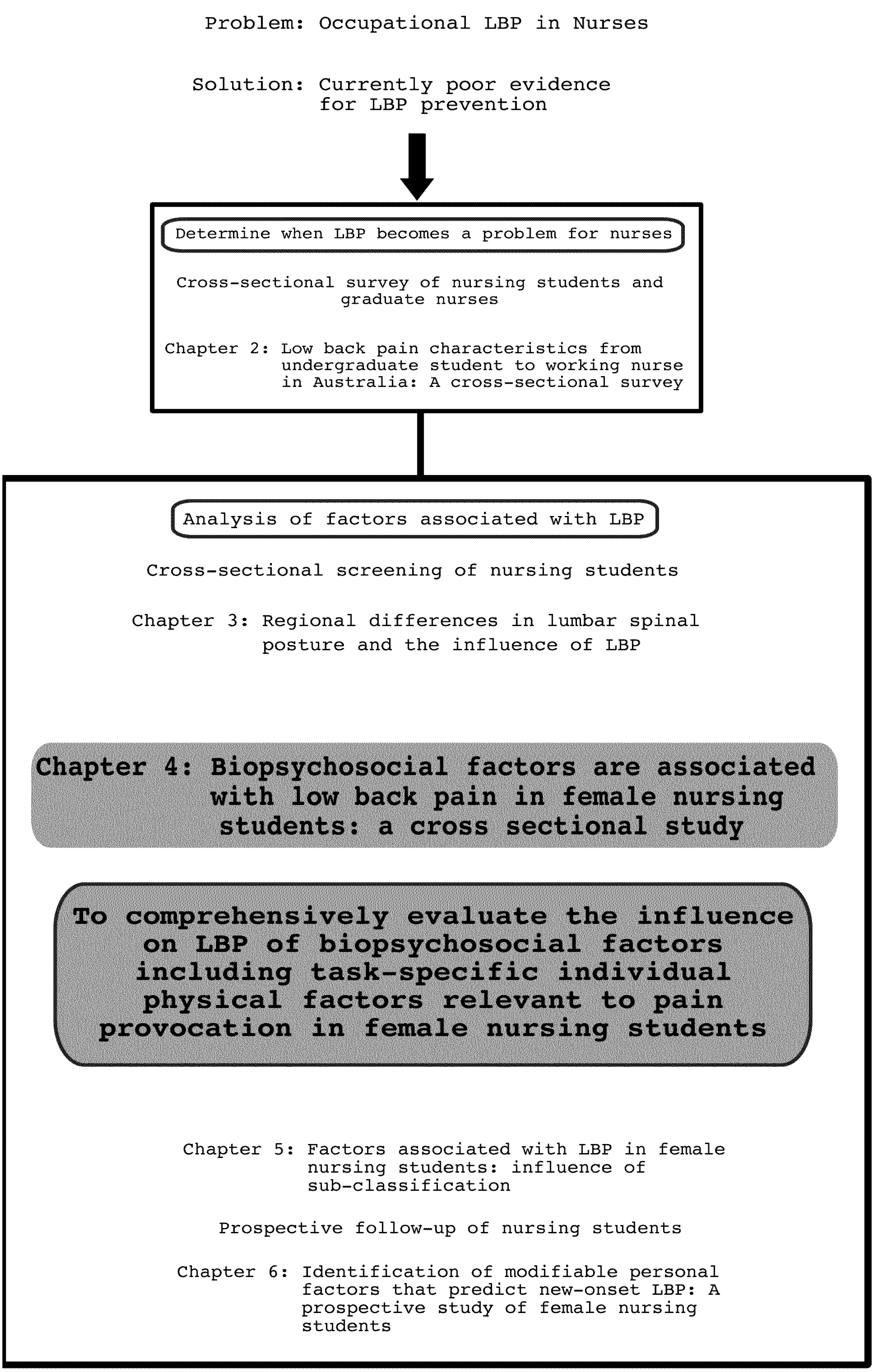

Figure 4.0. Schematic representation of Study III within the thesis.

Biopsychosocial factors are associated with low back pain in female nursing students: a cross sectional study.

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4.0. Abstract

Background: Occupational low back pain is a significant problem among nurses. Recent literature suggests current occupational preventative strategies for nurses have not been effective. Given low back pain is already prevalent before commencing employment, nursing students should be the target of preventative interventions. Modifiable personal factors which contribute to low back pain have proven difficult to identify, but are thought to play an important role in the biopsychosocial nature of low back pain.The aim of this study was to evaluate the contribution of personal biopsychosocial factors to low back pain in nursing students.

Methods: Cross sectional study was conducted on 170 female undergraduate nursing students from two nursing schools in Western Australia. Low back pain and control subjects were compared across social, lifestyle (physical activity), psychological (stress, anxiety, depression, back pain beliefs, coping strategies and catastrophising) and physical (spinal postures and spinal kinematics in functional tasks, leg and back muscle endurance, spinal repositioning error and cardiovascular fitness) characteristics. Low back pain was considered as either "minor" or "significant" depending upon pain severity, duration, impact and level of disability.

Results: Over 30% of all subjects (mean age 22.5 ± 4.5 years) reported "significant" low back pain in the preceding 12 months. *Univariate Analysis:* Social measures did not distinguish between groups. Subjects with "significant" low back pain were more physically active ($p = 0.04$), had higher stress scores ($p = 0.01$) and used passive coping strategies ($p < 0.001$) more than other subjects. "Significant" low back pain subjects held their lower lumbar spine in a more extended posture during transfers at bed height than other subjects. No differences between groups were found for sagittal spinal mobility, static spinal posture, muscle endurance, spinal repositioning error, cardiovascular fitness or other psychological measures. *Multivariate Analysis:* Regression analysis revealed stress, coping, physical activity, spinal kinematics, and

age all contributed independently to the presence of low back pain, representing a significant 23% of variance.

Conclusions: Modifiable lifestyle, psychological and physical factors were independently associated with low back pain in nursing students. Targeting personal factors associated with low back pain in nursing students, rather than occupational factors in working nurses may help improve the impact of low back pain in nurses. Prospective studies are required to confirm the relevance of these findings for risk of future low back pain in nurses.

4.1. Introduction

Low back pain (LBP) is widely regarded as a biopsychosocial problem (Waddell 2004). Occupations such as nursing, which involve physical (Smedley et al. 1997; Mohseni-Bandpei et al. 2006) as well as psychological (Feyer et al. 2000) stressors, are known to increase LBP risk (Violante et al. 2004; Yip 2004). A recent review found there is no strong evidence regarding the efficacy of workplace interventions preventing LBP in nurses (Dawson et al. 2007).

As LBP is already a significant problem among nursing students prior to commencing full-time employment (Videman et al. 2005), LBP prevention should perhaps target nurses before their careers begin (Mitchell et al. 2008). This would require that interventions focus on personal, rather than occupational factors associated with LBP. However, modifiable personal factors that influence LBP need to be identified before successful interventions can be developed.

Currently, previous LBP history explains the largest proportion of group variance in previous studies (Smedley et al. 1997; Feyer et al. 2000), which does not inform underlying mechanisms or guide management. This may suggest that identifying modifiable personal factors associated with non-disabling LBP in younger populations could assist in guiding LBP interventions to prevent future LBP in these populations. This notion is supported by recent research demonstrating that LBP can be prevented by a physiotherapy intervention that targets personal factors in female adolescents (Perich et al. 2007). It is proposed that this approach may help reduce the likely cumulative influence of these personal factors and occupational factors on subsequent chronic LBP development in older working populations.

Current evidence of psychological factors associated with LBP development in nursing staff identifies occupational factors such as interpersonal workplace stress and job satisfaction (Eriksen et al. 2004; Yip 2004). In terms of psychological factors outside the workplace however, there is some evidence that pre-existing psychological distress is linked with future LBP episodes in younger populations including nursing students (Feyer et al. 2000; Power et al. 2001).

Other personal psychological factors such as fear and distress are linked to LBP chronicity, disability and sick leave patterns rather than the development of LBP (Boersma and Linton 2006). Other factors include catastrophising (Peters et al. 2005), and passive coping strategies (Mercado et al. 2005). The role of these factors in the development of LBP remains unclear.

Most physical risk factors for LBP in nurses are focussed on occupational factors such as volumes of bending and lifting (Yip 2004; Mohseni-Bandpei et al. 2006). A range of personal physical factors including poor back muscle endurance (Moffroid et al. 1994), reduced cardiovascular fitness (Cady et al. 1979), altered motor control patterns (Cholewicki et al. 2005), poor spinal posture (Dankaerts et al. 2006), and reduced sagittal range of motion (Wong and Lee 2004) have been found in various LBP populations. However, it is unclear whether these factors are important in nursing students. There is also a lack of consensus regarding the influence of other personal (such as gender, age, and weight) and social (such as alcohol, smoking and injury history) factors on LBP (Dempsey et al. 1997). Further, lifestyle factors such as physical inactivity (Wedderkopp et al. 2008) and high levels of vigorous physical activity (Kujala et al. 1999) have been associated with LBP.

Non-modifiable predictors such as previous LBP history and genetic factors explain over 40% of LBP variance (Hestbaek et al. 2004; Shelerud 2006). However, emerging evidence of altered movement and spinal postures in LBP subjects when performing pain provocative tasks (Dankaerts et al. 2006), along with differences in regional lumbar spine function (Gill et al. 2007), may help explain a greater proportion of modifiable physical LBP risk. Furthermore, it is likely that factors associated with LBP cannot be generalised across different populations (Schenk et al. 2007) and within a biopsychosocial model, no single factor can explain LBP (Adams et al. 2002).

The purpose of this study was to comprehensively evaluate the influence on LBP of personal biopsychosocial factors including task-specific individual physical factors relevant to pain provocation in female nursing students.

4.2. Methods

This cross-sectional study examined a range of personal psychological, physical and social/lifestyle characteristics in female undergraduate nursing students with and without a history of LBP as part of a larger prospective study.

4.2.1 Sample

Data were collected on female undergraduate nursing students from two undergraduate university nursing programs with approximately 1660 enrolled students. Ethical approval to conduct the study was granted from both universities involved, and written informed consent was obtained from subjects (Appendix 1). Subjects attended a single testing session of 60 – 90 minutes duration, which involved completion of both questionnaires and a range of physical assessments (listed below).

Subjects aged between 18 and 35 in their second or third year of the programs were recruited by personal invitation during lectures at both universities. A total of 196 students registered interest in the study and of these 175 subsequently agreed to participate. Sample size calculations were based on statistical requirements for the prospective component of this study, which indicated minimum group sizes (LBP and Control) of 30 subjects would provide sufficient statistical power to detect primary associations of interest.

All nursing students with or without LBP (symptoms from the region of the back between L1 and the gluteal folds) were invited to participate. However, based on our previous survey of LBP in a similar nursing student sample (Mitchell et al. 2008), we expected the majority of students (approximately 80%) to already have had some experience of LBP (ache pain or discomfort) and that most LBP subjects would have episodic rather than chronic, disabling LBP. This population was chosen to fulfil the objective of investigating personal factors associated with LBP in a cohort at high-risk of future chronic LBP in their working life.

Subjects were excluded if they had; an inability to understand written or spoken English; other conditions affecting the spine or lower limbs including inflammatory disorders, neurological diseases or metastatic disease; pregnancy or less than 6 months post-partum; inability to complete all physical tests; or pain greater than 3 out of 10 on a VAS at the time of testing (one subject). Pregnancy excluded two subjects, one had an active spondyloarthropathy and one subject had a forearm fracture, resulting in a study sample of 170 subjects.

Subjects who had acute LBP that limited their performance of the test procedures were excluded. As acute LBP has been shown to influence spinal posture (Harrison et al. 1998) and motor control (Hodges et al. 2003) as well as physical performance due to psychological influences (Swinkels-Meewisse et al. 2006), including these subjects would potentially limit the conclusions which could be drawn from the findings of this study. By comparing matched groups of subjects with different levels of LBP in the preceding 12-months (but not acute pain influencing their performance at the time of testing), differences found between the groups could therefore be more strongly linked to the presence of recent (or current) LBP. It is proposed that intervention directed at such identified factors could have strong implications for prevention of future LBP episodes.

4.2.2. LBP sub-groups

To investigate the influence of LBP, subjects were divided into three LBP categories; No LBP, 'Minor' LBP and 'Significant' LBP. Considering the multifactorial influences on LBP (Waddell 2004), and variance in LBP prevalence based on LBP definition (Marras et al. 2007), Significant LBP group allocation was defined by a combination of indicators across a range of domains from previous LBP research. Fifty-three female subjects were classified as having significant LBP as they scored above the designated cut off score in at least three of the following four criteria:

1. Lifetime LBP Severity > 4/10 for their worst ever LBP on a visual analogue pain scale (Bolton 1999).
2. Duration of LBP in previous 12-months >1 week (to differentiate subjects with a single, very short episode of LBP (Kuornika et al. 1987)).
3. LBP requiring treatment or medication or a reduction in activity in the past 12 months (Adams et al. 1999).
4. LBP disability levels at the time of testing of >20% as measured by the Oswestry Disability Index (ODI) (Fairbank et al. 1980).

The remaining LBP subjects who reported some pain in the previous 12 months, but did not satisfy the criteria for Significant LBP were considered as having Minor LBP (Table 1).

4.2.3. LBP screening questionnaires

The Nordic Low Back Pain Questionnaire (Kuornika et al. 1987) was used to determine LBP history, severity and impact, and to exclude subjects according to the inclusion / exclusion criteria. A visual analogue scale measured highest lifetime LBP severity. The Modified Core Network Low Back Pain Medical Screening Questionnaire assessed subject's general health status and screened for confounding "red flag" medical conditions (Committee 1997).

4.2.4. Social and lifestyle factors

Demographic and social data (socio-economic, marital status, compensation history, alcohol consumption and smoking), were obtained using a questionnaire based on previous research (Brasic 2003). This questionnaire was not tested for reliability and validity during this study. The International Physical Activity Questionnaire (IPAQ) self-report long form was used to record average physical activity levels of subjects over the last 7 days (Booth 2000). Subjects estimated average light, moderate and vigorous weekly physical activity levels across a range of domains including Occupational, Transport and Leisure time. Data were summed across the domains to give weekly averages (in hours) of time spent doing vigorous and moderate physical activity as well as total time spent sitting and walking.

4.2.5. Psychological factors

Four reliable and valid questionnaires were used to evaluate psychological characteristics. The Depression Anxiety Stress Scales (DASS) are a set of three self-report scales used to measure depression, anxiety and stress (Lovibond and Lovibond 1995). The Back Beliefs Questionnaire (BBQ) is a 14-item self-administered questionnaire which determines individual beliefs regarding the impact of back pain (Symonds et al. 1996). The General Short Form 19-item Coping Scale for Adults (CSA) investigates coping and the development of coping strategies (Frydenberg and Lewis 2004). It provides sub-scale scores for four coping styles; Dealing with the Problem; Non-productive Coping; Optimism (focus on positive); and Sharing (social interaction and support from others). The relationship between degree of LBP severity and coping was assessed at the level of coping style as well as four individual items (Play Sport, I Get Sick, Consciously Block out the Problem, and Worry About What Will Happen to Me) chosen by the authors as they reflect different strategies commonly described by patients as ways of dealing with different concerns. The Pain Catastrophizing Scale (PCS)(Sullivan et al. 1995) contains 13 items regarding past pain experiences and provides a total and three sub-scale scores assessing Rumination, Magnification and Helplessness.

4.2.6. Physical factors

Body Mass Index was calculated as an index of weight relative to height to provide an indication of adiposity.

4.4.6.1. Spinal angles

Lumbar spine sagittal plane (flexion / extension) angles (measured in degrees) were derived from sensors placed over T12, L3 and S2 using 3-Space® Fastrak™ (Polhemus, Kaiser Aerospace, Vermont). Spinal postures measured were usual sitting and usual standing. Sagittal spinal angles were measured in maximal slumped sitting, sway standing, and maximal forward bending and maximal backward bending in standing. Peak sagittal angles during a series of functional tasks were also examined in an attempt to replicate specific aspects of spinal loading in common nurse duties. Test postures are shown in Figure 1. All tests, except picking up a pen, were performed three times.

Figure 4.1. Test postures.

4.2.6.2. Sitting (usual and slumped)

It is acknowledged that measuring true "usual" posture is difficult in the laboratory setting. However, subjects were covertly observed when completing questionnaires prior to physical testing to gain an idea of their "usual" sitting posture, and to ensure a similar posture was adopted during testing. Further, subjects were not aware when the "usual" standing and sitting measures were being recoded, as they performed a number of tasks that involved sitting or standing as the starting position. Usual and slumped sitting postures were measured as follows using a previously described protocol (Dankaerts et al. 2006):

3. Subjects were asked to sit on a stool, which was selected to allow their thighs to be parallel with the floor and knees flexed at 90°. No direction of how to sit or an indication of what was being measured was provided. This position was recorded for five seconds as their usual sitting posture (defined as the sitting posture they would usually adopt during unsupported sitting).
4. Subjects were then assisted into their end of range lumbar flexion sitting posture for five seconds by an experienced therapist using standardised cues of asking the subject to "slouch" and using hand cues on the lateral shoulder and pelvis to guide posterior pelvic tilting.

4.2.6.3. Standing (usual, sway, and maximal forward and backward bending)

1. Subjects were asked to stand comfortably at a predetermined position. Whilst no specific instruction of how to stand was given, all subjects stood with their feet parallel. This position was recorded for five seconds as their usual standing posture (defined as the standing posture they would usually adopt during habitual unsupported standing).
2. Sway standing posture was defined as subject's relaxed standing posture with the pelvis translated anteriorly relative to the trunk. All subjects were guided into this position for five seconds by the same experienced therapist. Excellent reliability of positioning subjects in sway posture has been shown previously (O'Sullivan et al. 2002).
3. Subjects were then asked to bend forwards as far as possible with their knees straight, and a five second recording in this position was defined as maximal forward bending.

4. Similarly, maximal backward bending was measured by asking subjects to then bend backwards as far as possible for five seconds, keeping their feet stationary.

4.2.6.4. Lifting (pen drop, box lift and pillow and box transfer)

1. While in the standing position, a pen was placed in front of subjects and they were asked to pick it up. Subjects were directed to pick up the pen as if they had just dropped their own pen on the floor and needed to retrieve it. This test was performed only once.
2. Subjects were then directed to pick up a moderate 5kg load in a box with handles 20cm above floor height. No cues were given regarding how to pick up the box.
3. A height adjustable bed was then set at a height 10cm above each subject's superior patella margin as a standardised height. The task involved transferring a pillow from left to right a distance of 75cm, then back to the starting position. Subjects initially stood at the mid point between the pillow and target position marked on the bed, then were asked to transfer the pillow, with no specific directions regarding how to lift.
4. The task involving transferring a pillow was then repeated using a 5kg box. Hand position was 20cm above bed surface (analogous to box handle height).

4.2.6.5. Squatting (lower limb muscle endurance)

A measure of generalised lower limb muscle endurance was taken using a single trial semi-squat static hold test, which has been described previously and shown to discriminate between female rowers with and without LBP (Perich et al. 2006). Subjects were seated on a stool with thighs parallel and knees flexed at 90° and their arms folded across their chest. Subjects were then asked to adopt a squat position with their buttocks just clear of the stool, by an experienced therapist using standardised cues. Subject's lumbar spine posture was recorded throughout the squat test, with a five second Fastrak™ data sample taken as their squat posture once their position was stable after rising from the stool. The hold time was measured in seconds using a hand held stopwatch.

4.2.6.6. Back muscle endurance

Subject's back muscle endurance was measured using the Biering-Sorensen test (Biering-Sorensen et al. 1989). The length of time in seconds the subject was able to maintain neutral trunk alignment without deviating more than 10° into flexion or extension was recorded during a single trial.

4.2.6.7. Spinal repositioning sense (proprioception)

Spinal repositioning accuracy was determined using the 3-Space® Fastrak™. Repositioning accuracy was evaluated with subjects attempting to reproduce a criterion position of neutral lumbar lordosis in sitting, using criteria reported elsewhere (O'Sullivan et al. 2003). Repositioning accuracy in degrees was recorded as the angle from the criterion position the subject holds during each repositioning trial.

4.2.6.8. Cardiovascular fitness

The Astrand-Rhyming ergometer sub-maximal cardiorespiratory fitness test (Astrand and Rodahl 1986) was used to estimate VO_2 (max) score and compare to normative values to determine a fitness rating.

4.2.7. Data management

Analysis of spinal angles was conducted using custom software written in LabVIEW V8 (National Instruments, Texas, USA). Lower lumbar (LLx) (L3-S2), upper lumbar (ULx) (T12- L3), and total lumbar angles (T12-S2) were calculated for each movement trial, as previously defined and shown to possess excellent inter-trial reliability in sitting (Dankaerts et al. 2006). Reliability and validity of the Fastrak™ system for measuring spinal range of motion has been demonstrated (Pearcy and Hindle 1989; Jordan et al. 2004). For this study, only LLx angles were reported in the analysis. LLx spinal segments are most often the source of LBP (Beattie et al. 2000) and this study was examining spinal posture and kinematics relative to pain. Extension in the sagittal plane was assigned a positive value, and flexion a negative value.

Inter-trial reliability (from three trials for each subject) for all LLx measures in this study was excellent. The mean LLx $ICC_{(3,1)}$ was 0.97 (range: 0.93 - 0.99) and mean LLx SEM was 2.0° (range: 0.5° - 2.5°). The mean angle of three trials (averaged over 5 seconds of data collection) was calculated for each of; usual and maximal slumped sitting, usual and sway standing and maximal forward and backward bending in standing. The mean peak sagittal angles were calculated for the functional tasks. As there was no sustained hold during these tasks (except for the squat), the customised analysis software determined the point of peak sagittal flexion (or least sagittal extension) angle reached between the manually tagged start and finish of the task.

Further analysis was conducted on how far subjects held their LLx spine from their maximal end of range flexion angle during different postures. For sitting, usual sitting angle was compared to maximal slump sitting angle. The maximal forward bending angle in standing was used as the end of range reference angle to compare with; picking up the pen and box from the floor, transferring the pillow and box at bed height and squatting angle.

4.2.8. Statistical Analysis

All basic statistical analyses were performed using SPSS Version 13 (SPSS Inc., Chicago: USA) and Intercooled Stata 9.2 for Windows (Statacorp LP, College Station: USA). Differences in psychological, physical and social characteristics between the three pain groups were tested using chi-square analysis and one-way ANOVAs. Hochberg's GT2 and Games-Howell post-hoc analyses were used, dictated by Levene's test for homogeneity of variances. Kruskal-Wallis test was used for non-parametric variables. A critical alpha probability of .05 was used, with no adjustment for multiple comparisons to balance Type I and Type II errors.

A logit ordinal regression model (proportional odds model) was used to assess the independent association of variables from the physical and psychosocial domains with pain group membership, with pain group assumed to be a three level ordinal variable from No Pain to Significant Pain. The parallel regression assumption for each variable in the model was tested using the Brant test. Analysis of residuals was performed to check for cases with undue influence over model estimates. A two-step model selection procedure consisted of i) identifying those variables within each domain that were significantly and independently associated with pain group membership after adjusting for age, and ii) simultaneously entering those variables identified from step one into a final model, with age included as a covariate. Model fit was assessed using the model chi-squared likelihood ratio test and the substantive significance of the model was assessed by McKelvey and Zavoina's R^2, which has been suggested as the closest analogue to linear regression R^2 (Scott Long and Freese 2006).

4.3. Results

The highest proportion of subjects (48%) was in the Minor LBP group, with Significant LBP being experienced by 31% of subjects and only 21% of the subjects reporting no previous history of LBP (Table 1).

Table 4.1. Group comparisons of age, BMI and LBP characteristics [mean ± S.D, %, or median (interquartile range)].

	No LBP (n = 36)	Minor LBP (n = 81)	Significant LBP (n = 53)	p-value
Age (years)	21.7 ± 3.5	22.0 ± 4.2	23.9 ± 5.1	0.06
BMI (kg/m^2)	21.9 ± 2.8	23.3 ± 4.3	23.1 ± 3.4	0.18
Lifetime highest VAS (/10)	0	3.9 ± 2.3 [c]	6.6 ± 1.6 [a,b]	**< 0.001**
Annual LBP duration (% > 7days)	0	33.3 [c]	92.5 [a,b]	**< 0.001**
Significant LBP impact (%)	0	44.4 [c]	96.2 [a,b]	**< 0.001**
Oswestry Disability Index (%)	0	10.4 ± 6.6 [c]	21.2 ± 9.2 [a,b]	**< 0.001**

VAS = visual analogue scale, BMI = body mass index, significant LBP impact = requiring treatment, medication or activity reduction in the past 12 months. a = significant between No Pain and Significant Pain groups, b = significant between Mild Pain and Significant Pain groups, c = significant between No Pain and Mild Pain groups.

4.3.1. Social and lifestyle factors

No differences between LBP groups were found for any of the social factors including alcohol consumption or cigarette smoking (p-value range 0.17 – 0.90). Subjects with Significant LBP were involved with more hours of moderate plus vigorous activity per week [median 17.5 hours (IQR 14.3)] than subjects with Minor LBP [median 9.0 hours (IQR 14.0), p=0.04]. There were trends for Significant LBP subjects tending to sit less hours per week than other subjects (p = 0.18).

4.3.2. Psychological factors

A summary of psychological variables is provided in Table 4.2. The DASS total score and Stress subscale score were higher in the Significant LBP group when compared with No LBP subjects. Of the four subscales within the CSA, the only difference was in the Sharing scale, with the score being higher in the No LBP group, when compared with the Mild LBP group. Of the individual CSA items tested, “I Get Sick” was more frequently reported in the Significant LBP group, compared with both the No LBP and Mild LBP groups (p = 0.02). There were no differences in back beliefs or pain catastrophising scores between groups.

Table 4.2. Group comparisons of psychological variables [mean ± S.D, or median (interquartile range)].

	No LBP (n = 36)	**Minor LBP (n = 81)**	**Significant LBP (n = 53)**	**p-value**
DASS Total (/126)	8 (10)	12 (14)	16 (16) [b]	**0.007**
Depression (/42)	1 (2)	2 (4)	2 (4)	0.31
Anxiety (/42)	2 (4)	4 (4)	4 (4)	0.082
Stress (/42)	5 (6)	8 (10)	10 (10) [a,b]	**0.004**
Back Beliefs Questionnaire(/45)	28.9 ± 4.5	30.4 ± 4.9	29.3 ± 5.6	0.28
Coping Scale for Adults				
Dealing with Problem (/105)	73.0 ± 12.8	69.7 ± 13.1	69.8 ± 12.8	0.41
Non-productive coping (/105)	51.9 ± 11.2	53.1 ± 12.9	57.8 ± 20.1	0.14
Sharing (/100)	53.2 ± 16.5	45.4 ± 13.8[c]	47.2 ± 14.9	**0.027**
Optimism (/100)	64.7 ± 15.3	60.4 ± 12.8	61.2 ± 13.6	0.23
Pain Catastrophising Scale (/52)	9.5 (13.8)	7.5 (13)	9.0 (13.5)	0.24
Rumination (/16)	4.0 (6.5)	3.0 (5.75)	5.0 (8.0)	0.40
Magnification (/12)	1.0 (3.0)	2.0 (3.0)	2.0 (3.0)	0.24
Helplessness (/24)	3.5 (4.75)	2.0 (4.75)	3.0 (6.5)	0.28

a = significant between No Pain and Significant Pain groups, b = significant between Mild Pain and Significant Pain groups, c = significant between No Pain and Mild Pain groups

Table 4.3. Group comparisons of spinal angles and physical variables between (mean ± standard deviation).

	No LBP (n = 36)	Minor LBP (n = 81)	Sig. LBP (n = 53)	p-value
Sitting angles (°)				
Usual LLx sit angle	2.3 ± 9.4	4.2 ± 8.0	5.1 ± 9.6	0.33
LLx sit proximity to EOR	2.7 ± 4.4	1.8 ± 3.4	3.2 ± 4.5	0.13
Standing angles (°)				
Usual LLx stand angle	23.2 ± 12.4	22.6 ± 10.2	24.7 ± 11.8	0.56
LLx sway angle	31.0 ± 14.4	31.0 ± 13.2	31.6 ± 14.0	0.97
LLx extension angle	45.4 ± 19.4	44.2 ± 7.4	42.6 ± 21.6	0.80
LLx flexion angle	-11.7 ± 8.4	-11.6 ± 6.1	-12.1 ± 6.8	0.91
Functional posture angles (°)				
LLx pen angle	-8.5 ± 8.2	-8.6 ± 6.5	-6.9 ± 7.7	0.40
LLx pen proximity to EOR	3.3 ± 3.6	3.2 ± 2.6	5.3 ± 5.3 [b]	**0.005**
LLx 5kg lift angle	-6.1 ± 9.1	-5.6 ± 7.2	-4.4 ± 9.2	0.61
LLx 5kg lift proximity to EOR	5.7 ± 5.7	6.1 ± 5.1	7.8 ± 6.6	0.15
LLx pillow transfer angle	1.8 ± 9.0	2.7 ± 7.8	5.7 ± 9.3	0.06
LLx pillow transfer proximity to EOR	13.5 ± 7.0	14.3 ± 7.1 [c]	17.8 ± 8.3 [a,b]	**0.01**
LLx 5kg transfer angle	6.1 ± 8.7	7.8 ± 8.5	10.9 ± 9.3 [a]	**0.027**
LLx 5kg transfer proximity to EOR	17.8 ± 7.6	19.3 ± 8.1 [c]	23.0 ± 9.3 [a,b]	**0.008**
LLx squat angle	-4.1 ± 9.2	-3.3 ± 8.5	-2.3 ± 9.5	0.65
LLx squat proximity to EOR	7.8 ± 6.9	8.6 ± 6.4	9.8 ± 8.0	0.40
Performance measures				
Squat time (seconds)	37.7 ± 21.2	36.1 ± 18.8	39.9 ± 23.2	0.59
Sorensen time (seconds)	91.7 ± 48.2	85.0 ± 44.6	93.0 ± 56.9	0.61
Sitting repositioning error	0.7 ± 3.2	0.9 ± 3.1	1.5 ± 3.3	0.39
Predicted VO2 max (L/min)	2.3 ± 0.4	2.3 ± 0.5	2.3 ± 0.4	0.69

LLx = Lower Lumbar, EOR = End of Range flexion angle, Negative angle = lumbar flexion, Positive angle = lumbar extension, a = significant between No Pain and Significant Pain groups, b =

significant between Mild Pain and Significant Pain groups, c = significant between No Pain and Mild Pain groups.

4.3.3. Physical factors

There were no differences evident between the three groups for leg muscle endurance, back muscle endurance or spinal repositioning error (see Table 4.3). Across all subjects, the median cardiovascular fitness rating was “Average”(Astrand and Rodahl 1986) and there were no differences in mean cardiovascular fitness (VO_2max) scores between the three groups.

There were no differences in usual standing posture or usual sitting posture between the three groups. A comparison of LLx spinal angles in static postures and across functional tasks is shown in Table 4.3.

Subjects with Significant LBP were further away from their maximal forward bending angle when picking up a pen from the floor and transferring a pillow at bed height, than subjects with Minor LBP. Subjects with Significant LBP were also further away from their maximal forward bending angle when transferring a pillow and transferring a 5kg box at bed height than all other subjects. Significant LBP subjects had a more extended mean LLx angle when transferring a 5kg box at bed height than subjects with No LBP.

4.3.4. Multivariate model

After identifying those variables within each domain (physical/lifestyle, psychological and physical) that were independently associated with pain group membership, five variables remained in the final model. Older age; more hours of weekly vigorous activity; a higher stress score; more use of the coping strategy “I get sick”; and holding the LLx spine further from end range spinal flexion when transferring a 5kg box at bed height were associated with LBP group membership. Table 4.4 presents the odds ratios for each variable estimated in the final ordinal regression model showing the unique association of variables from the different domain (i.e. holding all other variables in the model constant) with pain group membership. The McKelvey and Zavoina’s R^2 value of this model was 0.229.

Table 4.4. Odds ratios, 95% CIs and p-values from multivariate ordinal logistic regression model.

	Odds Ratio[1]	95% CI	p-value
Age (yr)	1.06	0.99 -1.14	0.104
***Lifestyle:* Vigorous activity[2]**	1.30	1.05 – 1.62	**0.015**
***Psychological:* Stress[2]**	1.37	1.09 -1.72	**0.007**
***Psychological:* “I get sick”[2]**	1.52	1.12 – 2.07	**0.007**
***Physical*: 5kg transfer at bed height. LLx proximity to end range flexion[2]**	0.56	0.39 – 0.79	**0.001**

[1]The Odds Ratio represents the proportional increase in the odds of a higher outcome (i.e. a more severe pain group) versus a lower outcome, holding all other variables constant, for a unit increase in the independent variable. [2] To enable meaningful comparisons of odds ratios between variables a unit increase (approximating one standard deviation) in each independent variable is represented as; “stress”=5points, “I get sick”=1 point, “vigorous activity”=5 hrs, and “5kg transfer”=10^0.

4.4. Discussion

The results of this study support current views that LBP is multidimensional in nature (Turk 2005), with modifiable personal factors across different domains associated with LBP. Although not severely disabling, over 30% of this relatively young sample of female undergraduate nursing students had LBP in the preceding 12 months that would be regarded as clinically significant. High LBP prevalence rates in undergraduate student populations highlights the importance of targeting prevention interventions prior to the commencement of full time employment (Nyland and Grimmer 2003; Mitchell et al. 2008).

In the multivariate model, 23% of the variance between LBP groups was explained by personal factors from lifestyle, psychological and physical domains. This variance is considerably higher when compared to previous prospective studies on LBP personal risk factors (Papageorgiou et al. 1997; Adams et al. 1999) and supports assertions that different domains contribute independently to LBP (Leeuw et al. 2007). Despite being included in the final model, age did not contribute significantly, which may be explained by the small mean difference (2.2 years) in age between LBP groups. The strength of these preliminary findings is that a modest proportion of the variance can be attributable to factors that have the potential to change, providing some evidence towards developing more successful LBP interventions.

4.4.1. *Social and lifestyle factors*

Subjects with Significant LBP were involved in more hours of moderate and vigorous physical activity per week than other subjects, however this did not translate into higher aerobic fitness levels. Other studies report no relationship between physical activity and LBP (Brumagne et al. 2000; Sanya and Ogwumike 2005). High levels of physical activity may be a coping strategy for LBP in this sample of female nursing students and this is in agreement with previous research that found nurses with LBP did not show signs of physical deconditioning (Schenk et al. 2007). Although speculative, it is possible that this finding relates to increased spinal loading and a lack of pacing strategies in these subjects. Alternatively, as the measure of physical activity considered components including household and gardening activity, increased hours of moderate and vigorous activity may indicate increased exposure to bending and lifting tasks.

There were no differences between groups for any of the social measures including household income and smoking. There are contrasting findings for links between social measures and LBP (Dempsey et al. 1997), possibly indicating that such measures are important only in specific populations. This otherwise young, healthy university sample may be an example of a population whos LBP is not strongly influenced by such measures. Alternatively, sample size or other social factors not measured in this study may have influenced this finding.

4.4.2. *Psychological variables*

In terms of psychological measures, high stress and "I get sick" scores were included in the final multivariate model, indicating the importance of psychological stress and aspects of coping strategies in LBP populations. There is some evidence that high psychological distress levels are predictive of future LBP episodes (Croft et al. 1995; Feyer et al. 2000). Recent research supports a biochemical link between psychological stress and spinal pain in a working population (Schell et al. 2008), possibly associated with changes in the regulation of the hypothalamus-pituitary-adrenal (HPA) axis (Derijk and de Kloet 2008).

Another proposed mechanism for the relationship between stress and LBP may be via direct influences of emotions on the autonomic nervous system, resulting in altered tissue sensitivity in some individuals (Martinez-Lavin 2007). Descending inhibitory pain modulation systems are known to be influenced by forebrain activity including emotional responses (Zusman 2002) and longer term stress is thought to reduce central descending tonic pain inhibition (Ashkinazi and Vershinina 1999). Higher psychological stress among nursing students may also contribute to pain via increased mechanical spinal loading due to higher levels of muscle tension. Marras and co-workers have shown that psychologically stressful environments produced higher trunk muscle co-activation responses in certain female subjects (Marras et al. 2000). They hypothesized that this muscle co-activation could make them more susceptible to increased spinal loading and low back disorder risk. Although this cross-sectional study cannot distinguish whether high stress is a characteristic of the individual or is caused by having LBP, given subjects with acute LBP were excluded, high stress was less likely to be related to current pain. This may be supported by the fact that the Significant LBP group had LBP beliefs within a normal range (Symonds et al. 1996).

The coping strategy "I Get Sick" was used most among Significant LBP subjects, and least among the No LBP subjects. It has been proposed that individuals with poorer coping strategies are more prone to a range of health problems, including LBP (Leboeuf-Yde et al. 2006). "I get sick" is a typical somatisation response. Somatisation is a cognitive style which has been linked with LBP (Bacon et al. 1994), and there is some evidence of higher prevalence in females with LBP (Schneider et al. 2006).

Perhaps the most notable measure that was not related to LBP was pain catastrophising, which has been reported to be consistently higher in chronic pain populations studies (Peters et al. 2005; Sullivan et al. 2005). This is likely to be explained by the population sample being young, otherwise healthy nursing students, without chronic LBP. This may also explain the lack of difference in depression and anxiety scores between the groups.

4.4.3. *Physical variables*

The importance of measuring physical variables that are related to specific functional or pain provocative tasks is highlighted by one such variable being retained in the final multivariate model. The position of the LLx spine when transferring a box at bed height was the most important physical variable. Subjects who held their LLx spine further from end range flexion were more likely to be in the Significant LBP group. Guarded or protective movement patterns are also associated with high levels of protective muscle tone, and may further contribute to compressive joint loading and pain (Dankaerts et al. 2006). As Significant LBP subjects held their LLx spine further from end of range flexion during a number of bending related functional tasks, it is speculated that these subjects were adopting guarded type movement patterns, possibly due to previous pain experience. Further research utilising EMG would be required to verify this.

Measures of physical performance (fitness and endurance) failed to distinguish between subject groups. This is consistent with the lack of consensus in physical factors associated with LBP between different studies (Dempsey et al. 1997). It is unlikely that strong associations between such variables and LBP in one study population (Ready et al. 1993), and a complete lack of association in another population (Cady et al. 1979) can be explained entirely by method differences. It may be that physical performance measures are only relevant when they relate to the mechanical exposures of the specific population under investigation, such as fire-fighters (Cady et al. 1979) and manual workers (O'Sullivan et al. 2006). In nursing students, reduced back muscle endurance may be more relevant later in their course when they increase their practical nursing exposure, or once they commence work.

4.4.4. Limitations

These preliminary findings on this moderate size sample of young female nursing students cannot be considered representative of broader populations. This is important to consider not only from a socio-demographic perspective, but also in terms of LBP classification. Characteristics identified as being associated with clinically significant but not chronic, disabling LBP in this sample may not be generalisable in other population types, males or other LBP classification. Validation of these findings is required in a larger, representative sample of nursing students. Further, sub-groups of LBP were not considered in this study, which may have revealed other factors associated with different sub-groups of students with LBP (McCarthy et al. 2004).

Defining multidimensional pain inventory profiles (Turk and Rudy 1988) in this study would have helped determine if the findings of this study were influenced by specific psychologic profiles, and whether female nursing students at risk consist of one predominant profile. It is possible that other factors not examined in this study may contribute to LBP variance. These include muscle activation levels (Cholewicki et al. 2005), fear avoidance (Thomas and France 2007) and genetic factors (Battie et al. 1997). Prospective data is needed to determine if the factors identified in this cross sectional study are predictive of future LBP recurrence in this population.

This exploratory investigation used novel kinematic measures that considered only absolute difference between functional spinal postures and end of range spinal flexion. Whether a percentage of total range for each individual is more relevant than an absolute angle across subjects warrants further investigation in future studies.

4.5. Conclusions

This study supports that LBP is a multifactorial biopsychosocial problem, with modifiable personal characteristics being associated with LBP. Increased physical activity, stress and coping strategies other than catastrophising were associated with LBP. Physical measures that are related to specific functional or pain provocative tasks, rather than general measures of physical performance, were also associated with LBP.

These preliminary results support the concept of targeting modifiable personal characteristics in nursing students as an alternative to occupational prevention strategies in working nurses. The findings require more extensive investigation in prospective studies. Further, the strength of these associations may differ across specific sub-groups of LBP.

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CHAPTER 5 – Study IV

Identification of valid non-specific LBP sub-groups has been identified as a research priority. Based on O'Sullivan's mechanism-based classification system, there is preliminary evidence that LBP sub-groups display different physical characteristics in sitting and bending when compared to each other, and to Controls. However, this biopsychosocial classification system requires further validation in respect to other physical characteristics as well as psychological characteristics. Given the results of Chapter 4 showed that modifiable personal characteristics were associated with LBP in female nursing students, further investigation of these factors in different LBP sub-groups was warranted.

The *general aim* of this study was to investigate if there are different modifiable personal characteristics associated with different LBP sub-groups in female nursing students. The specific aims and its overall place in this doctoral research are shown in Figure 5.0.

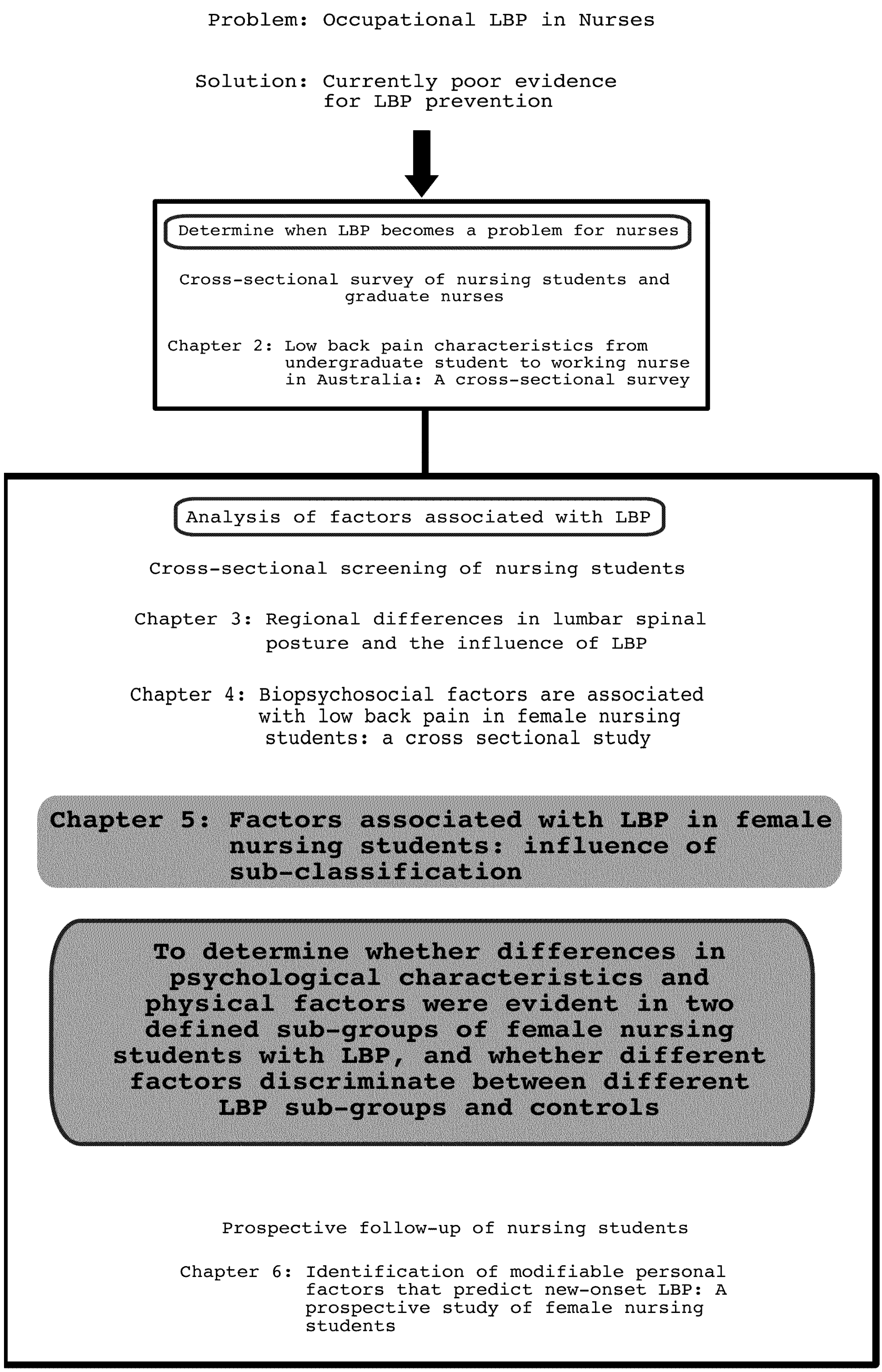

Figure 5.0. Schematic representation of Study IV within the thesis.

Factors associated with low back pain in female nursing students: The influence of sub-classification.

T. Mitchell, PB. O'Sullivan, A. Burnett, L. Straker, A. Smith, C.Rudd

Submitted to Spine

5.0. Abstract

Background: Identification of non-specific LBP sub-groups is a research priority. Validation of sub-groups requires identification of modifiable personal characteristics associated with different LBP sub-groups. The objectives of this study were to determine whether differences in psychological and physical factors were evident in sub-groups of female nursing students with low back pain (LBP), and whether different factors discriminate these LBP sub-groups from Controls.

Methods: Nursing students with LBP were sub-grouped based on O'Sullivan's mechanism-based classification system. Flexion pattern (n=30) and Extension pattern (n=23) subjects were compared with each other and also to Controls (n=36). Comparisons were made across physical (spinal postures and spinal kinematics in functional tasks, leg and back muscle endurance, spinal repositioning error and cardiovascular fitness) and psychological (stress, anxiety, depression, back pain beliefs, coping strategies and catastrophising) characteristics in addition to physical activity levels.

Results: Flexion pattern and Extension pattern subjects differed across physical (lower lumbar lifting angle; OR 0.21, 95% CI 0.09-0.45) and psychological (non-productive coping; OR 3.85, 95% CI 1.72-8.33) measures. Extension pattern subjects were distinguished from Controls primarily based on a number of physical measures (lower lumbar lifting angle; OR 2.54, 95% CI 1.38-4.54) as well as higher stress (OR 2.30, 95% CI 1.16-4.53). Conversely, Flexion pattern subjects were distinguished from controls based on psychological measures (Stress; OR 2.24, 95% CI 1.16-4.27, and non-productive coping; sOR 2.27, 95% CI 1.14-15.37), but not physical measures.

Conclusions: LBP sub-groups displayed different psychological and physical characteristics when compared to each other, and to Controls. This exploratory study supports that different sub-groups exist in LBP populations, and further validates O'Sullivan's classification system. The findings may suggest that different

combinations of psychological and physical factors are linked to LBP in different sub-groups, and therefore may require different intervention approaches based on these factors.

5.1. Introduction

Low back pain (LBP) remains a common and challenging primary care issue which consumes enormous health care expenditure (Borkan et al. 2002). Despite extensive research, consistent evidence for effective LBP interventions is limited (Joines 2006). Recent randomised trials on non-specific patient populations do not support the use of any single conservative intervention type over another (Ferreira et al. 2007; Petersen et al. 2007). There is preliminary evidence however, that interventions based on specific sub-groups within the non-specific LBP group are more effective than treatment provided to a non-specific LBP patient sample (Fritz et al. 2003; Brennan et al. 2006).

The development and validation of classification systems that direct treatment and improve outcomes for LBP patients has been considered as a priority for ongoing research (Borkan and DC 1996; Ford et al. 2007). If a classification system contains sub-groups of non-specific LBP patients with common, modifiable personal characteristics (such as posture in habitual and functional movements or beliefs about low back pain), the likelihood of the classification system leading to efficacious treatment is possibly enhanced. There is preliminary evidence that personal, physical and psychological characteristics can be identified within LBP sub-groups (such as sitting posture, back muscle endurance, lifting style and self-efficacy) (Dankaerts et al. 2006a; O'Sullivan et al. 2006; Slaboda et al. 2008), however this concept requires further investigation in the context of validating LBP classification systems (Ford et al. 2007).

O’Sullivan proposed a mechanism-based classification system, for localised LBP, in which sub-groups of patients are classified according to specific motor control impairments that provoke their LBP (O'Sullivan 2000). This classification system also considers psychosocial contributors to LBP and its associated behaviours (O'Sullivan 2005), and there is growing evidence for both its validity (Burnett et al. 2004; Dankaerts 2006; Dankaerts et al. 2006a; O'Sullivan et al. 2006) and clinical efficacy (Dankaerts et al. 2007) in specific sub-groups. Different motor control mechanisms for the development of LBP in specific sub-groups of patients are proposed in O’Sullivan’s classification system, specifically flexion pattern (FP) and extension pattern (EP) (O'Sullivan 2000). In addition to motor control deficits, it is proposed that psychological factors act to amplify pain and reinforce mal-adaptive behaviours promoting disability (O'Sullivan 2006).

From previous research examining female nursing students with LBP (Chapter 4), it was found that psychological and physical characteristics that independently contributed to the presence of LBP were evident. It was unclear whether these findings reflected characteristics of all LBP subjects, or perhaps sub-groups existed with different psychological and physical characteristics associated with their LBP.

The purpose of this study was to determine whether differences in psychological and physical characteristics were evident in two defined sub-groups (FP and EP) of female nursing students with LBP, and whether personal factors discriminate between these sub-groups and controls.

5.2. Materials and Methods

5.2.1. Design

This cross-sectional study examined a range of psychological and physical characteristics in female nursing students with and without a history of LBP. Eighty-nine participants were recruited from two undergraduate university nursing programs. This occupational group was chosen due to its high LBP prevalence and is at risk of future chronic disabling LBP (Mitchell et al. 2008a). Subjects were aged between 18 and 35 years and were in their second or third year of undergraduate study at the time of testing. Ethical approval to conduct the study was granted from both universities involved, and written informed consent was obtained from subjects (Appendix 1). Subjects attended a single testing session that involved completion of both questionnaires and a range of physical assessments (listed below).

Nursing students with ‘significant’ (see definition below) LBP (N=53 who were later sub-classified) were compared with Controls (N=36) in this study. Subjects were excluded if they had; an inability to understand written or spoken English; other conditions affecting the spine or lower limbs including inflammatory disorders, neurological diseases or metastatic disease; pregnancy or less than 6 months post-partum; or inability to complete all physical tests. Potential subjects were excluded due to pregnancy (2), active spondyloarthropathy (1) and a forearm fracture (1).

Subjects who had LBP that limited their performance of the test procedures (pain greater than 3 out of 10 on a VAS at the time of testing) were also excluded (one subject). As acute LBP has been shown to influence spinal posture (Harrison et al. 1998) and motor control (Hodges et al. 2003) as well as physical performance due to psychological influences (Swinkels-Meewisse et al. 2006), including these subjects would potentially limit the conclusions which could be drawn from the findings of this study. By comparing matched groups of subjects with different levels of LBP in the preceding 12-months (but not acute pain influencing their performance at the time of testing), differences found between the groups could therefore more strongly linked to the presence of recent (or current) LBP.

5.2.2. Significant LBP group

The Nordic Low Back Pain Questionnaire (Kuornika et al. 1987) was used to determine LBP history. Subjects were classified as having significant LBP as they scored above the designated cut off score in at least three of four criteria (lifetime LBP severity; duration of LBP in previous 12-months; LBP requiring treatment or medication or a reduction in activity in the past 12 months; and Oswestry Disability Index score (ODI)) (Mitchell et al. 2008b).

5.2.3. Classification of LBP subjects

Subjects with significant LBP were sub-classified according to the physical criteria of O’Sullivan’s classification system (O'Sullivan 2000). In brief, the physical component of the classification system is based on sub-grouping patients according to their reported provocative and relieving spinal postures and functional tasks, and how these relate to each patient’s spinal postural and movement patterns (O'Sullivan 2000). The majority of patients with chronic and recurrent LBP can be classified as having a primary sagittal flexion or extension bias to provocation of their symptoms, associated with proposed impairments of spinal motor control (O'Sullivan 2000; O'Sullivan 2005). Acceptable inter-examiner reliability of this classification system has been previously demonstrated (Dankaerts et al. 2006b).

Subjects with significant LBP were independently classified by two Specialist Physiotherapists (TM and PO), who were blinded to each other. This was done using questionnaire data of pain aggravating and relieving postures / tasks, as well as video footage of functional tasks performed by each subject (Dankaerts et al. 2006b). For the purposes of this study, the primary direction of pain provocation (flexion or extension) formed the basis of classification of subjects. This classification method was used to identify whether this primary direction of pain provocation influenced characteristics associated with LBP.

For example, if a subject reported pain with sitting, sustained flexion, bending and lifting, they sat slumped and initiated bending and lifting with lumbar spine flexion, then they were classified as having a flexion pattern (FP). Alternatively, if a subject reported pain with sitting, standing, sustained bending, lifting and walking, and they sat with hyperlordotic LLx spine posture, performed bending and functional tasks with LLx spine hyperlordotic then they were classified as an extension pattern (EP). In order to be classified as FP or EP, postures linked with pain provocation needed to be consistent in the pain directional bias (flexion or extension). Subject classification was compared between the two examiners, with 94% agreement. The three subjects with a multi-directional classification were considered as displaying a dominant classification of either FP or EP by consensus, based on the directional provocation of their main aggravating activity (taken from ODI score). As a result of sub-group classification, 30 LBP subjects were classified as having a FP, and 23 were classified as having an EP. Subject characteristics are described in Table 5.1. Minimum sub-group sizes of 20 subjects was based upon a previous study (Dankaerts et al. 2006a).

5.2.4. Psychological Measures

Four validated questionnaires were used to evaluate psychological characteristics. These were the Depression Anxiety Stress Scales (DASS) (Lovibond and Lovibond 1995), the Back Beliefs Questionnaire (BBQ) (Symonds et al. 1996), the General Short Form 19-item Coping Scale for Adults (CSA) (Frydenberg and Lewis 2004) and the Pain Catastrophizing Scale (PCS) (Sullivan et al. 1995).

5.2.5. Physical Measures

5.2.5.1. Physical Activity

The long-form of the International Physical Activity Questionnaire (IPAQ) was used to record average physical activity levels (Booth 2000). Data were summed across Occupational, Transport, Household and Leisure domains to give weekly averages (in hours) of sitting, walking and doing moderate and vigorous physical activity.

5.2.5.2. Performance Measures

Lower limb muscle endurance was measured during a functional squatting task (Perich et al. 2006) back muscle endurance using the Biering-Sorensen test (Biering-Sorensen et al. 1989) and cardiovascular fitness was measured using the Astrand-Rhyming sub-maximal bicycle ergometer test (Astrand and Rodahl 1986). Spinal repositioning accuracy was evaluated with subjects attempting to reproduce a criterion position of neutral lumbar lordosis in sitting (O'Sullivan et al. 2003).

5.2.5.3 Spinal Angles

Lumbar spine sagittal plane (flexion / extension) angles were derived from sensors placed over T12, L3 and S2 using 3-Space® Fastrak™ (Polhemus, Kaiser Aerospace, Vermont) (Dankaerts et al. 2006a). Spinal postures were measured in usual sitting and usual standing. Sagittal spinal angles were measured in maximal slumped sitting, sway standing, and maximal forward bending and maximal backward bending in standing. Peak sagittal bending angles during a series of functional tasks were also examined in an attempt to replicate common pain provocative functional tasks in this group. These were; picking up a pen and a 5kg box from the ground, transferring a pillow and a box at mid thigh level, and squatting. Test postures are shown in Figure 5.1.

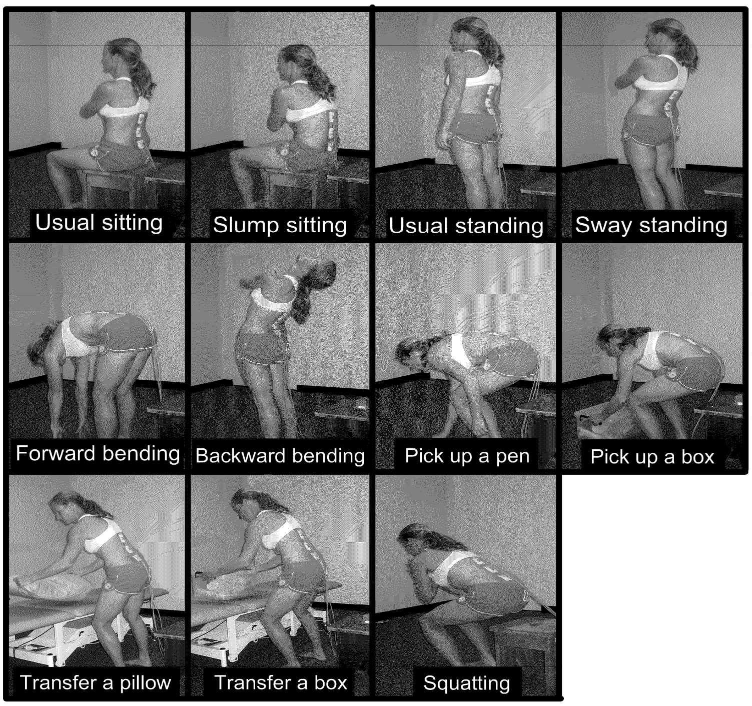

Figure 5.1. Test postures.

5.2.6. Data Management

Analysis of spinal angles was conducted using custom software written in LabVIEW V8 (National Instruments, Texas, USA). Lower lumbar (LLx) (L3-S2) angles were calculated and shown to possess excellent inter-trial reliability in sitting (Dankaerts et al. 2006a). Extension in the sagittal plane was assigned a positive value, and flexion a negative value. Mean posture angles, peak angles during movement and differences from end of range flexion were calculated (Mitchell et al. 2008b).

5.2.7. Statistical Analysis

All statistical analyses were performed using SPSS Version 13 (SPSS Inc., Chicago: USA). Differences in pain measures between the two LBP groups (FP and EP) were tested using chi-square analysis and independent t-tests. Differences in psychological and physical characteristics between the two LBP groups and controls were tested using chi-square analysis and one-way ANOVA. Non-parametric statistical tests (Kruskal-Wallis and Mann-Whitney) were used when data was highly skewed and non-amenable to transformation. Multivariate analysis on predictors of group allocation was conducted using forward stepwise multinomial logistic regression. Given the large number of variables and strong correlation between spinal angle measures, only the three variables from each domain with the lowest p-values were entered into the model. Adjustment of estimates for age and BMI did not significantly alter results and has not been reported. Significance level was set at 0.05.

5.3. Results

Age distribution, anthropometric data, back pain characteristics and subjective disability are shown in Table 5.1. Age ($p = 0.09$) and BMI ($p = 0.17$) did not differ significantly across the three groups. There were also no significant differences between FP and EP subjects for LBP intensity ($F = 0.13$, $p = 0.49$), duration ($x^2 = 0.08$, d.f. = 1, $p = 0.78$), impact ($x^2 = 1.59$, d.f. = 1, $p = 0.21$) or disability ($F = 1.01$, $p = 0.79$) measures.

Table 5.1. Subject characteristics and history of LBP [mean ± S.D, median, or %].

		LBP	
	Control (n = 36)	**Flexion Pattern (n = 30)**	**Extension Pattern (n = 23)**
Age (years)	21.7 ± 3.5	23.6 ± 5.1	24.3 ± 5.3
BMI	21.9 ± 2.8	22.8 ± 3.1	23.5 ± 3.9
Lifetime highest VAS (/10)	0	6.4 ± 1.7	6.8 ± 1.6
Annual LBP duration (median days)	0	8-30	8-30
Proportion requiring treatment, medication or activity reduction in past 12 months (%)	0	93.3	100
Oswestry Disability Index (%)	0	21.5 ± 10.1	20.8 ± 8.0

BMI = body mass index, VAS = visual analogue scale

5.3.1. Psychological Factors

Psychological questionnaire results are summarised in Table 5.2. Anxiety, stress and total score from the DASS were higher in the FP group than Controls. Non-productive coping was higher in the FP group than both EP and Control groups. No significant differences were found for back pain beliefs or pain catastrophising, although FP subjects tended to score higher than other groups on the PCS.

Table 5.2. Comparison of psychological variables between LBP groups [mean (95% CI) or median (95% CI)].

	Control (n = 36)	Flexion Pattern (n = 30)	Extension Pattern (n = 23)	p-value
DASS total (/126) [1]	8.0 (5.2–12.8)	17.0 (16.0-22.0)	12.0 (6.5-21.5)	**0.002** [b]
Depression (/42) [1]	1.0 (0.0-2.0)	3.0 (2.0-4.0)	1.0 (0.0-2.0)	0.06
Anxiety (/42) [1]	2.0 (0.0-4.0)	4.0 (2.0-6.0)	4.0 (1.3-6.0)	**0.049** [b]
Stress (/42) [1]	5.0 (3.2-8.0)	11.0 (10.0-14.0)	6.0 (4.0-14.0)	**0.004** [b]
Back Beliefs Score (/45) [2]	28.9 (27.4-30.4)	29.1 (27.2-31.1)	29.5 (26.8-32.2)	0.91
Coping scale for adults				
Dealing with Problem (/105) [2]	73.0 (68.7-77.3)	71.3 (66.3-76.2)	67.8 (62.4-73.2)	0.32
Non-productive coping (/105) [2]	51.9 (48.1-55.7)	62.4 (57.1-67.7)	49.3 (43.8-54.8)	**0.001** [a,b]
Sharing (/100) [2]	53.2 (47.6-58.8)	47.9 (41.9-54.0)	46.3 (40.2-52.3)	0.20
Optimism (/100) [2]	64.7 (59.5-69.9)	63.3 (58.4-68.1)	58.5 (52.3-64.7)	0.25
Pain Catastrophising Scale (/52) [1]	9.5 (4.0-12.8)	12.5 (7.17.9)	9.0 (5.0-12.2)	0.16
Rumination (/16) [1]	4.0 (2.0-6.0)	5.0 (2.1-8.9)	3.0 (1.0-5.0)	0.18
Magnification (/12) [1]	1.0 (1.0-3.0)	2.0 (1.1-3.9)	2.0 (1.0-3.0)	0.14
Helplessness (/24) [1]	3.5 (1.0-4.0)	3.0 (2.0-8.5)	3.0 (1.3-4.7)	0.33

[a] = significant between Flexion and Extension Pattern groups, [b] = significant between Flexion Pattern and Control groups, [1] = median score, [2] = mean score.

5.3.2. Physical Factors

5.3.2.1. Physical Activity and Performance Measures

Despite EP median scores for physical activity levels being much higher and sitting time lower than Controls, due to the large range of scores, there were no significant differences between groups (Table 5.3). Similarly, EP mean endurance scores, particularly on the Sorensen test, were higher than other groups, but not significantly so. Cardiovascular fitness and spinal repositioning sense were similar across all groups.

Table 5.3. Comparison of activity levels and physical performance variables between groups [mean (95% CI) or median (95% CI)].

	Control (n = 36)	**Flexion Pattern (n = 30)**	**Extension Pattern (n = 23)**	**p-value**
Activity levels				
Sitting (hours / week) [1]	44.5 (34.8-53.0)	42.5 (35.3-45.9)	38.0 (33.5-43.5)	0.41
Walking (hours / week) [1]	5.8 (2.8-11.1)	8.5 (4.1-10.4)	10.5 (4.5-19.9)	0.33
Moderate activity (hours / week) [1]	5.5 (3.5-12.4)	9.0 (5.3-11.4)	13.0 (4.1-23.9)	0.23
Vigorous activity (hours / week) [1]	2.0 (0.6-4.2)	5.2 (1.1 -9.0)	5.0 (0.1 – 8.0)	0.22
Performance variables				
Squat time (seconds) [2]	37.7 (30.6-44.9)	38.2 (28.7-47.7)	42.0 (32.9-51.2)	0.75
Sorensen time (seconds)	91.7 (75.4-108.0)	87.3 (63.2-111.3)	100.4 (80.7-120.1)	0.67
Predicted VO2 max (L/min) [2]	2.3 (2.2-2.5)	2.3 (2.1-2.5)	2.3 (2.2-2.5)	0.83
LLx sit repositioning error (°) [2]	3.0 (2.3-3.8)	2.8 (2.0-3.6)	3.3 (2.1-4.5)	0.76

LLx = lower lumbar, [1] = median score, [2] = mean score.

5.3.2.2. Spinal Angles

Group comparisons for spinal angles are shown in Table 5.4. EP subjects held their LLx spine more extended in usual sitting compared to both FP and Control subjects. The same pattern was evident in usual standing, though not significant. Range of LLx motion and peak LLx angles in standing was similar across groups.

EP subjects held their LLx spine relatively more extended across all functional tasks as well as when sitting in maximal flexion when compared with both FP and Control subjects. Similarly, EP subjects held their LLx spine further from their end of range flexion position during all functional tasks, except squatting. There were no spinal angle differences between FP and Control subjects.

5.3.3. Multivariate Analysis

The multinomial logistic regression model selected two psychological variables (stress and non-productive coping) as significant predictors of group allocation (Table 5.5). Stress was higher in FP and EP sub-groups than Controls, but after controlling for non-productive coping, it was not different between the LBP sub-groups. Higher non-productive coping distinguished FP subjects from both Control and EP subjects. Due to the high correlation between spinal angle measures, only one such measure (5kg box lift) was retained in the final model. Having less LLx flexion when lifting the box from the floor distinguished EP subjects from both Control and FP subjects.

Table 5.4. Comparison of kinematic variables (in degrees) between groups [mean (95% CI)].

	Control (n = 36)	Flexion Pattern (n = 30)	Extension Pattern (n = 23)	p-value
Usual postures				
Usual sitting	2.3 (-0.9-5.5)	1.0 (-1.6-3.7)	10.5 (6.2-14.8)	< **0.001**[a,c]
Usual standing	23.2 (19.0-27.4)	21.5 (17.4-25.6)	28.9 (23.8-34.0)	0.07
Range of motion				
Standing extension	22.3 (18.6-25.9)	17.1 (11.4-22.8)	19.0 (13.6-24.4)	0.27
Standing flexion	33.9 (30.5-37.2)	36.0 (31.7-40.3)	37.9 (33.3-42.5)	0.36
Standing total	57.1 (51.4-62.8)	52.3 (44.4-60.3)	57.8 (49.5-66.2)	0.49
Peak spinal angles				
Flexion in standing	-11.7 (-14.6--8.9)	-13.7 (-16.2--11.2)	-10.0 (-12.8--7.2)	0.20
Extension in standing	45.4 (38.8-52.0)	38.6 (30.3-47.0)	47.8 (39.3-56.4)	0.23
Sway standing [2]	31.0 (26.1-35.9)	27.9 (22.9-32.9)	36.4 (30.4-42.3)	0.09
Flexion in sitting	-0.5 (-3.8-2.8)	-0.9 (-4.0-2.2)	5.6 (1.6-9.6)	**0.02** [a,c]
Pick up pen	-8.5(-11.3--5.8)	-10.5(-12.4--8.5)	-2.3 (-5.8-1.1)	< **0.001**[a,c]
5kg box lift	-6.1 (-9.2--3.0)	-9.2 (-11.5--6.9)	1.8 (-2.3-5.6)	< **0.001**[a,c]
Pillow transfer	1.8 (-1.2-4.9)	2.4 (-0.7-5.5)	10.1 (6.3-13.9)	**0.001** [a,c]
5kg box transfer	6.1 (3.1-9.0)	8.0 (5.2-10.9)	14.8 (10.4-19.1)	**0.001** [a,c]
Squatting	-4.1 (-7.2--0.9)	-5.1 (-8.1--2.1)	1.3 (-3.2-5.7)	**0.034** [a,c]
Proximity to spinal flexion end of range				
Usual sitting	2.7 (1.3-4.2)	2.0 (0.7-3.2)	4.9 (2.6-7.2)	**0.047** [a]
Pick up pen	3.3 (2.1-4.5)	3.5 (2.3-4.8)	7.7 (4.8-10.5)	**0.001** [a,c]
5kg box lift	5.7 (3.8-7.7)	4.8 (3.2-6.3)	11.8 (8.7-14.9)	< **0.001**[a,c]
Pillow transfer	13.5 (11.2-15.9)	16.1 (12.9-19.2)	20.1 (16.8-23.3)	**0.008** [c]
5kg box transfer	17.8 (15.2-20.3)	21.7 (18.2-25.2)	24.8 (20.8-28.7)	**0.01** [c]
Squatting	7.8 (5.4-10.1)	8.5 (5.7-11.4)	11.3 (7.7-15.0)	0.20

Negative angle = lumbar flexion, Positive angle = lumbar extension, [a] = significant between Flexion and Extension Pattern groups, [c] = significant between Extension Pattern and Control groups.

Table 5.5. Multinomial logistic regression model of predictors of group allocation.

Group Comparison	Variable	Odds Ratio[1]	95% CI	p-value
FP v Control	5kg box lift	0.54	0.29-1.00	0.067
	Stress	2.24	1.16-4.27	**0.016**
	Non-productive coping	2.27	1.14-15.37	**0.025**
EP v Control	5kg box lift	2.54	1.38-4.54	**0.003**
	Stress	2.30	1.16-4.53	**0.016**
	Non-productive coping	0.59	0.29-1.14	0.144
FP v EP	5kg box lift	0.21	0.09-0.45	**<0.001**
	Stress	0.98	0.50-1.85	0.942
	Non-productive coping	3.85	1.72-8.33	**0.002**

FP = flexion pattern, EP = extension pattern, **[1]** The Odds Ratio represents the increase in the odds of being in the first listed (reference) group, holding all other variables constant, for a unit increase (approximating one standard deviation) in the independent variable.

5.4. Discussion

In this exploratory study, female nursing students with significant LBP who were sub-grouped into two of the most common motor control patterns of O'Sullivan's classification system (O'Sullivan 2000) displayed different physical characteristics from each other. These results of this study support the validity of this classification process by experienced clinicians. However, there were also differences in psychological characteristics between the sub-classified groups. This arguably further validates the classification approach, as although O'Sullivan's classification system considers biospychosocial factors in assessment and management (O'Sullivan 2000; O'Sullivan 2005), physical factors alone formed the basis of sub-grouping subjects in this study.

5.4.1. Flexion Pattern

FP subjects had very similar physical and kinematic characteristics to the Control subjects, but there were differences in psychological scores between these two groups (higher psychological distress and non-productive coping in the FP group). These psychological rather than physical differences between FP and Control subjects raises questions as to the potential underlying pain mechanism/s associated with this sub-group.

Previous research suggests that higher levels of psychological distress can result in altered tissue sensitisation via the central nervous system (Martinez-Lavin 2007), making spinal structures more sensitised to pain provocative end range loading positions (such as flexion and extension) (Cholewicki and McGill 1996). Higher psychological distress may also contribute to pain via increased mechanical spinal loading due to higher levels of muscle tension in certain individuals (Marras et al. 2000). Despite clear links with passive coping and LBP chronicity, evidence for passive coping being predictive of new episodes of LBP is limited (Larsen and Leboeuf-Yde 2006). As to whether these psychological factors precede, or are secondary to LBP, should be determined by prospective studies.

5.4.2. Extension Pattern

EP subjects could also be clearly differentiated from Control subjects, primarily based on a range of physical characteristics, with the 5kg box lift retained in the final multivariate model. The only psychological difference between EP and Control subjects was the higher stress score in EP subjects. This factor was equally strong for both FP and EP subjects, reflecting that higher psychological stress is associated with LBP across both of the sub-groups in this study.

The kinematic findings associated with the EP sub-group may reflect a protective motor response secondary to pain, resulting in altered spinal posture and movement. Alternatively, these altered spinal movement patterns may be inherent in these individuals, suggesting that the causal mechanism of pain in this sub-group is primarily physical, with the adoption of provocative postures and movements leading to LBP (O'Sullivan 2005). Previous studies support that EP subjects maintain extended spinal postures, associated with high levels of back muscle activity (Dankaerts 2006), potentially causing pain via excessive compressive and extension spinal load (Dankaerts et al. 2006a). Prospective research is required to determine whether these findings are cause or effect.

5.4.3. Clinical implications

The finding that subjects with a FP and EP display different physical and psychological (lower non-productive coping in EP) characteristics to each other supports previous research validating the identification of these sub-groups (Burnett et al. 2004; Dankaerts 2006; Dankaerts et al. 2006a). The varying factors linked to LBP in the two sub-groups examined in this study may reflect different underlying psychological and physical drivers for pain. This concept is supported in a review paper by Turk (Turk 2005), who identified the importance of patient classification based on both psychological and physical characteristics. Given these findings, it is logical that the prevention and management of LBP patients will need to consider characteristics of particular sub-groups. It may be that different interventions need to be targeted to different sub-groups in order to improve patient outcomes (Turk 2005).

It is important to note that all mean psychological scores (including the DASS and PCS scores) were well below reported clinical "at risk" scores (Sullivan et al. 1995; Crawford and Henry 2003), despite statistical differences being evident between LBP sub-groups and Controls. This is hardly surprising given that the sample were otherwise healthy nursing students that were not presenting with chronic disabling LBP. However, these differences may still be clinically significant in terms of increasing risk of being vulnerable to an episode of LBP (such as poorer coping leading to lowered thresholds for pain reporting (Hoogendoorn et al. 2002)). For example, it could be hypothesized that elevated psychological distress (ie. higher than normal stress for a particular individual) in conjunction with other factors (such as increased exposure to mechanical load) may combine to place an individual at high risk for a LBP episode. This could result in LBP being triggered by a seemingly innocuous event (McBeth et al. 2007).

5.4.4. Limitations and Future Research

Given the exploratory nature of the study, the results may be sample specific and therefore, need to be reproduced in an independent validation sample. The results of this study reflect LBP characteristics of a young, otherwise healthy female nursing student population comparing Controls to LBP subjects who experienced moderate levels of pain and disability in the 12-months prior to testing. By excluding subjects with an acute pain episode, differences found between groups in this study are more likely to reflect actual physical and psychological group differences linked with the underlying pain problem, rather than just the well documented characteristics reflective of acute pain.

Although clinically significant, the nature of the subjects LBP in this study would not be regarded as chronic, disabling LBP. However, as nursing is recognised as a high-risk occupation and previous LBP history is the strongest predictor of future LBP (Maul et al. 2003; Hestbaek et al. 2006), findings in this subject sample may reflect implications for future LBP. It should also be considered that gender may influence the contribution of LBP factors (Schneider et al. 2006). Comparison with a similar male population is currently being undertaken.

Trends observed in levels of physical activity, back muscle endurance, as well as psychological differences warrant further investigation in a larger sample. Finally, this cross-sectional study cannot determine the cause and effect nature of the relationships between psychological and physical factors and LBP. This study is being extended prospectively to evaluate these relationships.

5.4. Conclusions

Specific LBP sub-groups (EP and FP) within this exploratory study displayed different psychological and physical characteristics from each other, and when compared with the Control group. This study supports that different subgroups exist in LBP populations, and further validates O'Sullivan's classification system. Subjects with an EP were distinguished from Control subjects primarily based on a number of physical measures. Conversely, subjects displaying a FP were distinguished from Control subjects based only on psychological measures. These findings suggest that different combinations of psychological and physical factors may be linked to these LBP sub-groups and therefore different intervention approaches based on these characteristics may be required. Further research into this concept is required.

5.6. Acknowledgements

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CHAPTER 6 – Study V

As current occupational LBP prevention strategies for nurses have not proven effective, emphasis on targeting personal characteristics in prevention strategies may be indicated. Currently, the best personal predictor of LBP is previous history. Therefore, there is a need to identify other *modifiable* personal factors that improve the ability to predict LBP in nurses before they commence employment. Given the results of Chapter 4 showed that modifiable personal characteristics were associated with LBP in female nursing students, further investigation of whether these factors are predictors of new-onset LBP was indicated. This investigation was conducted on a sub-group of the cohort who had no significant LBP in the 12-months preceding the study.

The *general aim* of this study was to investigate if there are different modifiable personal characteristics that predict new-onset low back pain in female nursing students. The specific aims and its overall place in this doctoral research are shown in Figure 6.0.

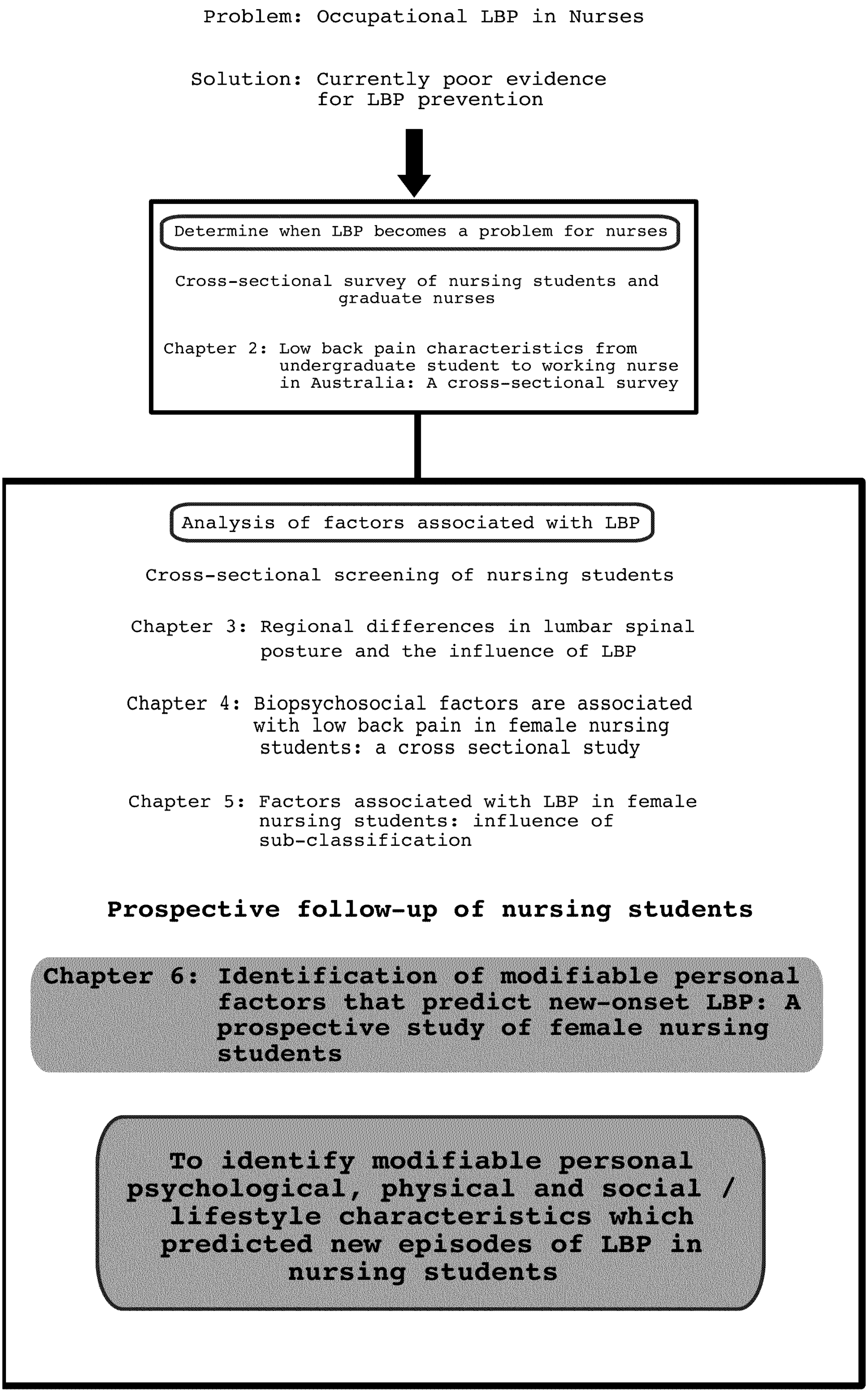

Figure 6.0. Schematic representation of Study V within the thesis.

Identification of modifiable personal factors that predict new-onset low back pain: A prospective study of female nursing students.

T. Mitchell, PB. O'Sullivan, A. Burnett, L. Straker, A. Smith, C. Rudd

Submitted to Clinical J Pain

6.0. Abstract

Background: Prevention of occupational low back pain (LBP) in nurses is a research priority. Recent research suggests intervening prior to commencing nursing employment is ideal, however identification of modifiable personal risk factors is required.

Methods: This prospective study was conducted on female nursing students (n = 117) without LBP at baseline to predict new-onset LBP (an episode of significant LBP during the follow-up period). At the 12-month follow-up, subjects with (n=31) and without new-onset LBP (n=76) were compared across baseline social/lifestyle, psychological (distress, back pain beliefs, coping strategies and catastrophising) and physical (spinal postures and spinal kinematics in functional tasks, leg and back muscle endurance, spinal repositioning error and cardiovascular fitness) characteristics.

Results: Subject response rate at follow up was excellent (91%). After controlling for previous LBP, age and BMI, regression analysis showed that modifiable social/lifestyle, psychological and physical risk factors (namely, smoking, increased physical activity, higher stress, reduced back muscle endurance, greater posterior pelvic rotation in slump sitting and more accurate spinal repositioning in sitting) were significant and independent predictors of new-onset LBP at follow-up. Inclusion of these factors in multivariate logistic regression analysis, with significant new-onset LBP as the outcome resulted in a substantial model R^2 of 0.45.

Conclusions: Modifiable personal characteristics across multiple domains are associated with new-onset LBP in female nursing students. These findings have implications for the development of prevention and management interventions for LBP in nurses.

6.1. Introduction

Manual occupations such as nursing are known to be associated with a high risk of occupational low back pain (LBP), possibly due to a combination of physical load (Smedley et al. 1997; Mohseni-Bandpei et al. 2006) as well as psychological stressors (Feyer et al. 2000; Yip 2004). It is recognised that LBP is best considered as a biopsychosocial problem (Waddell 2004; Gatchel et al. 2007), and therefore multifactorial interventions are likely to be most effective (Dawson et al. 2007).

Despite extensive efforts to reduce LBP, there is no strong evidence supporting the efficacy of any specific workplace intervention preventing LBP in nurses (Dawson et al. 2007). As LBP is already a significant problem in nurses prior to commencing full-time employment (Smith and Leggat 2004; Videman et al. 2005), it has been proposed nursing students should be the focus of prevention interventions (Mitchell et al. 2008). To improve efficacy of LBP prevention, it is proposed that emphasis should be on identifying *modifiable* personal factors, rather than occupational factors, associated with the development of LBP. Further, as nursing students are not yet exposed to the same volume of occupational LBP risk factors as working nurses, a clearer indication of the influence of modifiable personal factors on the development of LBP could be determined by using a student cohort.

Currently, the strongest personal predictor of future LBP is a previous history of LBP (Smedley et al. 1997; Feyer et al. 2000; Hestbaek et al. 2006b), which limits the targeting of prevention strategies, given around 80% of the population experience some LBP in their life (Walker et al. 2004). Previous prospective studies have identified personal physical risk factors including poor back (Biering-Sorensen 1984; Stroyer and Jensen 2008) and leg muscle endurance (Klaber-Moffett et al. 1993), reduced or increased back mobility (Biering-Sorensen 1984; Adams et al. 1999) impaired motor control of the lumbar spine (Cholewicki et al. 2005), and both increased and decreased physical activity levels (Bergstrom et al. 2007; Mattila et al. 2008). Key psychological risk factors identified are psychological distress (Adams et al. 1999; Feyer et al. 2000; Harkness et al. 2003) and job dissatisfaction (Bigos et al. 1991; Hoogendoorn et al. 2002). Other individual LBP risk factors include smoking (Battie et al. 1989; Feuerstein et al. 2006; Mattila et al. 2008), age (Battie et al. 1990; Cassidy et al. 2005) and increased body weight (Battie et al. 1990; Croft et al. 1999).

To date, prospective studies on nursing students identified factors from the psychological domain as being the strongest modifiable predictors of future LBP episodes (Klaber-Moffett et al. 1993; Feyer et al. 2000). However, a large multidimensional cohort study of health care workers found all personal characteristics accounted for less than 12% of new LBP episode variance (Adams et al. 1999).

Another key issue related to identifying LBP risk factors is measurement of targeted factors that are likely to be associated with LBP in the specific population under investigation. Findings may not be generalisable across other populations (Schenk et al. 2007). It is proposed that selecting a homogenous population (such as by occupation and gender) and then considering factors hypothesised to be relevant to that specific population, may assist in identifying modifiable predictors of LBP.

Clearly, multiple factors may contribute to an episode of LBP (Cholewicki et al. 2005), making identification of LBP risk factors across multiple domains an important goal. The purpose of this study was to investigate modifiable personal characteristics that predicted new-onset LBP in a known high-risk occupational group (nursing students).

6.2. Method

6.2.1. Design

This prospective study examined the influence of a range of baseline personal characteristics (social/lifestyle, psychological and physical) on LBP in undergraduate nursing students during a 12-month follow-up period.

6.2.2. Sample

This study was part of a larger prospective study that examined new-onset and recurrent LBP in undergraduate male and female nursing students (n=199). Subjects were recruited via personal invitation from two undergraduate university nursing programs. At the time of baseline testing, subjects were aged between 18 and 35 years and were in their second or third year of their respective programs. Ethical approval to conduct the study was granted from both universities involved, and written informed consent was obtained from subjects (Appendix 1).

For this study, students without ‘significant’ LBP (see definition under 6.2.4) were invited to participate. Subjects were excluded if they had: an inability to understand written or spoken English; other conditions affecting the spine or lower limbs including inflammatory disorders, neurological diseases or metastatic disease;

pregnancy or less than 6 months post-partum; or inability to complete all physical tests (see Figure 6.1).

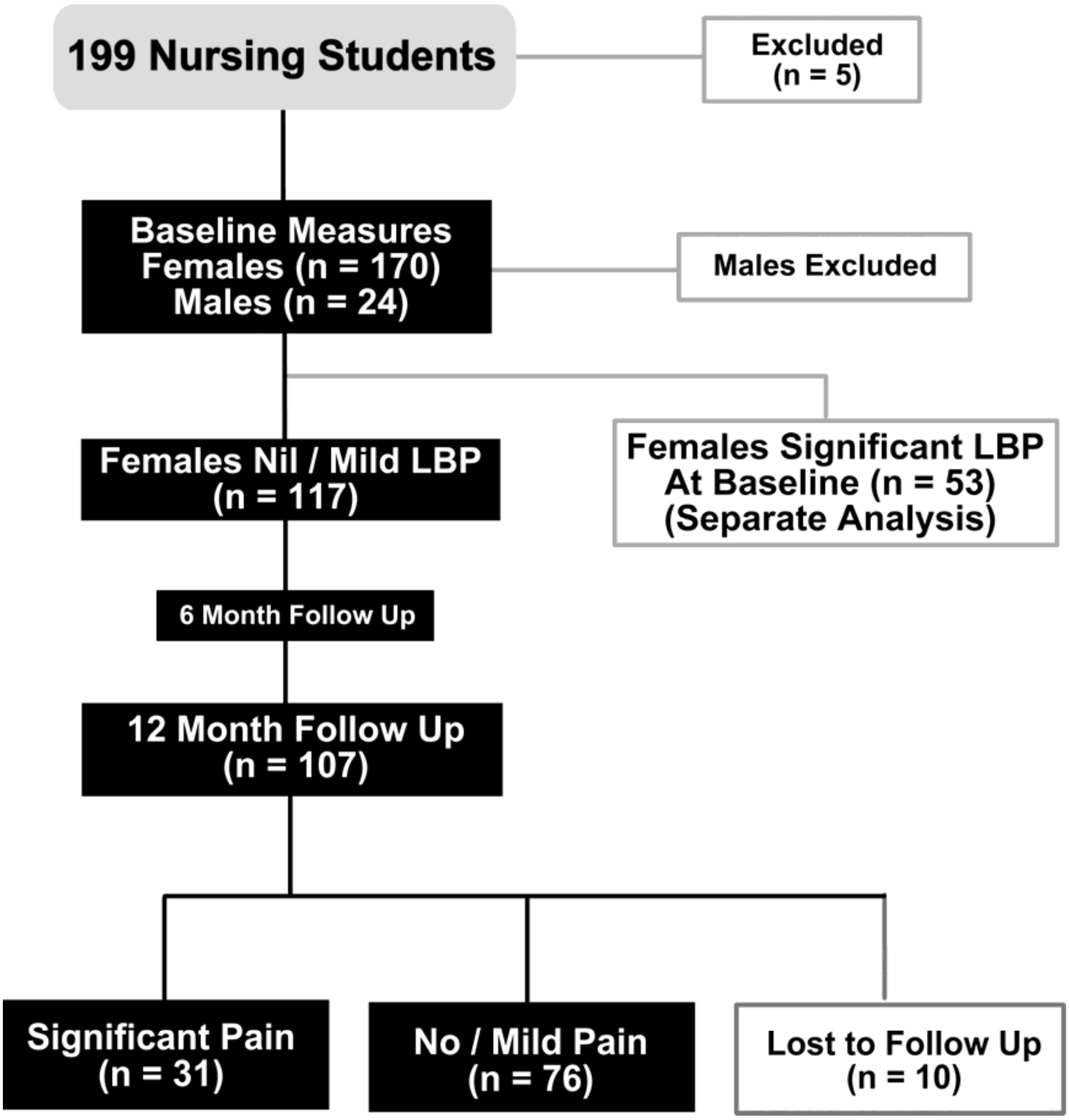

Figure 6.1. Subject recruitment and follow-up.

6.2.3 Baseline Measures

6.2.3.1. LBP screening questionnaires

The Nordic Low Back Pain Questionnaire (Kuornika et al. 1987) was used to determine LBP history, severity and impact whilst the Modified Core Network Low Back Pain Medical Screening Questionnaire assessed subjects' general health status and screened for confounding "red-flag" medical conditions (Committee 1997).

6.2.3.2. Social / lifestyle factors

Social/lifestyle data (household income, marital status, previous history of compensation claim, smoking and alcohol consumption) were obtained using a questionnaire based on previous research (Brasic 2003). The self-report long form of the International Physical Activity Questionnaire (IPAQ) was used to record average physical activity levels of subjects over the last 7 days (Booth 2000). Subjects estimated average light, moderate and vigorous weekly physical activity levels across Occupation, Transport, Household and Leisure domains. Data were summed across the domains to give weekly averages (in hours) of time spent doing vigorous and moderate physical activity as well as total time spent sitting and walking. These data are summarised in Table 6.1.

6.2.3.3. Psychological factors

Four reliable and valid questionnaires were used to evaluate psychological characteristics. The Depression Anxiety Stress Scales (DASS) are a set of three self-report scales used to measure depression, anxiety and stress (Lovibond and Lovibond 1995). The Back Beliefs Questionnaire (BBQ) is a 14-item self-administered questionnaire which determines individual beliefs regarding the impact of back pain (Symonds et al. 1996). The General Short Form 19-item Coping Scale for Adults (CSA) investigates coping and the development of coping strategies (Frydenberg and Lewis 2004). It provides sub-scale scores for coping styles including Dealing with the Problem and Non-productive Coping. The Pain Catastrophizing Scale (PCS) (Sullivan et al. 1995) contains 13 items regarding past pain experiences and provides a total and three sub-scale scores assessing Rumination, Magnification and Helplessness.

6.2.3.4. Physical factors

Body Mass Index was calculated as an index of weight relative to height and subjects were categorised as normal or overweight/obese according to current convention (BMI>25 kg/m^2) (de Onis and Habicht 1996). Lower limb muscle endurance was measured during a functional squatting task (Perich et al. 2006), back muscle endurance using the Biering-Sorensen test (Biering-Sorensen et al. 1989) and cardiovascular fitness was measured using the Astrand-Rhyming sub-maximal bicycle ergometer test (Astrand and Rodahl 1986). Spinal repositioning accuracy was evaluated with subjects attempting to reproduce a criterion position of neutral lumbar lordosis in sitting (O'Sullivan et al. 2003).

6.2.3.4. Spinal posture and kinematics

Flexion / extension angles of the lumbar spine were derived from sensors placed over the spinous processes of T12, L3 and S2 using the 3-Space® Fastrak™ (Polhemus, Kaiser Aerospace, Vermont) based on previously described protocol (Dankaerts et al. 2006a). Reliability and validity of the Fastrak™ system for measuring spinal range of motion has been previously demonstrated (Pearcy and Hindle 1989; Jordan et al. 2004). Flexion-extension angles of the spine were measured in usual sitting and usual standing, maximal slumped sitting, sway standing, and maximal forward bending and maximal backward bending in standing. Maximal flexion / extension angles during a series of functional tasks were also examined in an attempt to replicate common pain provocative functional tasks in this group. These tasks included; picking up a pen and lifting a 5kg box from the ground, transferring a pillow and a box at mid thigh level, and squatting. All tests, except picking up a pen and squatting, were performed three times (Figure 6.2).

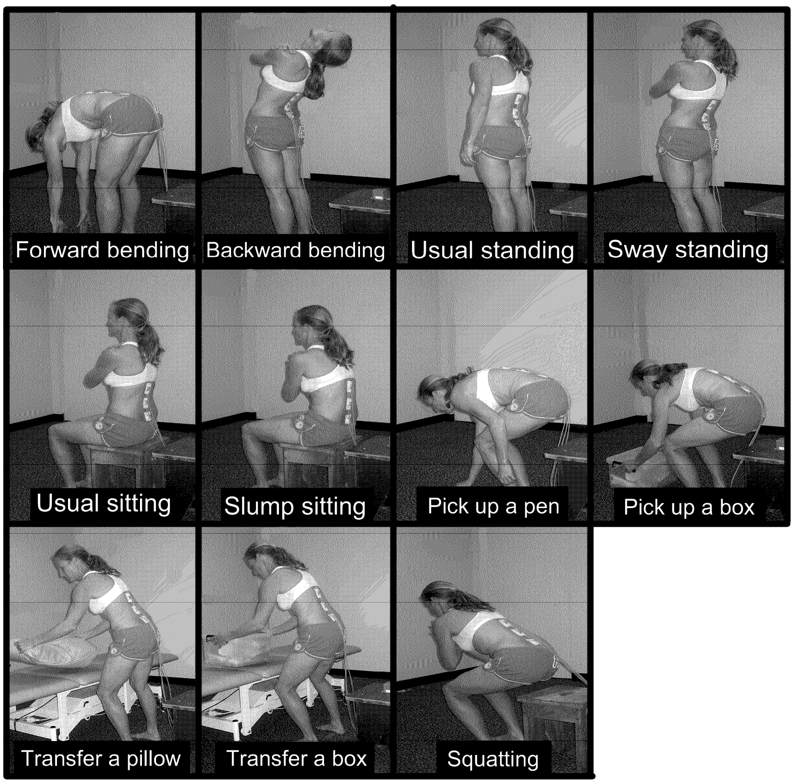

Figure 6.2. Test postures.

6.2.4. Follow-up questionnaires

Subjects were followed up over 12-months to monitor new-onset LBP incidence. To minimise recall bias, follow up questionnaires were posted to subjects at both 6- and 12-months after baseline assessment (Dawson et al. 2002). Questionnaires included the Nordic Low Back Pain Questionnaire, and the Oswestry Disability Index (ODI). An additional question on self-reported aggravating postures / activities was also included (subjects were asked whether bending / lifting, sitting / driving, standing / walking or other aggravated their pain). Subjects were also asked to mark on a VAS the highest level of LBP they had experienced in the previous 6 months. Subjects were classified as having had a significant LBP episode if they scored above the designated cut off score in at least three of the following four criteria:

i) LBP Severity > 4/10 for their worst LBP in the previous 12-months on a visual analogue pain scale (Bolton 1999).

ii) Duration of LBP in previous 12-months >1 week (to differentiate subjects with a single, very short episode of LBP (Kuornika et al. 1987)).

iii) LBP requiring treatment or medication or a reduction in activity in the past 12 months (Adams et al. 1999).

iv) LBP disability levels at the time of testing of >20% as measured by the Oswestry Disability Index (ODI) (Fairbank et al. 1980).

Subjects with no LBP, or minor LBP at baseline were defined as having new-onset LBP if they experienced an episode of significant LBP during the follow-up period.

6.2.5. Data Management

Calculation of spinal angles was conducted using custom software written in LabVIEW V8 (National Instruments, Texas, USA). Pelvic (S2), lower lumbar (LLx) (L3-S2) and upper lumbar angles (ULx) (T12- L3) were calculated for each movement trial, as previously defined and shown to possess excellent inter-trial reliability in sitting (Dankaerts et al. 2006a). Forward (anterior) pelvic tilt was assigned a positive value and backward (posterior) pelvic tilt a negative value.

The mean angle from three trials (averaged over 5 seconds of data collection) was calculated for each of; usual and maximal slumped sitting, usual and sway standing and maximal forward and backward bending in standing. Further, the mean peak flexion-extension angles were calculated for each functional task. As there was no sustained hold during these tasks (except for the squat), the start and finish of the task were manually identified and the customised analysis software determined the point of peak flexion (or least sagittal extension) angle reached during the task.

Given the proposed association between passive end range spinal loading and LBP (Colloca and Hinrichs 2005), further analysis was conducted on how far subjects held their spine from end of range flexion during different bending postures and tasks. For sitting, the usual sitting angle was compared to maximal slump sitting angle. The maximal forward bending angle in standing was used as the end of range reference angle to compare with; picking up the pen and box from the floor, transferring the pillow and box at bed height and squatting angle.

6.2.6. Statistical Analysis

Statistical analyses were performed using SPSS Version 13 (SPSS Inc., Chicago: USA). Univariate differences in social/lifestyle, psychological and physical characteristics between the no/mild LBP and significant LBP groups were tested using binomial logistic regression, with LBP history, age and BMI included as covariates. A stepwise model for independent predictors of LBP was developed. To limit the potential of identifying chance variables due to the large number of variables, three variables from each category (social/lifestyle; psychological; physical performance; spinal angles) with the lowest p-values from univariate regression analyses were included in both forward and backward stepwise multivariate analyses to confirm model validity. Model fit was evaluated using; the Hosmer Lemeshow test and Nagelkerke $R^{2,}$ and analysis of residuals performed to confirm the absence of influential outlying cases. Alpha probability was set at $p < 0.05$.

6.3. Results

Subject response rate was 94% (n=110) at 6 months and 91% (n=107) at 12 months. If subjects who initially displayed no/mild LBP at baseline reported a significant LBP episode during either the 6- or 12-month follow up, they were included in the significant LBP group for final analysis. Of the 117 subjects included at baseline, ten were lost to follow up (Five failed to respond to follow up, four withdrew from their university course and one fell pregnant). Of the remaining 107 subjects, 76 (71%) remained in the same group, while 31 (29%) reported at least one new significant episode of LBP over the subsequent year (see Figure 6.1). The 31 subjects with significant LBP were compared at follow-up based on characterising the course of LBP described by Dunn and co-workers (Dunn et al. 2006). Only one subject described their pain as a single short episode, 24 (77.4%) had multiple episodes with pain free periods in between and six (19.4%) had what they deemed persistent ongoing pain. Of factors that aggravated subjects' pain, bending / lifting (49%) was most common, followed by sitting / driving (30%) and standing / walking (25%).

6.3.1. Uni-variate analyses

As 73 of the 107 subjects had previously experienced some mild LBP, analyses were performed adjusting for lifetime history of LBP, with age and BMI also included as covariates. As shown in Table 6.1, none of the covariates significantly predicted new-onset LBP.

Cigarette smoking was the only significant predictor from the social domain of new-onset LBP (Table 6.1). Higher levels of both moderate activity (such as housework and moderate exercise) and vigorous activity (such as heavy gardening and vigorous exercises) were significant lifestyle predictors of new-onset LBP. These variables are composite variables derived from the IPAQ, which include components of both physical exercise and manual work. Before combining these variables however, statistical analysis confirmed most individual items of the grouped variable (eg moderate activity: job-related, garden or yard, inside home and leisure time) was associated with future LBP with a significance level of $p < 0.2$ (data not shown. See Appendix 5).

Table 6.1. Univariate group comparisons of baseline social and lifestyle variables adjusted for LBP history, age and BMI [mean ± standard deviation, n (%), or median (interquartile range)].

	No/Mild LBP (n = 76)	Significant LBP (n = 31)	Odds Ratio	95% CI	p-value
Covariates					
Any History of LBP	51 (67.1 %)	26 (83.9 %)	2.48	0.85-7.26	0.098
Age (yrs)	21.7 ± 3.7	21.7 ± 4.5	1.00	0.90-1.12	0.993
Overweight / Obese	18 (23.7 %)	10 (32.3 %)	1.44	0.57-3.67	0.444
Social / Lifestyle Measures					
Cigarette Smokers	3 (3.9 %)	6 (19.4 %)	8.67	1.75-42.87	**0.008**
> 5 alcoholic drinks per week	16 (21.1 %)	5 (16.1 %)	0.72	0.23-2.24	0.565
Household income <AUD 59 000 p/anum	27 (35.5 %)	13 (41.9 %)	0.75	0.30-1.84	0.524
Marital status (% single)	67 (88.2 %)	26 (83.9 %)	0.49	0.11-2.26	0.359
Previous compensation claim	2 (2.6 %)	2 (6.5 %)	3.37	0.36-31.37	0.286
Moderate physical activity (hours/week)	5.0 (9.9 IQR)	7.0 (12.5 IQR)	1.08	1.02-1.15	**0.009**
Vigorous physical activity (hours/week)	3.0 (5.0 IQR)	5.0 (11.0 IQR)	1.07	1.00-1.14	**0.047**
Walking (hours/week)	6.25 (9.0 IQR)	7.5 (16.0 IQR)	1.02	0.98-1.06	0.265
Sitting (hours/week)	45.0 (17.9 IQR)	43.0 (19.0 IQR)	1.00	0.98-1.02	0.760

IQR = Interquartile Range.

Only one physical and one psychological measure were uni-variate predictors of new-onset LBP. Higher stress was the only significant psychological predictor (Table 6.2). Back beliefs, coping strategies and catastrophising scores at baseline did not predict future LBP. Greater posterior pelvic tilt in the slump sitting position was the only physical predictor (Table 6.3). Fitness, back muscle and lower limb endurance, spinal repositioning sense and other static and functional postural angles were not univariate predictors of new-onset LBP.

Table 6.2. Univariate group comparisons of baseline psychological variables adjusted for LBP history, age and BMI [mean ± S.D, or median (interquartile range)].

	No/Mild LBP (n = 76)	**Significant LBP (n = 31)**	**Odds Ratio**	**95% CI**	**p-value**
Depression, Anxiety and Stress Scales					
Total (/126)	8.0 (14.0)	14.0 (22.0)	1.03	1.00-1.06	0.054
Depression (/42)	2.0 (4.0)	2.0 (6.0)	1.05	0.98-1.13	0.129
Anxiety (/42)	2.0 (6.0)	2.0 (6.0)	1.03	0.95-1.12	0.329
Stress (/42)	4.0 (6.0)	10.0 (10.0)	1.08	1.01-1.15	**0.021**
Back Beliefs Questionnaire					
Total (/45)	30.0 ± 4.6	30.2 ± 5.3	0.99	0.90-1.09	0.850
Coping Scale for Adults					
Dealing with Problem (/105)	70.6 ± 12.2	72.0 ± 15.1	1.01	0.98-1.05	0.525
Non-productive coping(/105)	51.9 ± 11.5	52.4 ± 14.0	1.00	0.97-1.05	0.945
Pain Catastrophising Scale					
Total (/52)	10.0 (13.0)	5.0 (14.0)	0.99	0.94-1.04	0.673
Rumination (/16)	4.0 (6.0)	2.0 (5.0)	0.96	0.86-1.08	0.528
Magnification (/12)	1.0 (3.0)	1.0 (3.0)	1.04	0.83-1.31	0.711
Helplessness (/24)	3.0 (5.0)	1.0 (4.0)	0.96	0.85-1.08	0.455

Table 6.3. Univariate group comparisons of baseline spinal angles and physical variables adjusted for LBP history, age and body weight (mean ± standard deviation).

	No/Mild LBP (n = 76)	Significant LBP (n = 31)	Odds Ratio	95% CI	p-value
Sitting angles (°)					
Pelvic sit angle	0.7 ± 7.3	-0.8 ± 8.3	0.96	0.90-1.02	0.191
LLx sit angle	3.3 ± 8.3	3.0 ± 8.0	0.99	0.94-1.04	0.603
ULx sit angle	-1.3 ± 8.0	-3.2 ± 8.2	1.04	0.98-1.10	0.197
Pelvic slump angle	-8.1 ± 7.1	-10.4 ± 7.5	1.08	1.00-1.15	**0.040**
LLx slump angle	1.3 ± 8.9	1.9 ± 8.5	1.00	0.95-1.05	0.876
ULx slump angle	-8.0 ± 5.1	-9.5 ± 5.1	1.09	0.99-1.19	0.080
Pelvic sit proximity to EOR	8.9 ± 5.2	9.6 ± 5.7	1.04	0.96-1.12	0.374
LLx sit proximity to EOR	2.0 ± 3.2	1.0 ± 3.0	0.92	0.79-1.08	0.317
ULx sit proximity to EOR	6.7 ± 6.3	6.2 ± 6.0	0.99	0.92-1.06	0.758
Standing angles (°)					
Pelvic stand angle	26.8 ± 7.3	25.8 ± 7.0	0.98	0.93-1.04	0.461
LLx stand angle	23.0 ± 11.2	21.5 ± 10.6	0.99	0.95-1.03	0.577
ULx stand angle	16.3 ± 9.2	15.6 ± 9.5	0.99	0.95-1.04	0.695
Pelvic sway angle	24.4 ± 9.1	23.2 ± 11.0	0.98	0.94-1.03	0.443
LLx sway angle	30.7 ± 13.6	30.8 ± 13.3	1.00	0.97-1.03	0.979
ULx sway angle	17.7 ± 12.5	17.0 ± 10.6	1.00	0.96-1.03	0.828
Pelvic extension angle	19.6 ± 10.5	17.0 ± 13.3	0.98	0.94-1.01	0.226
LLx extension angle	44.2 ± 20.0	43.4 ± 15.7	1.00	0.97-1.02	0.829
ULx extension angle	28.0 ± 15.6	25.4 ± 14.5	0.99	0.96-1.02	0.516
Pelvic flexion angle	80.4 ± 11.9	81.8 ± 12.8	1.01	0.97-1.04	0.692
LLx flexion angle	-11.2 ± 6.2	-12.3 ± 6.9	1.03	0.96-1.10	0.372
ULx flexion angle	-14.7 ± 5.2	-16.0 ± 5.5	1.06	0.98-1.16	0.144
Functional posture angles (°)					
Pelvic pen angle	61.6 ± 15.3	63.7 ± 16.9	1.01	0.98-1.03	0.656
LLx pen angle	-8.5 ± 7.1	-8.9 ± 6.5	1.01	0.94-1.08	0.831
ULx pen angle	-12.1 ± 6.3	-13.5 ± 5.5	1.04	0.97-1.12	0.274
Pelvic pen proximity to EOR	18.8 ± 17.1	18.1 ± 15.8	1.00	0.98-1.03	0.907
LLx pen proximity to EOR	2.7 ± 3.0	3.5 ± 3.3	1.10	0.96-1.27	0.170

ULx pen proximity to EOR	2.6 ± 4.7	2.5 ± 3.4	0.99	0.90-1.09	0.834
Pelvic 5kg lift angle	51.9 ± 13.0	50.1 ± 10.9	0.98	0.95-1.02	0.398
LLx 5kg lift angle	-5.8 ±7.7	-7.0 ± 8.0	1.02	0.96-1.08	0.487
ULx 5kg lift angle	-8.1 ± 8.1	-10.5 ± 8.2	1.04	0.91-1.11	0.142
Pelvic lift proximity to EOR	28.5 ± 13.8	31.8 ± 13.3	1.02	0.99-1.05	0.263
LLx lift proximity to EOR	5.4 ± 4.8	5.4 ± 5.0	1.00	0.92-1.10	0.929
ULx lift proximity to EOR	6.9 ± 7.3	6.1 ± 7.4	0.98	0.93-1.04	0.584
Pelvic pillow transfer angle	46.8 ± 7.9	45.8 ± 8.3	0.98	0.93-1.03	0.467
LLx pillow transfer angle	3.1 ± 8.4	0.7 ± 7.1	0.95	0.90-1.01	0.117
ULx pillow transfer angle	-4.2 ± 8.3	-5.4 ± 7.8	1.03	0.97-1.09	0.303
Pelvic pillow transfer EOR	18.8 ± 17.1	18.1± 15.8	1.00	0.98-1.03	0.907
LLx pillow transfer EOR	14.3 ± 7.3	13.1 ± 5.7	0.96	0.90-1.03	0.298
ULx pillow transfer EOR	10.5 ± 8.0	10.6 ± 8.7	1.00	0.95-1.05	0.954
Pelvic 5kg transfer angle	44.9 ± 8.3	44.3 ± 7.7	0.99	0.93-1.04	0.610
LLx 5kg transfer angle	7.4 ± 9.2	5.9 ± 7.3	0.98	0.93-1.03	0.355
ULx 5kg transfer angle	2.3 ± 8.2	0.9 ± 8.7	0.97	0.92-1.03	0.274
Pelvic transfer EOR	35.5 ± 11.9	37.5 ± 13.3	1.01	0.98-1.05	0.470
LLx transfer EOR	18.6 ± 8.1	18.3 ± 6.8	0.99	0.94-1.05	0.760
ULx transfer EOR	17.0 ± 8.2	17.0 ± 9.7	1.00	0.95-1.05	0.900
Pelvic squat angle	53.1 ± 10.9	52.7 ± 11.7	1.00	0.96-1.05	0.866
LLx squat angle	-3.7 ± 7.1	- 5.0 ± 9.3	1.02	0.97-1.09	0.400
ULx squat angle	-2.4 ± 9.1	-4.1 ± 9.0	1.03	0.98-1.08	0.281
Pelvic squat EOR	26.8 ± 14.8	29.0 ± 17.7	1.01	0.98-1.04	0.562
LLx squat proximity to EOR	7.7 ± 6.1	7.4 ± 5.6	0.99	0.92-1.07	0.786
ULx squat proximity to EOR	12.2 ± 8.7	11.9 ± 8.8	1.00	0.95-1.05	0.872
Performance measures					
Squat time (seconds)	37.6 ± 19.6	32.2 ± 18.6	0.99	0.96-1.01	0.225
Sorensen time (seconds)	91.2 ± 44.9	77.4 ± 41.6	0.99	0.98-1.00	0.186
Pelvic sitting repo error (°)	2.5 ± 1.7	2.7 ± 1.9	1.06	0.84-1.34	0.625
LLx sitting repo error (°)	3.2 ± 2.3	2.4 ± 1.9	0.82	0.65-1.04	0.107
ULx sitting repo error (°)	4.0 ± 2.9	2.8 ± 1.9	0.82	0.66-1.00	0.054
Predicted VO2 max (L/min)	2.3 ± 0.5	2.3 ± 0.4	1.27	0.50-3.26	0.616

LLx = Lower Lumbar, ULx = Upper Lumbar, TLx = Total Lumbar, ROM = Range of Motion, EOR = End of Range flexion angle, Repo = repositioning, Negative lumbar angle = lumbar flexion, Positive lumbar angle = lumbar extension, Negative pelvic angle = posterior pelvic rotation, Positive pelvic angle = anterior pelvic rotation.

6.3.2. Multivariate Analysis

Although cigarette smoking was found to be a significant predictor of new-onset LBP, only 8% of subjects smoked, therefore this variable was excluded from further analyses as small cell sizes limited the precision of estimates. The final multivariate model retained at least one variable from each of the domains examined in this study (Table 6.4). These variables were higher stress levels, higher levels of moderate activity, greater posterior pelvic tilt in slump sitting, reduced back muscle endurance and greater spinal repositioning accuracy in sitting. Due to their known influence on LBP risk factors in previous studies, LBP history (Hestbaek et al. 2006a), age (Croft et al. 1999) and adiposity (Leboeuf-Yde et al. 2006) were retained as covariates in the final model. Of these covariates, lifetime history of LBP was the only significant predictor of new-onset LBP.

The Nagelkerke R^2 for the eight variables included in the final model was 0.448. The proportion that each variable contributed to this value is also shown in Table 6.4. Notably, there was a relatively even contribution to the R^2 value across all domains, with previous LBP history contributing the least amount. As an indication of the validity of the model, the same variables were retained with both forwards and backwards step-wise entry methods.

Table 6.4. Final logistic regression model for predicting new-onset LBP.

	Odds Ratio[1]	**95% CI**	**p-value**	**Relative contribution to R^2**
Age (yrs)	1.03	0.90-1.18	0.656	
BMI (kg/m^2)	1.03	0.29-3.64	0.968	
History of LBP	7.65	1.60-36.60	**0.011**	0.052
Stress	2.49	1.33-4.64	**0.004**	0.059
Moderate activity (hours/week)	3.18	1.60-6.29	**0.001**	0.078
Back muscle endurance (seconds)	0.34	0.17-0.70	**0.004**	0.061
Pelvic angle slump sit (°)	2.70	1.43-5.00	**0.002**	0.111
LLx sitting repositioning error (°)	0.30	0.14-0.65	**0.002**	0.087

[1]The Odds Ratio represents the increase in the odds of having significant LBP, holding all other variables constant, for a unit increase (approximating one standard deviation) in the independent variable.

6.4. Discussion

This exploratory prospective study found that factors from social/lifestyle, psychological and physical domains were all independently associated with new-onset LBP in a modest sample of female undergraduate nursing students. This supports previous assertions that LBP is a multi-dimensional biopsychosocial problem, involving complex interactions between different factors (Cholewicki et al. 2005). The strength of this study is the identification of *modifiable* personal characteristics that substantially contribute to a predictive model of LBP. As LBP prevalence is known to be very high in nursing students prior to commencing university study (Mitchell et al. 2008), identifying factors associated with new-onset LBP has implications for LBP prevention in nurses.

The incidence of new-onset significant LBP over a 12-month period was 29%, supporting the importance of early LBP intervention. The reported LBP incidence is similar to some studies (Klaber-Moffett et al. 1993; Feyer et al. 2000), but higher than others (Adams et al. 1999; Harkness et al. 2003). Clearly varying definitions of LBP (e.g., new-onset or recurrent) will influence such incidence statistics (Marras et al. 2007), as will gender (Schneider et al. 2006). Although novel, the LBP definition used in this study was robust as it defined LBP based on a number of clinically relevant criteria namely: pain severity, duration, health care seeking, impact and disability level.

6.4.1. Lifestyle / social factors

Smoking was found to be a predictor of new-onset LBP in this study and has been previously been shown to be predictive of LBP in general, industrial and adolescent cohorts (Battie et al. 1989; Mattila et al. 2008; Mikkonen et al. 2008). The link between smoking and LBP may be via increased atherosclerosis of the lumbar vessels (Leino-Arjas et al. 2006), altered gene expression contributing to intervertebral disc degeneration (Uei et al. 2006), or an association between smoking, LBP and socio-economic factors, personality, or psychological distress (Mikkonen et al. 2008). Social factors including household income, previous compensation claims and marital status were not associated with LBP risk in this study, perhaps suggesting such factors are not important to LBP development in this female nursing student population.

6.4.2. Physical Activity

Increased hours of moderate and vigorous physical activity were predictors of new-onset LBP. Other research suggests that higher levels of physical activity in young populations may either be protective of (Wedderkopp et al. 2008) or increase the risk of (Kujala et al. 1999; Mattila et al. 2008) LBP. Both higher education and female gender have been previously associated with higher levels of physical activity (Salmon et al. 2000), suggesting links between physical activity and LBP may be dependent on a number of factors, not least the sample under investigation. It is important to note that the activity ratings in this study were a composite measure including exercise, household and occupational activity. Although speculative, increased physical activity in the LBP group may reflect increased exposure to spinal loading.

6.4.3. Stress

Stress was a predictor of LBP in this study, which supports the findings of other cohort studies on health care populations (Adams et al. 1999; Feyer et al. 2000). In chronic pain patients, risk of pain onset was predicted by psychosocial factors including psychological distress. However, not all "at risk" subjects necessarily develop pain (McBeth et al. 2001). It was hypothesized that the influence of such factors would be moderated through the hypothalamic-pituitary-adrenal (HPA) axis (McBeth et al. 2001), with subsequent evidence of the failure to suppress the HPA-axis being associated with higher risk of a new-onset pain episode, supporting that these pain episodes are influenced by both psychological and physical antecedents (McBeth et al. 2007). Whether similar mechanisms for pain development may apply to some individuals in less chronic pain conditions is not clear.

Stress scores in this otherwise healthy female nursing student cohort did not reach a clinical threshold defined as high stress. However, elevated stress bio-markers have been shown to have an influence on LBP development in some healthy individuals (Schell et al. 2008). Importantly, in the current study, higher stress was only one of a number of factors across multiple domains that predicted new-onset LBP. It is hypothesized that higher stress in combination with other factors (such as increased physical activity and reduced muscle endurance) may have an additive effect on the risk of future LBP via complex interactions between factors.

An additional mechanism for LBP development in this cohort could be the higher levels of psychological stress in LBP subjects contributing to and/or exacerbating LBP via increased mechanical spinal loading from higher levels of muscle tension (Marras et al. 2000). Although strongly associated with the development of chronic pain, coping strategies, LBP beliefs and catastrophising were not found to be predictors of new-onset LBP.

6.4.4. Physical predictors

Interestingly, only one physical measure was associated with new-onset LBP in the univariate analysis. However, the inclusion of three physical variables in the final multivariate model supports the concept of complex interactions between LBP risk factors. The strongest kinematic measure was pelvic angle in slump sitting, with greater posterior pelvic tilt being predictive of LBP. Increased posterior pelvic tilt has been associated with increased lower lumbar spinal flexion (Dankaerts et al. 2006a), which was supported by this study, with a strong correlation being evident between the two variables ($r=0.73$, $p<0.001$). As the two most commonly reported mechanisms for symptom aggravation were bending / lifting and sitting / driving, these findings may suggest that the majority of LBP subjects had a flexion-related pain mechanism (Dankaerts et al. 2006b). Although the habitual posture angles in this study did not clearly support that LBP subjects held greater lower lumbar flexion, this may have been due to the short exposure times for these measures. Given the findings in the pain subjects of increased activity and potential loading times, poorer back muscle endurance and greater maximal posterior pelvic tilt, it is possible that during sustained or repeated spinal loading, deficits in back muscle endurance may result in greater exposure to lumbar flexion loading. This concept requires further investigation.

A physical mechanism for LBP could be increased flexion loading of passive spinal structures, with a tendency to rely less on the muscular support system (Colloca and Hinrichs 2005). This is supported by the finding of lower muscle endurance scores (leg and back) in the LBP group, with reduced back muscle endurance also being included in the final regression model. It could be speculated that as increased physical activity levels were also predictive of future LBP, a greater amount of time spent bending and lifting (with the spine more flexed) by LBP subjects may further contribute to this mechanism. Reduced back muscle endurance and increased time spent in flexed postures (sitting) has also been associated with LBP in a group of male industrial workers with flexion-related LBP (O'Sullivan et al. 2006).

The finding of more accurate spinal repositioning being a predictor of future LBP was unexpected. In the only other prospective study identified, spinal proprioception did not predispose college athletes to LBP (Silfies et al. 2007). Better repositioning accuracy in the LBP group could be reflective of higher levels of attentional vigilance. Increased vigilance to sensations associated with pain or pain region has been associated with high pain-related fear in chronic pain populations (Peters et al. 2002; Crombez et al. 2004), however, this was not examined in this study.

6.4.5. Multifactorial nature of LBP

As modifiable factors across a number of domains were independent and collectively substantial predictors of LBP in the final regression model (Nagelkerke $R^2 = 0.448$), this study supports the widely accepted biopsychosocial approach to LBP prevention and management (McCarthy et al. 2004; Waddell 2004; Gatchel et al. 2007). Whilst other personal factors not measured in this study (e.g., trunk muscle activity levels (Cholewicki et al. 2005) and biochemical stress markers (Schell et al. 2008)) may contribute further to a predictive model of LBP, non-modifiable factors such as genetics may also be significant predictors (Chan et al. 2006; Battie et al. 2007).

Although the need for multifactorial preventative interventions is supported by a recent systematic review of LBP prevention strategies in nurses (Dawson et al. 2007), it is likely that factors associated with the development of LBP vary between different occupational groups, as well as individuals. A review paper by Turk highlights the importance of matching treatment to specific sub-groups of chronic pain patients, based on physical and psychosocial-behavioural characteristics (Turk 2005). Historically, multi-modal interventions have been based on a generic cognitive behavioural therapy approach with a general exercise component (van der Hulst et al. 2005), without being tailored to identified physical and/or psychological impairments. However, recent reviews support the need to address both physical and psychosocial components within specific sub-groups of LBP patients (Turk 2005; Balague et al. 2007).

It is proposed that successful LBP interventions should include aspects such as stress management, movement and postural training, pacing, and targeted conditioning, according to the characteristics of the LBP sub-group undergoing the intervention (O'Sullivan 2006). The key to injury management and indeed prevention, is likely to lie in the identification of modifiable risk factors specific to groups of individuals and the resultant development of a targeted intervention. The findings of this study indicate this is a realistic objective given the relatively large R^2 value for this model of modifiable factors.

6.4.6. Limitations and future research

The specificity of this sample of young, otherwise healthy female nursing students should be considered when interpreting the findings of this study. LBP predictors may not translate to other populations such as males or other occupational groups. Clearly, a larger sample size and longer follow-up period may also have strengthened the results of this study. Defining LBP remains an ongoing problem when comparing related studies, however a recent consensus paper on standardizing LBP definitions may help resolve this problem in future studies (Dionne et al. 2008).

Earlier cross-sectional analyses of this cohort showed that LBP sub-groups existed and had differing physical and psychological factors associated with their LBP. Sub-grouping subjects with LBP during follow-up was not possible in the prospective analysis, as subjects were not physically re-examined on follow-up. Those subjects from this cohort with significant LBP at baseline are the subject of ongoing prospective research, to examine factors which predict resilience to the recurrence of LBP.

6.5. Conclusion

This study supports the biopsychosocial nature of LBP. Factors from social/lifestyle, psychological and physical domains were all independently associated with significant new-onset LBP in female nursing students. These potentially modifiable personal factors contributed substantially to the prediction of new-onset significant LBP. Interventions utilising a prevention approach that targets modifiable characteristics across a number of domains, such as those identified in this study may have the potential to reduce the impact of occupational LBP in nurses. This would need to be verified in subsequent intervention studies.

6.6. References

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CHAPTER 7 - Discussion

7.1. Introduction

LBP remains a common, recurrent problem that affects many individuals and also places a large economic burden on society. Manual occupations such as nursing are known to be at high risk of occupational LBP. The lack of clear evidence to support any particular intervention or prevention strategy for LBP is a major hurdle in reducing its impact. To date, the best predictor of future LBP is a previous history of LBP (Maul et al. 2003; Hestbaek et al. 2006) and there is no strong evidence regarding the efficacy of workplace interventions preventing LBP in nurses (Dawson et al. 2007).

In order to improve the efficacy of LBP prevention, it was proposed that an emphasis on identifying modifiable personal factors associated with the development of LBP, rather than occupational factors, should be considered. The series of studies outlined in this thesis represents a thorough investigation of personal factors associated with the development of LBP in nursing students from a biopsychosocial perspective. This chapter provides a summary of the research undertaken as part of this doctoral research and discusses the findings in relation to the relevant literature. The clinical implications of these studies are then presented. Finally, limitations of the research are outlined and recommendations for future research are presented.

7.2. Factors associated with LBP in female nursing students: Discussion of main findings.

Studies with a cross-sectional design cannot determine the cause or effect relationship of factors identified to be associated with LBP. Further, those studies that use a prospective design have often been uni-dimensional in their investigation of factors associated with future LBP explaining only a small component of the disorder (Adams et al. 1999). As LBP is widely regarded as a biopsychosocial problem, studies are required that investigate the influence of personal factors from multiple domains, on the development of LBP. Consequently, the *general aim* of this doctoral research was:

- To investigate the influence of personal physical, psychological and social / lifestyle factors on LBP in a high-risk occupational population (nurses).

Following a review of relevant research examining predictors of LBP in general as well as specific nursing populations, modifiable personal factors across multiple domains were selected to examine their influence on the development of LBP. The results of the studies contained in this thesis support the biopsychosocial nature of LBP. In addition, they provide evidence that modifiable personal factors across a range of domains are associated with the development of LBP. This evidence will be discussed in relation to the *research aims* (Chapter 1, section 1.6) that formed the basis of this thesis (listed below).

7.2.1 When to intervene

In order to identify factors associated with the development of LBP in nurses, it was first necessary to determine when LBP prevalence increases. Previous research suggests that LBP in nurses; is already a problem prior to commencing nursing training (Feyer et al. 2000), increases as clinical exposure increases during undergraduate training (Klaber-Moffett et al. 1993), and/or does not change during undergraduate training (Smith and Leggat 2004). Considering this conflicting information, the specific research aims for Chapter Two were: (i) *To determine LBP prevalence in undergraduate nursing students and recently graduated nurses. Then whether LBP prevalence significantly alters across university training or once full-time employment commences.* (ii) *To examine the relative contributions of age and occupational exposure on the duration and severity of LBP episodes.*

The results presented in Chapter Two revealed that LBP (any self-reported ache, pain or discomfort) had already been experienced by over 75% of nursing students prior to commencing undergraduate studies. Prevalence of LBP did not significantly change during nursing training, but did increase significantly in the first year of commencing work as a nurse. Mean age was consistent across the undergraduate year groups and did not influence these findings. However, increased LBP episodes were associated with increased occupational exposure to bending and lifting.

In the LBP prevalence survey in Chapter Two, over 60% of all nursing students reported LBP that could be classified as clinically significant (ie. resulting in reduced activity levels, seeking treatment or taking medication). These cross-sectional LBP prevalence rates were in line with adult Australian general population prevalence rates (Walker et al. 2004), but higher than other studies investigating LBP among nursing students (Klaber-Moffett et al. 1993; Feyer et al. 2000; Kim et al. 2000; Smith and Leggat 2004; Videman et al. 2005). This difference may be explained by the Australian nursing staff undersupply and resultant changing nature of the workforce in Australia (Chrisopoulos and Waters 2003). This has resulted in an increase in mean age of both the qualified nurse and nursing student populations (Stein-Parbury 2000). As a previous episode of LBP is the strongest predictor of LBP recurrence and chronicity (Jones and Macfarlane 2005), the high levels of prevalence and associated impact for the first year nursing students supports the importance of implementing prevention LBP strategies before nursing students reach the hospital wards (Hellsing et al. 1993).

Furthermore, as mean age remained stable across all years of nursing students and graduate nurses, factors other than age were hypothesized to be more important to the development or recurrence of LBP. This was confirmed in both the cross-sectional and prospective results of the thesis (described below), with factors across multiple domains being associated with LBP, even when accounting for age and previous LBP history. As LBP prevalence further increases (along with the frequency and severity of the LBP episodes) once commencing full-time nursing duties (Chapter Two), targeting nurses at the transition from student to working nurse appears optimal. Linking this intervention as part of a structured Graduate Nurse Training Program (which is common in tertiary Australian teaching hospitals (Johnstone et al. 2008)) is a realistic method of integrating LBP prevention into the workplace and monitoring its effect.

As 12-month LBP prevalence was around 71% for all three undergraduate year groups, it was concluded that any of the year groups would provide a sufficient number of new LBP episodes (and thus sufficient statistical power) for a 12-month prospective study design. Further, as these nursing students were not yet exposed to the occupational LBP risk factors of working nurses, a clearer indication of the influence of modifiable personal factors on the development of LBP could be determined by using a student cohort. Undergraduate nursing students who were not in their final year of study were selected for ease of follow-up at 12-months and to retain a student population, as they would still be at university 12-months later.

7.2.2. Regional differences in lumbar spine angles

The selection of personal variables potentially associated with the development of LBP was based on a review of relevant literature as well as clinical expertise of the investigators. Although current evidence does not clearly support a relationship between spinal posture and LBP, recent cross-sectional studies suggest that the manner by which lumbar posture is measured may strongly influence these findings. Dankaerts and co-workers were able to distinguish between different sub-groups of LBP subjects as well as healthy controls based on regional rather than global lumbar spine sitting posture (Dankaerts et al. 2006). Further, Gill and co-workers showed that in healthy subjects, different lifting styles were associated with upper lumbar and thoracic posture differences, while lower lumbar posture remained constant. This further supports the importance of measuring regional differences in the lumbar spine (Gill et al. 2007).

Thus in order to determine the influence of spinal posture and kinematics on the development of LBP, the concept of regional lumbar spine function during common aggravating postures and movements warranted further investigation. The specific research aims of Chapter Three were: (i) *To determine whether regional (LLx / ULx) differences exist in spinal sagittal; static posture angles, range of motion and dynamic spinal angles during functional tasks.* (ii) *To determine if the nature of these differences vary in subjects with and without a history of LBP.*

Following the initial analysis of data collected during the cross-sectional component of this doctoral research, clear between-gender differences were found despite only 24 of the 194 subjects being male. Results of this analysis are presented in Appendix VI. When controlling for age, BMI and previous history of LBP, gender differences were evident across psychological, physical and lifestyle measures. These findings support gender differences in LBP reported in previous research (Schell et al. 2008; Smith et al. 2008; Suuden et al. 2008). As female gender is also widely regarded to be associated with higher LBP prevalence (Schneider et al. 2006), clearly factors associated with and predictive of LBP are likely to differ between-gender. These findings support that gender differences should also be considered in intervention studies for LBP subjects. As males only accounted for 12% of the sample, further analysis was restricted to female nursing students.

The results in Chapter Three strengthen the concept of regional differences within the lumbar spine during common postures and movements. These findings support and extend previous literature that has found global lumbar spine kinematics do not accurately reflect the kinematics of the ULx or LLx spinal regions (Burton 1987; Dankaerts et al. 2006; Gill et al. 2007). Rather, the ULx and LLx spine display some functional independence. For the purposes of investigation of spinal posture, motion and loading, these regions should be considered separately. This was evidenced by the regional differences in spinal angles with sitting, standing, range of motion and functional tasks.

Although previously hypothesized from clinical observation (O'Sullivan 2000; O'Sullivan 2005), Chapter Three also provided quantitative data to support the proposition that movement into the sway standing position is primarily a function of extension motion through the LLx segments, with very little motion occurring in the ULx spine. From a clinical perspective, if adopted habitually this sway standing position may result in increased load on passive spinal structures in the LLx spine due to inhibition of supporting spinal muscles (O'Sullivan et al. 2002). This may be a possible mechanism for LLx spine pain in some individuals during standing tasks. This was also partly supported in Chapter Five by the trend of ‘extension pattern’ subjects (with LBP provoked by extension postures and activities) holding greater LLx extension in usual standing posture than other subjects. Recent adolescent research supports that sway standing posture is associated with increased risk of LBP compared to neutral standing postures (Smith et al. 2008). This concept requires further research in a larger sample of adult LBP sub-groups.

Most of the regional differences found in Chapter Three were accounted for by the subject’s BMI, which may be an indication that the body adapts its position in response to load. This explanation is supported by previous evidence of; BMI modifying posture and movement of the lumbar spine (Gilleard and Smith 2007), different movement strategies when moving from sitting to standing between obese and individuals of ‘normal weight’ (Sibella et al. 2003), and a recent study showing higher BMI was related to hyper-lordotic standing posture in adolescents (Smith et al. 2008). Although the role of BMI in spinal posture and function requires further investigation, the results of this study clearly support that regional lumbar posture is associated with BMI. Given trends of increasing population obesity (Dal Grande et al. 2005), the association between BMI and LBP may become a greater issue in the future.

LBP however, was not associated with differences in regional lumbar spine angles in this sample of female nursing students. As previous regional differences in lumbar sitting posture between LBP and control subjects was only evident when LBP subjects were sub-grouped based on directional pain provocation (Dankaerts et al. 2006), it was concluded that postural influences on LBP would need to be considered in specific sub-groups of LBP subjects in future studies.

Results of preliminary exploratory analysis of influences of posture on LBP when subjects are sub-classified according to pain provocation are outlined in Appendix VII. These results showed LLx posture in sitting correlates with LLx posture in functional positions such as lifting, bending and squatting. Further, LBP influenced the strength of these correlations, particularly in functional bending related tasks. Subjects with LBP showed greater LLx postural variation. One possible explanation for this increased variation in lumbar posture with LBP could be positional avoidance due to previous pain experience and fear of re-injury (Swinkels-Meewisse et al. 2006). Alternatively, it could also reflect disrupted motor programming related to pain provocative postures and activities (O'Sullivan 2005). These exploratory findings were not the focus of this doctoral research, but do suggest that further research into the relationship between LBP and habitual spinal posture across a range of common pain provocative positions is indicated.

Whilst there were no clear regional differences in spinal kinematics between subjects with and without LBP when grouped according to LBP severity (Chapter Three), differences were clearly apparent in Chapter Five (outlined below) when LBP subjects were sub-grouped according to O’Sullivan’s classification system (O'Sullivan 2005). This data suggests that the manner by which LBP subjects are sub-grouped greatly influences whether postural differences are detected (O'Sullivan 2005; Dankaerts et al. 2006). It is hypothesized that in terms of clinical application, the justification for and the effectiveness of postural correction in clinical management of LBP patients may only be valid when there is a clear link between a patient’s spinal posture and mechanisms of provocation of their symptoms. Clinical intervention studies involving sub-grouping of LBP patients using a mechanism-based classification system may show greater efficacy and effectiveness compared with studies on non-homogenous samples.

7.2.3. Cross-sectional factors associated with LBP

Evidence of personal factors from multiple domains being associated with LBP in cross-sectional studies supports the biopsychosocial nature of LBP. However, studies are conflicting in their findings as to which factors are associated with LBP. These conflicting findings may be due to differing definitions of LBP, methodological differences, gender, occupational differences, or the widely accepted existence of different sub-groups within non-specific LBP populations (Borkan et al. 1998). Personal factors specifically associated with LBP in nursing populations formed the basis of selection of variables for further studies in this doctoral research. The specific aim of Chapter Four was: *To comprehensively evaluate the influence on LBP of biopsychosocial factors including task-specific individual physical factors relevant to pain provocation in female nursing students.*

The results in Chapter Four add to the evidence supporting the biopsychosocial nature of LBP. Over 30% of all subjects reported significant LBP in the 12-months preceding the study. Regression analysis revealed higher stress levels, passive coping strategies, increased physical activity levels, holding the LLx spine further from end range flexion during functional tasks, and increased age all contributed independently to the presence of LBP. Identifying modifiable personal factors that are associated with LBP may assist in the management of LBP.

In this cross-sectional analysis, a specific functional kinematic measure was associated with LBP and retained in the final regression model. However, measures of physical performance (fitness and endurance) failed to distinguish between subject groups. It may be that physical performance measures are only relevant when they relate to the mechanical exposures of the specific population under investigation, such as fire-fighters (Cady et al. 1979) and manual workers (O'Sullivan et al. 2006). In nursing students, reduced back muscle endurance may be more relevant later in their course when they increase their practical nursing exposure, or once they commence work. This concept may be supported by the prospective results in Chapter Six**,** where in the subsequent 12-months, poorer back muscle endurance was associated with future LBP.

The cross-sectional results of this thesis support current views that LBP is multidimensional in nature, with factors across different domains associated with LBP (Waddell 2004a; Turk 2005). Although these results do not provide an indication regarding cause or effect of LBP, they do support the need to develop multifactorial interventions to manage LBP. It is also important to consider that although the 23% of the LBP variance explained by lifestyle, psychological and physical factors was higher than other studies, it still indicates that 77% of the variance is explained by other factors not identified in this study. These other factors may include stress response measures, motor control deficits and genetic factors. Alternatively, different sub-groups within the LBP subjects in this study may have different factors associated with their LBP episode. By combining them as one single group, the strength of these factors may not be apparent. Therefore, it was concluded that sub-grouping LBP subjects using a mechanism-based classification system (O'Sullivan 2000) warranted investigation, to determine the influence of sub-grouping on these personal factors associated with LBP.

7.2.4. The influence of sub-groups on personal factors associated with LBP

Recent evidence supports the concept of sub-classification of non-specific LBP patients to achieve more successful treatment outcomes (Fritz et al. 2003; Brennan et al. 2006). Given different treatment approaches are more appropriate to different patient sub-groups, it is logical to expect that various factors would be associated with LBP in these different sub-groups. The need for validated multidimensional classification systems is recognised (Ford et al. 2007). O’Sullivan’s proposed multidimensional mechanism-based classification system sub-groups patients with localised LBP according to specific directional motor control impairments provocative of their LBP (O'Sullivan 2000). It was hypothesized that within nursing students with LBP, different sub-groups of LBP would exist, and these sub-groups could be distinguished within the biopsychosocial framework adopted in the previous study (Chapter Four). The specific aim of Chapter Five was: *To determine whether differences in psychological characteristics and physical factors were evident in two defined sub-groups of female nursing students with LBP, and whether different biopsychosocial factors discriminate between different LBP sub-groups and controls.*

The results in Chapter Five support the validity of sub-groups of non-specific LBP patients. Further, as factors associated with LBP were shown to differ across specific sub-groups of LBP, it may be that different interventions need to be adopted for different sub-groups of LBP patients (Turk 2005). Subject sub-grouping was based on visual analysis of lumbo-pelvic posture and kinematics during self-reported pain provocative functional tasks.

Five specific patient sub-groups are described by O'Sullivan's classification system (O'Sullivan 2000). The majority of patients can be more broadly classified as having flexion pain provocation and extension pain provocation, either separately or in combination. Subjects in this doctoral study were assigned a primary direction of pain provocation of flexion or extension based on their primary painful activity/ies. Flexion pattern and Extension pattern subjects differed across psychological (non-productive coping) and physical (static postures, peak spinal angles, proximity to end of range flexion) domains. Extension pattern subjects were distinguished from controls based on a number of physical measures (static postures, peak spinal angles and proximity to end of range flexion). Conversely, Flexion pattern subjects were distinguished from controls based on psychological measures (stress, anxiety, and non-productive coping).

It is important to note however, that all mean psychological scores (including the DASS and PCS scores) were well below reported "at risk" psychological scores (Sullivan et al. 1995; Crawford and Henry 2003), despite statistical differences between LBP sub-groups and control subjects. This is hardly surprising given the sample were otherwise healthy nursing students that were not presenting with chronic disabling LBP, or obvious psychiatric disorders. However, these differences in psychological scores may still be clinically significant in terms of increasing the risk of being vulnerable to an episode of LBP (such as higher stress levels and poorer coping leading to lowered thresholds for pain reporting (Hoogendoorn et al. 2002)). For example, elevated psychological distress (ie. higher than normal stress for a particular individual) in conjunction with other factors, such as higher physical activity, exposure to mechanical load, and reduced back muscle endurance, may combine to place an individual at high risk for a LBP episode. This LBP episode could be triggered by a seemingly innocuous event (McBeth et al. 2007).

The importance of measuring kinematic variables that are related to specific functional or pain provocative tasks was also highlighted when subjects were sub-grouped in Chapter Five. There were consistent peak regional spinal angle differences between Flexion pattern subjects and Extension pattern subjects, as well as between Extension pattern and control subjects across the functional tasks such as lifting objects from the floor and bed height, and squatting. Unfortunately as the study design did not allow for sub-grouping of subjects within the prospective aspect of the study, the predictive validity of these functional measures could not be determined.

These preliminary exploratory findings support that different combinations of psychological and physical factors are linked to LBP sub-groups, and sub-groups may therefore require different intervention approaches based on these factors. It was concluded that a prospective investigation was required to confirm the relevance of these cross-sectional findings for increasing risk of future LBP in nurses.

7.2.5. Predictors of new-onset LBP

Whilst there is broad evidence from cross-sectional studies supporting the biopsychosocial nature of LBP, prospective evidence remains limited. As the cross-sectional results of this doctoral research identified that personal factors from multiple domains were associated with LBP in nursing students, the next step was to determine if these factors were also predictive of future LBP episodes. The specific aim of Chapter Six was: *To identify personal physical, psychological and social / lifestyle characteristics which predicted new episodes of LBP in nursing students.*

The results in Chapter Six strongly support that personal factors from multiple domains are predictors of new-onset LBP. After controlling for previous LBP, age and body weight, regression analysis identified that smoking, increased physical activity levels (both exercise and spinal loading), higher stress levels, reduced back muscle endurance, greater posterior pelvic tilt in slump sitting and more accurate spinal repositioning in sitting were all independent predictors of new-onset LBP. Inclusion of these factors in multivariate logistic regression analysis with significant new-onset LBP as the outcome resulted in a substantial model R^2 of 0.45. This is considerably more than findings of another prospective study on personal LBP risk factors in a similar cohort (R^2 of 0.12) (Adams et al. 1999). However the strength of each individual risk factor in this doctoral study are similar to previous reports (Croft et al. 1995; Adams et al. 1999), supporting that each domain independently contributes to the risk of a new episode of LBP. This may explain why uni-dimensional interventions are largely ineffective, as they only target a small component of the overall problem. These findings support that future LBP prevention and management research should consider modifiable personal LBP risk factors, across different domains specific to nurses. Whilst other personal factors not measured in this study (e.g., job satisfaction (Hoogendoorn et al. 2002), spinal motor control (Cholewicki et al. 2005) and biochemical stress markers (Schell et al. 2008)) may predict a greater proportion of LBP, non-modifiable factors such as genetics may also constitute a significant proportion of the unexplained LBP variance (Chan et al. 2006; Battie et al. 2007).

The incidence of new-onset significant LBP over a 12-month period was 29%. Over 75% of subjects with significant LBP during the follow up period reported multiple episodes interspersed with pain-free periods, thus supporting the recurrent nature of LBP in this group (Maul et al. 2003; Kaaria et al. 2006). Again, these findings clearly indicate that this nursing student population should be the target group for preventative interventions, before LBP becomes chronic, and the costs and impairments related to the disorder escalate (Hawkes 2007).

Smoking is recognised as a LBP risk factor across different populations (Battie et al. 1989; Mattila et al. 2008; Mikkonen et al. 2008) and was also a predictor in this study, despite only a small proportion of subjects actually smoking. However, other social factors were not associated with LBP risk in this study, perhaps suggesting such factors are not important to LBP development in this female nursing student population.

The increased levels of physical activity being associated with LBP in both cross-sectional and prospective results in this thesis may similarly reflect personal LBP characteristics being specific to the population under investigation. For example, higher education and occupational skill levels are associated with increased physical activity levels (Salmon et al. 2000), while other occupations report a link between physical inactivity and LBP (Croft et al. 1999; O'Sullivan et al. 2006). Alternatively, as the instrument that measured physical activity considered components including household and gardening activity, increased hours of moderate and vigorous activity may indicate increased exposure to bending and lifting tasks. This is plausible, as increased hours of physical activity did not correlate with increased fitness levels.

Stress was consistently associated with LBP in this study, which supports the findings of other cohort studies on health care populations (Adams et al. 1999; Feyer et al. 2000). Due to likely complex interactions between stress and pain, type of stress (interpersonal / non-interpersonal) is also considered important (Keefe et al. 2001). Specific examination of interpersonal stress was not conducted in this student cohort, but should perhaps be considered in future studies. Although strongly associated with the development of chronic pain, coping strategies, LBP beliefs and catastrophising were not found to be predictors of new-onset LBP in this cohort, possibly suggesting these factors are not so important in this LBP group.

As LBP prevalence peaks at around 22 years of age (Hestbaek et al. 2006) and the mean age of newly graduated nurses is higher than this age (Mitchell et al. 2008), the majority of LBP episodes in nursing populations will be recurrent in nature. Therefore, identification of factors associated with LBP recurrence, not just new-onset LBP, is an important objective in the management of occupational LBP. The 53 subjects that had significant LBP at the time of baseline measures were also followed prospectively. The differences between these subjects who reported further significant LBP episodes compared to those who did not, at 6- and 12-months (n=49), are listed in Appendix VIII.

Although the sample size was not large, univariate binomial logistic regression analysis identified higher levels of catastrophising and less difference between usual standing and sway standing pelvic angles as significant predictors of reporting further episodes of LBP. There were also trends for higher back and leg muscle endurance and other kinematic measures such as less upright sitting postures being protective for reducing the recurrence of LBP. Levels of catastrophising, which are commonly linked with LBP disability (Peters et al. 2005; Sullivan et al. 2005), did not differ between subjects with no LBP or new-onset LBP during follow-up. However, catastrophising differed between those with significant LBP at baseline who did or did not continue to have significant LBP during follow-up. This suggests that these findings are consistent with the type of LBP of the sample under investigation. Catastrophising is linked with pain avoidant coping strategies, which are more common in specific sub-groups of personality profiles often associated with chronic LBP subjects (Turk and Rudy 1988). Given these exploratory findings on a small sample, further prospective research is warranted to identify factors that may prevent the recurrence of LBP episodes.

7.3. The multifactorial nature of LBP

As modifiable personal factors across a number of domains were independent predictors of LBP in the final regression model (Chapter 6), this study supports the widely accepted biopsychosocial model of LBP (Waddell 2004b; Gatchel et al. 2007). Whilst mean psychological scores for all subjects were well below reported “at risk” psychological scores (Sullivan et al. 1995; Crawford and Henry 2003), stress was still a significant predictor of future episodes of significant new-onset LBP. It is proposed that this may indicate that higher sub-clinical psychological scores such as stress may become relevant to the development of LBP, particularly when they occur alongside a combination of other factors (such as increased physical activity and reduced muscle endurance). Elevated sub-clinical scores may have an additive effect on the risk of future LBP via complex interactions with other factors.

Given that pain and illness are subjective experiences, with recognised interrelationships between biological changes, psychological status and socio-cultural factors (Gatchel et al. 2007), it is not surprising that multiple factors combine to influence individual LBP experiences. It is hypothesized that a combination of factors if present, interact to enhance the cumulative risk to an individual, whereby a relatively minor tissue strain can result in a significant LBP episode. Figure 7.1 provides a conceptual representation of how different groups of individuals may be at higher risk of LBP due to different weightings of such components. Targeted interventions would therefore need to address each domain of the biopsychosocial model relevant to its importance for each LBP sub-group, with consideration of likely individual variation.

Although the biopsychosocial model for LBP provides a plausible explanation of the complex, multifactorial nature of LBP, it does not necessarily provide a clear framework for LBP prevention or treatment. Prevention interventions that are multi-dimensional in nature have been supported by a recent systematic review of LBP prevention strategies in nurses (Dawson et al. 2007). However, a generalised multi-dimensional approach is not necessarily the most appropriate or cost-effective approach. Most biopsychosocial LBP treatment approaches are generic in nature and have not been shown to be more effective than other approaches (Ostelo et al. 2005).

Historically, multi-modal interventions have been based on a generic cognitive behavioural therapy approach with a general exercise component (van der Hulst et al. 2005). Such programs have not been tailored to the individual based on identified modifiable risk factors. General exercise programs have been shown to have limited effect for managing non-specific LBP (Hayden et al. 2005). Recent reviews support the need to address specific physical and psychosocial components within specific sub-groups of LBP patients (Turk 2005; Balague et al. 2007).

Broad physical and psychological sub-groups could provide a framework for selecting the general focus of intervention, but optimal outcomes are thought to require an integrated management approach tailored to each individual’s requirements within more specific sub-groups (O'Sullivan 2005). Future LBP interventions need to be developed for nursing populations, that target the different domains such as stress management, motor learning and targeted conditioning, according to the characteristics of the LBP sub-group undergoing the intervention (O'Sullivan 2006). It is proposed that different weightings of components of the biopsychosocial model need to be identified for different sub-groups of LBP patients.

The key to more successful injury management and LBP prevention, may lie in the identification of personal risk factors specific to groups of individuals and the resultant development of a targeted intervention (Turk 2005). The findings of this study suggest further research into this approach is indicated, given the large proportion of variance explained by modifiable personal factors and exploratory evidence of physical and psychological differences between LBP sub-groups.

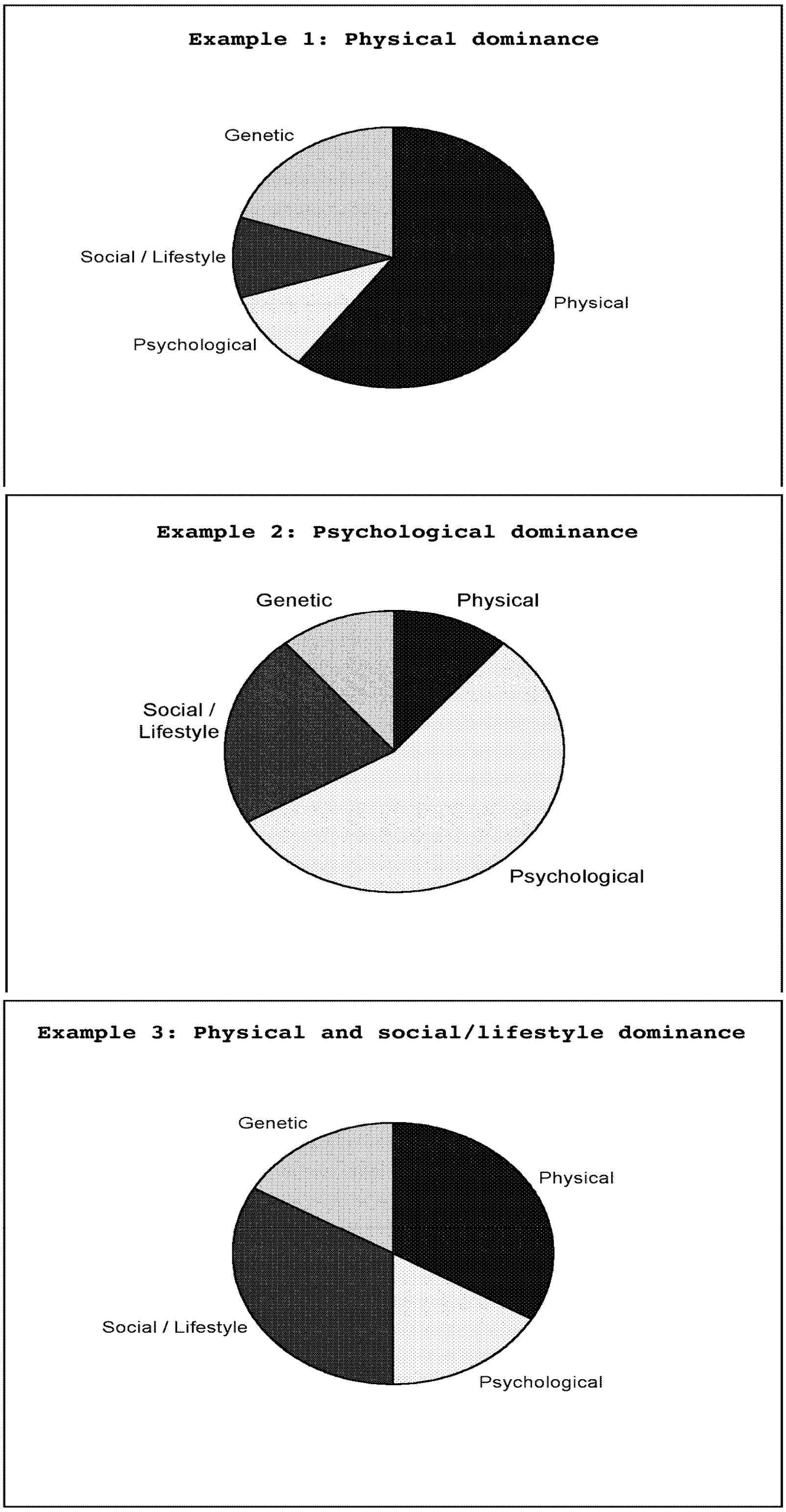

Figure 7.1. A conceptual representation of how different groups of individuals may be at high risk of LBP due to different risk factor weightings.

7.4. Limitations of present research

Although designed as a comprehensive evaluation of biopsychosocial factors associated with LBP, a number of broad limitations of this thesis warrant consideration. Factors associated with LBP in this otherwise young, healthy university based sample may not be reflective of LBP characteristics across a general population. Firstly, the type of LBP in this sample requires consideration. Although clinically significant in terms of requiring treatment, medication or activity modification, the nature of the subject's LBP in this study would not be regarded as chronic, disabling LBP. However, as nursing is recognised as a high-risk occupation, reducing the impact and costs associated with LBP in this population is arguably an important objective (Dawson et al. 2007), making nursing students an ideal target population for LBP prevention.

The issue of definition of LBP is also likely to influence these findings (Marras et al. 2007). Our novel LBP definition was selected to reflect clinically significant LBP in this specific population as recent published consensus LBP definitions were not available at the commencement of this thesis (Dionne et al. 2008).

Secondly, the decision to exclude subjects with pain > 3/10 on a VAS at the time of baseline assessment is likely to influence the findings reported in this thesis. Although one could argue that this excludes all patients with significant levels of LBP from entering the study, it was not the purpose of this study to investigate factors associated with acute / current LBP. By taking subjects who did have significant LBP in the previous 12-months, but not at the time of the study, ongoing physical and psychological differences with those without such a LBP history could be determined, with reduced likelihood that these differences would be due to current pain at the time of testing. Further, only one subject was excluded on the basis of pain level at time of testing, so the sample was arguably representative of nursing students with and without LBP. Therefore, the results and conclusions of this thesis are limited in their application to non-acute LBP groups. However, the recognition of the need to consider factors associated with LBP in specific populations (such as nursing students prior to being exposed to higher risk of LBP chronicity of working nurses), rather than attempting to generalise across broader populations may in fact be the key to identifying modifiable personal LBP characteristics.

A number of other limitations of this thesis also warrant consideration:

- Results of these studies cannot be generalised across broader populations and the male gender, as it is likely that factors associated with LBP differ between populations. As education level is shown to influence factors such as physical activity levels and LBP disability (Salmon et al. 2000; Alexopoulos et al. 2008), these university students are likely to display different LBP characteristics from other occupational groups such as process plant operators.
- The moderate size of the convenience sample of nursing students in the cross-sectional and prospective components of this research also limits the generalisability of these findings.
- The findings pertaining to physical and psychological differences between LBP sub-groups are exploratory and require further validation.
- The small sample of subjects with significant LBP at baseline did not allow for thorough investigation of prospective factors associated with LBP recurrence or resilience.
- With multi-dimensional predictive cohort studies, there is always the possibility of failing to measure variables that may also be strong predictors (such as EMG muscle activity). However, measurement of all known variables was not possible due to subject burden limitations.
- Follow-up in the prospective study was by postal questionnaire only, which did not allow for sub-classification of subjects who experienced new-onset LBP. Given the cross-sectional differences found between LBP sub-groups, a similar analysis of prospective findings may have identified personal LBP predictors specific to each sub-group.

7.5. Summary of clinical implications

The following clinical implications have emerged from this thesis:

- The results from Chapter Two indicate that patterns of LBP in nurses appear to be well established prior to the commencement of full-time employment. Therefore, future prevention or management of LBP in nurses should consider targeting nursing students or nurses beginning their careers.

- The results from Chapter Three provide support for the concept of regional differences in lumbar spine motion and function. This concept may be important when considering the clinical application to postural interventions in LBP management.
- Gender differences identified across variables from multiple domains in cross sectional analysis support that LBP interventions are likely to differ between males and females.
- Factors from multiple domains independently associated with LBP in Chapter Four, support that multifactorial LBP interventions are required.
- The results of Chapter Five showed that factors associated with LBP differ between sub-groups of LBP patients. Therefore, multi-dimensional interventions may need to be targeted to address these different sub-group characteristics.
- Individual personal characteristics from multiple domains are able to account for a significant proportion of new-onset LBP variance, supporting that such factors need to be considered in the development of LBP prevention strategies.

7.6. Recommendations for further research

In light of the findings of this thesis and its acknowledged limitations, the following recommendations for future research can be made:

- The results from Chapter Two indicate that patterns of LBP in nurses appear to be well established prior to the commencement of full-time employment. Therefore, future studies directed at the prevention or management of LBP in nurses should consider targeting nursing students or nurses beginning their careers.
- Considering the gender differences identified from the cross-sectional measures, future research into gender specific predictors of LBP is recommended.
- In terms of physical predictors, future research should distinguish between performance type measures (such as muscle endurance) and measures of functional posture and volitional movement (such as functional spinal kinematics). Importantly, measures of spinal kinematics need to consider the

potential for regional lumbar spine variation in function. Further, physical predictor variables should be related to the specific occupational group under investigation.

- Consideration of sub-groups of individuals may advance the identification of modifiable predictors of both new-onset and the recurrence of LBP. Whether greater benefits are gained from identification of sub-groups derived from validated classification systems, compared with simple symptom based sub-grouping (such as mechanism of symptom provocation) also requires investigation.
- Further prospective research into modifiable personal factors associated with the development of LBP using large cohorts is required. Future studies need to consider predictors across multiple domains. The factors that need to be considered may vary depending on the population under investigation.
- A new approach to LBP prevention and management focusing on modifiable personal risk factors, based on findings from this doctoral investigation, warrants investigation. This could take the form of a prospective intervention study, where a cohort graduate nurses are screened for LBP risk before starting their careers, based on the findings of the current research. An individualised multi-factorial intervention based on the results of this screening could be compared with no intervention by randomising the nurses into an intervention and control group. The primary outcome of low back injury incidence could be used to determine the effect of the intervention over time. Health economics could also be used to determine a cost-benefit ratio of implementing such a program compared with rehabilitating injured workers if the program proves effective.

7.7. Conclusions

The following conclusions can be drawn from the results of this thesis:

- LBP prevalence is already very high in nursing students who are not yet exposed to the occupational LBP risk factors of working nurses. Therefore, the influence of modifiable personal characteristics on the development of LBP should be investigated in a student cohort.
- Gender differences should be considered in future LBP research.

- Global lumbar spine kinematics do not accurately reflect the kinematics of the upper lumbar or lower lumbar spinal regions in common postures and movements. Regional rather than global lumbar spine measures should be considered in future LBP research.
- Factors associated with LBP differ between different sub-groups of nursing students with LBP, which adds validity to O'Sullivan's LBP classification system.
- Modifiable personal characteristics from multiple domains were associated with both current LBP (cross-sectional) as well as future episodes of new-onset LBP (prospective) in nursing students.
- Modifiable personal characteristics should be a focus for future LBP research and prevention interventions. However, the selection of important modifiable characteristics may be population specific.

Results from this doctoral investigation support the multi-factorial and biopsychosocial nature of LBP. The important distinction of this research is the selection of a cohort at the beginning of their working life, with a focus on modifiable personal rather than occupational factors associated with LBP. Factors from physical, psychological and social/lifestyle domains were all independently associated with significant new-onset LBP in female nursing students. Interventions utilising a prevention approach that target modifiable characteristics, such as those identified in this cohort of nursing students, may have the potential to reduce the impact of occupational LBP in this group.

7.8. References

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Walker, B., Muller, R. and Grant, W. (2004). "Low back pain in Australian adults: prevalence and associated disability." J Manip Physiol Ther 27(4): 238-44.

APPENDIX I - ETHICS APPROVALS

memorandum

Curtin University of Technology

To	Dr Angus Burnett Dr Peter O'Sullivan Mr Tim Mitchell
From	Shannon Wagner
Subject	Protocol Approval **PT0012**
Date	21 July 2005
Copy	

Thank you for your "Form C Application for Approval of Research with Minimal Risk for the project titled "THE INCIDENCE OF LOW BACK PAIN AMONG WESTERN AUSTRALIAN NURSING STUDENTS" On behalf of the Human Research Ethics Committee I am authorised to inform you that the project is approved.

Approval of this project is for a period of six months **21 July 2005** to **21 December 2005.**

If at any time during the six months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is PT0012. *Please quote this number in any future correspondence*.

Shannon Wagner
Coordinator for Human Research Ethics

School of Physiotherapy

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

HUMAN RESEARCH ETHICS COMMITTEE
For all queries, please contact:
Research Ethics Officer
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170
Fax: 6304 2661
E-mail: research.ethics@ecu.edu.au

28th July 2005

Mr Tim Mitchell
Curtin University of Technology
School of Physiotherapy
GPO Box U1987
Perth WA 6845

Dear Mr Mitchell

PROJECT CODE	**05-128 BURNETT**	
PROJECT TITLE	The Incidence Of Low Back Pain Among Western Australian Nursing Students	
INVESTIGATOR	Mr T Mitchell	
ETHICS APPROVAL	FROM: 28th July 2005	TO: 31st December 2005

Thank you for your recent application for ethics approval. This proposal has been reviewed by members of the Human Research Ethics Committee.

I am pleased to advise that the proposal complies with the provisions contained in the University's policy for the conduct of ethical research, and your application for ethics approval has been granted. The Committee noted that the project has previously been approved by the Curtin University Human Research Ethics Committee.

Please note the following conditions of approval:

The HREC has a requirement that all approved projects are subject to monitoring conditions. This includes completion of an annual report (for projects longer than one year) and a completed final report at the completion of the project. The Edith Cowan University HREC would be happy to accept the report submitted to the Curtin University Human Research Ethics Committee.

With best wishes for success in your work.

Yours sincerely

Kim Gifkins
RESEARCH ETHICS OFFICER
Phone 6304 2170
Fax: 6304 2661
Email: research.ethics@ecu.edu.au

Attachment – Monitoring form

cc: Dr Angus Burnett, Investigator
Dr Cobie Rudd, Head of School

Department of Health

MP/fm/Ethics 2005-212
Ext 2999

Friday, December 30, 2005

Sir Charles Gairdner Hospital

Dr Angus Burnett & Dr Tim Mitchell
Curtin University
GPO Box U1987
Bentley WA 6845

Dear Drs Burnett & Mitchell

HUMAN RESEARCH ETHICS 2005-212 The incidence of low back pain among Western Australian nursing graduates

Patient Information Sheet
Modified Nordic Low Back Screening Questionnaire

Please be advised that the Human Research Ethics Committee has granted expedited ethical approval of the project. The approval is for the above named protocol and participant documents. Approval is granted on the understanding that the project will commence within twelve months of the date of this letter or a new application may have to be submitted. Equally if the project is discontinued before the expected date of completion the committee must be informed and the reasons provided for the cessation.

Please be advised that this Committee complies with the National Statement on Ethical Conduct in Research involving Humans by the National Health and Medical Research Council (NH&MRC) and as such has responsibility to monitor the progress of all approved projects until completion to ensure that they continue to conform to approved ethical standards.

It is the responsibility and obligation of the researcher under the Good Clinical Practice (GCP) guidelines to advise the Committee of any departure from the original protocol that could impact on the ethical approval of the study. Please note that the attachment entitled "Reporting Guidelines for Adverse Events and Deviations from Protocol" forms part of this approval letter. Under these reporting guidelines you are required to submit formal notice of any changes to documentation, relevant information arising out of ongoing safety monitoring and annual reports on the human rights aspects of your study. An annual report form for your study will be posted to you several weeks in advance of the anniversary of the project's approval date.

As the responsibility for the conduct of the trial lies with you as the investigator, you should sign all communications to the committee.

Please quote Ethics number : 2005-212 on all correspondence associated with this study.

Yours sincerely

SUE DAVIS
ACTING CHAIR
HUMAN RESEARCH ETHICS COMMITTEE
cc: MAH/CDT

Hospital Avenue, Nedlands, Western Australia 6009
Telephone + 618 9346 3333 Facsimile + 618 9346 3759 T.T.Y. Line + 618 9346 3900
Website: http://www.scgh.health.wa.gov.au, ABN: 13 993 250 709

431F 2/02

memorandum

To	A/Professor Peter O'Sullivan, Physiotherapy
From	Dr Stephan Millett, Executive Officer, Human Research Ethics Committee
Subject	Protocol Approval **HR 201/2005**
Date	27 October 2008
Copy	Mr Tim Mitchell, Physiotherapy Dr Angus Burnett, Physiotherapy Graduate Studies Officer, Division of Health Sciences

Curtin University of Technology
Office of Research and Development

Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL L.Teasdale@curtin.edu.au

Thank you for your application submitted to the Human Research Ethics Committee (HREC) for the project titled "*A Prospective Study To Identify Predictors Of Low Back Pain (Lbp) In Western Australian Nursing Students*".

Your application has been reviewed by members of the HREC reviewing panel who have recommended that your application be **APPROVED**. Please note the suggestions for improvement below from the reviewers:

- Please include the Oswestry Index at Section 7 (send an addendum). Please alter the information sheet to advise people it may take 90-120 minutes. Otherwise a well-prepared application."
- several minor conditions on the cardio-respiratory stress testing component need to be addressed:
  - The subjects must be asked about any history of heart disease, arrhythmia or hypertension prior to participation and their response must be recorded on the consent form.
  - Stress testing must only be conducted in the presence of at least one person with a current CPR certificate.
  - A working telephone must be present in the testing laboratory.

- You are authorised to commence your research as stated in your proposal.
- The approval number for your project is **HR 201/2005**. *Please quote this number in any future correspondence.*
- Approval of this project is for a period of twelve months **22/02/2006** to **22/02/2007**.

If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Divisional Graduate Studies Committee.

Applicants should note the following:

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.
- All recommendations for approval are referred to the next meeting of the HREC for ratification. In the event the Committee does not ratify the recommendation, or would like further information, you will be notified. **The next meeting of the HREC is on 4/04/2006.**

The attached **FORM B** is to be completed and returned as soon as possible to the Secretary, HREC, C/- Office of Research & Development:

- When the project has finished, or
- If at any time during the twelve months changes/amendments occur, or
- If a serious or unexpected adverse event occurs.

An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted. Please find attached your protocol details together with the application form/cover sheet.

Dr Stephan Millett
Executive Officer
Human Research Ethics Committee

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

HUMAN RESEARCH ETHICS COMMITTEE

For all queries, please contact:
Research Ethics Officer
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170
Fax: 6304 2661
E-mail: research.ethics@ecu.edu.au

7 June 2006

Mr Tim Mitchell
School of Physiotherapy
Curtin University

Dear Tim

PROJECT CODE	**06-98 MITCHELL**		
PROJECT TITLE	**A prospective study to identify predictors of low back pain (LBP) in Western Australian nursing students**		
CHIEF INVESTIGATOR	**Mr Tim Mitchell**		
ETHICS APPROVAL	**FROM: 2 June 2006**	**TO: 31 October 2007**	

Thank you for your recent application for ethics approval. The ECU Human Research Ethics Committee (HREC) has reviewed your application and has granted ethics approval for your research project. The Committee noted that the project has previously been approved by the Curtin University Human Research Ethics Committee.

Please note the following conditions of approval:
The HREC has a requirement that all approved projects are subject to monitoring conditions. This includes completion of an annual report (for projects longer than one year) and completion of a final report at the completion of the project. The ECU HREC would be happy to accept the report submitted to the Curtin University Human Research Ethics Committee.

With best wishes for success in your work.

Yours sincerely

Kim Gifkins
RESEARCH ETHICS OFFICER
Phone 6304 2170
Fax: 6304 2661
Email: research.ethics@ecu.edu.au

APPENDIX II - SUBJECT INFORMATION SHEETS

Title of Project: **The incidence of low back pain among Western Australian nursing students.**

Principal Investigators:

Dr Angus Burnett, PhD
Research Fellow Curtin University, School of Physiotherapy. Telephone: 9266 3662
Dr. Peter O'Sullivan PhD
Lecturer, Curtin University, School of Physiotherapy
Mr Tim Mitchell
Musculoskeletal Physiotherapist

Purpose of Study

You have been asked to participate in a brief survey investigating the incidence and some basic characteristics of low back pain among Western Australian nursing students enrolled in the two related tertiary programs (Curtin University and Edith Cowan University)

Manual occupations such as nursing are know to be at particularly high risk of low back pain and injury. This can result in ongoing disability and impact on future work and lifestyle capacity. Some low back pain is directly the result of work tasks, but other low back pain is thought to be influenced by an individual's physical characteristics.

Research has been done to identify individual physical characteristics following injury, but to date these is little evidence to prove these characteristics are present prior to injury. The purpose of this survey is to determine the incidence of low back pain among all years of nursing students to see if there is a pattern of increased back pain in a particular nursing year group. This will help target future research which aims to predict which nursing students are at greater risk of experiencing low back pain. It will also enable us to provide advice and training to nursing students to reduce their risk of back pain.

Procedures:

If you are prepared to be involved in this study, you are simply asked to fill out the brief questionnaire attached. This should take approximately 2 minutes.

This is a confidential questionnaire. You are not required to identify yourself by name or student number. On completion of the questionnaire, it will be placed in a sealed box, which will be managed by the investigators.

You are under no obligation to participate in this study. Completion of the questionnaire is indication of your consent to participate in the study. This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

Subject Information Sheet

Title of Project: **A prospective study to identify predictors of low back pain in student nurses.**

Principal Investigators: **Mr Tim Mitchell** Musculoskeletal Physiotherapist
Telephone: 9381 1082
Assoc. Prof. Peter O'Sullivan PhD
Curtin University of Technology, School of Physiotherapy

Purpose of Study

You have been asked to participate in a study investigating physical and psycho-social characteristics of low back pain.

Lower back and abdominal muscles have an important role in protecting your back from injury. Some of these muscles have been shown to work well in some postures, but not well in others. This may mean that people who commonly adopt certain postures are at a high risk of developing low back pain. This study will look at whether student nurses with specific sitting and lifting postures have less stamina in their low back muscles and leg muscles, and if they have less awareness of the position of their low back in relation to the rest of their spine.

Our group's previous research has shown a link between posture, back muscle endurance and low back pain, but it is not known whether these physical characteristics are present before a back injury occurs. We will also be comparing these findings with other simple physical measures, levels of psychological distress and lifestyle information.

Procedures:

If you are prepared to be involved in this study, we will require approximately 60 minutes of your time. You will initially be asked to fill out some short questionnaires, which look at some basic lifestyle factors, and your back pain history. You will be required to wear shorts and to tuck your shirt up or wear a sports bra (females) to expose your lower back for placement of adhesive skin sensors for posture measurements.

You will have some basic measures of height, weight and spinal position recorded. You will then have some measures taken while you are sitting, bending and then lifting a 5kg box. The sensors on your skin will be used to measure the angles of your back and hips with the use of a computer program. You will only be required to maintain each posture for a few seconds. Therefore, with respect to these tests there is no excessive physical exertion. There will be some brief video-taping of your posture during some of the above movements

You will then be asked to adopt a squatting position with your hips and knees at right angles, and then hold the position for as long as you are able. This will give us a measure of your leg muscle endurance.

Your next test will be for back muscle endurance. You will be lying face down on a padded bench, with your hips and legs secured, and your head and trunk over the end of the bed. You will be assisted into the required posture by one of the researchers, and asked to maintain the position for as long as you are able.

Your final test is on an exercise bike to test your fitness level. You will be on the bike for up to 6 minutes and will be aiming to build up to pedal at approximately 65% of your capacity. You may get a little breathless, but this is not too strenuous and is a similar test to that used in a health club from screening individuals starting exercise programs. All tests will be conducted by experienced and reputable personnel. The total time requirement for all testing is a single session lasting 1 hour.

At 6 months and 1 year following the above tests, we will be monitoring whether or not you have had any back injuries in that time. We will do this by sending you a questionnaire in the post with a stamped self addressed envelope.

Risk, Discomfort and Benefits
There are minimal risks to be being involved in this study. You will be asked to lift with an equivalent force of 5 kg for a few seconds. There is no evidence to suggest that you can injure your back lifting this weight once. You may experience some fatigue of your back muscles or leg muscles during the endurance test. Following this, you may experience a condition known as Delayed Onset Muscle Soreness. This is a normal aching sensation in your lower back muscles 1-3 days following an activity that you do not regularly perform. In the other test sitting and standing postures, you should not experience any discomfort, as these will be your normal postures that you use every day. There are no long term effects of any of the above testing postures.

If you agree to take part in this study, you will become aware of your own sitting and lifting postures, and the level of endurance of your back and leg muscles. You will also have access to your individual results in the other measures taken at the end of the study.

Financial Obligations
There are no financial obligations to yourself, as the study will be conducted on-site during your working hours.

Confidentiality
You will be allocated an identification number, and your name will only appear on the identification number master list. On all other forms and, only your identification number will be used. Access to the master list will be restricted to the researchers and project supervisor. We will only use the identification codes to identify you for the purposes of contacting you to mail out the two follow up questionnaires

All data recorded will be stored, using identification numbers only, at the Curtin University, School of Physiotherapy in a locked filing cabinet. Information stored on computer will be password restricted to the researchers. Digital photographs will not be used for any presentations of publications without your express written consent.

The results of this study will be reported, but it will not be possible to identify individual subjects. Once the study is completed, data will be securely stored with the project supervisor for 5 years, and then will be destroyed. This is a requirement of Curtin University of Technology.

Request for More Information
You are encouraged to discuss any questions or concerns with the principal investigator at any time. Contact details are listed above.

Refusal or Withdrawal
You may refuse to participate in the study. If you agree to participate, you are free to withdraw at any stage without fear of prejudice. If you decide to withdraw, please contact the principal investigator as soon as possible and all your data will be destroyed. This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

APPENDIX III - SUBJECT CONSENT FORM

Title of Project: **A prospective study to identify predictors of low back pain in student nurses.**

Principal Investigators: **Mr Tim Mitchell** Musculoskeletal Physiotherapist
Telephone: 9381 1082
Assoc. Prof. Peter O'Sullivan PhD
Curtin School of Physiotherapy.
Telephone: 9266 3629

You are voluntarily making a decision whether or not to participate in this research study. Your signature certifies that you have decided to participate, having read and understood the information presented. Your signature also certifies that you have had an adequate opportunity to discuss this study with the researchers, and you have had all your questions answered to your satisfaction. You will be given a copy of this consent form to keep.

I, (the undersigned)____

of ____
Postcode________.

consent to participate in this study and give permission for any results from this study to be used in any report or research paper, on the understanding that my confidentiality will be preserved. I consent to the use of my personal details only for the purpose of contacting me for the follow up questionnaires. I understand that I may withdraw from the study at any time without prejudice. If so, I undertake to contact the principal investigator (Telephone: 9381 1082) at the earliest opportunity.

Signature ______________________________ Date______________
Subject

I have explained the nature of and the procedures involved in the study to which the subject has consented to participate and have answered all questions. In my judgement, the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to do so.

Principal Investigator ______________________ Date_______________

My signature as witness certifies that the subject signed this consent form in my presence as a voluntary act and deed.

Witness __________________________________ Date______________

APPENDIX IV – Additional methodology for Chapter 2

IV.I. Population sample

For study one (Chapter 2), a convenience sample of nursing students and graduate nurses was used to examine the relative contributions of age and occupational exposure on the prevalence, duration and severity of LBP episodes. The sample was derived from a total of 1668 nursing students (1st, 2nd and 3rd years), from the two major Western Australian undergraduate nursing courses. Graduate nurses enrolled in the Graduate Training Program at a major metropolitan teaching hospital were also invited to participate (n=134). These graduate nurses had been working for approximately12 months at the time of the survey. Age limit for all participants was 18-60 years.

IV.II. Sample size

A finite population sample size calculator was used to determine the required sample size for each nursing student year group and also for the graduate nurse population. It used conservative estimated proportions of 50% and a confidence level of 95% with a 5% error margin. Required and actual response rates are shown in Table IV.I.

Table IV.I. Required Sample Size and Actual Response Rates for Each Year Group

Year Group	Total Population	Required Response Rate (%)	Actual Response Rate (%)
NS1	663	244 (36.8%)	349 (52.6%)
NS2	505	219 (43.4%)	271 (53.7%)
NS3	500	218 (43.6%)	277 (55.4%)
All Nursing Students	1668	N/A	897 (53.8%)
Graduate Nurses	134	100 (74.6%)	111 (82.8%)

IV.III. Screening questionnaires

Modified versions of the Nordic Low Back Pain Questionnaire were used to determine LBP history, frequency and severity (Kuornika et al. 1987). Slightly different questions were used for student and graduate nurses. Question 2 was added to the questionnaire to gather information regarding postures/activities which aggravate LBP. Question 3 was modified from "*Have you ever had to change job or duties because of low back trouble?*" to a more specific question regarding nursing studies/duties. A question was added to gather information regarding the number of LBP episodes in the past 12-months. Graduate nurses were also questioned regrading the frequency and severity of their LBP since starting work. The final question gathered specific demographic information not included in the original questionnaire.

These modified versions of the Nordic LBP Questionnaire was pilot tested on 10 health professionals and 10 nursing students to ensure clarity of the revised questions. This pilot testing included discussion of the questions and answers with the subjects after completion of the questionnaire to ensure face validity of the questionnaire.

Modified Nordic Low Back Screening Questionnaire (Nursing Students)

How to answer the questionnaire: In this picture, you can see the approximate position of the part of the body referred to in the questionnaire as the low back. By low back trouble is meant ache, pain or discomfort in the shaded area, whether or not it extends from there to one or both legs (sciatica).

Please answer by putting a cross in the appropriate box. You may be in doubt as to how to answer, but please do your best anyway.

1. Have you **ever** had low back trouble (ache, pain or discomfort)?

1 ☐ NO 2 ☐ Yes ☐

If you answered NO to Qu. 1, Skip to Qu. 10.

2. What activity/s can hurt your back? (You can mark more than one box)

- 1 ☐ Bending and/or Lifting ☐
- 2 ☐ Sitting and/or Driving ☐
- 3 ☐ Standing and/or Walking ☐
- 4 ☐ Sudden movements
- 5 ☐ No specific event

3. Have you **ever** hurt your back associated with your nursing studies or employment in nursing type duties?

1 ☐ NO 2 ☐ Yes ☐

4. How many **episodes** of low back pain have you had during the **last 12 months?**

- ☐ 0
- ☐ 1
- ☐ 2-3
- 4 ☐ more than 3

☐

5. Have you taken **any** medication because of low back trouble during **the last 12 months?**

1 ☐ NO 2 ☐ Yes ☐

6. What is the total length of time you have had low back trouble during the **last 12 months**?

- ☐ 0 days
- ☐ 1-7 days
- ☐ 8-30 days
- ☐ more than 30 days, but not every day.
- 5 ☐ Every day

☐

7. Has low back trouble caused you to **reduce** your activity in the **last 12 months?**

a) Work activity (at home or away from home)?
1 ☐ NO 2 ☐ Yes ☐

b) Leisure activity?
1 ☐ NO 2 ☐ Yes ☐

8. Have you **been seen** by a doctor, physiotherapist, chiropractor or other such person because of low back trouble during **the last 12 months?**
1 ☐ NO 2 ☐ Yes ☐

9. Have you had low back trouble at any time in the **last 7 days?**
1 ☐ NO 2 ☐ Yes ☐

10. a) Sex
1 ☐ Female 2 ☐ Male ☐

b) Year of Study (Eg N1) ________ ☐

c) Age ________ ☐

Modified Nordic Low Back Screening Questionnaire (Graduate Nurses)

How to answer the questionnaire: In this picture, you can see the approximate position of the part of the body referred to in the questionnaire as the low back. By low back trouble is meant ache, pain or discomfort in the shaded area, whether or not it extends from there to one or both legs (sciatica).

Please answer by putting a cross in the appropriate box. You may be in doubt as to how to answer, but please do your best anyway.

1. Have you **ever** had low back trouble (ache, pain or discomfort)?

1 ☐ NO 2 ☐ Yes ☐

If you answered NO to Qu. 1, Skip to Qu. 11.

2. What activity/s can hurt your back? (You can mark more than one box)

1 ☐ Bending and/or Lifting ☐
2 ☐ Sitting and/or Driving ☐
3 ☐ Standing and/or Walking ☐
4 ☐ Sudden movements

3. Have you **ever** hurt your back associated with your nursing studies or employment in nursing type duties? ☐

1 ☐ NO 2 ☐ Yes

4. Since you commenced working as a nurse, is your low back trouble :

a) More **severe** ?
1 ☐ NO 2 ☐ Yes ☐

b) More **frequent**? ☐
1 ☐ NO 2 ☐ Yes

5. How many **episodes** of low back pain have you had during the **last 12 months**?

- ☐ 0
- ☐ 1
- ☐ 2-3 ☐
- 4 ☐ more than 3

6. Have you taken **any** medication because of low back trouble during **the last 12 months?**

1 ☐ NO 2 ☐ Yes ☐

7. What is the total length of time you have had low back trouble during the **last 12 months**?

- ☐ 0 days ☐
- ☐ 1-7 days
- ☐ 8-30 days
- ☐ more than 30 days, but not every day.
- 5 ☐ Every day

8. Has low back trouble caused you to **reduce** your activity in the **last 12 months?**

a) Work activity (at home or away from home)? ☐
1 ☐ NO 2 ☐ Yes

b) Leisure activity? ☐
1 ☐ NO 2 ☐ Yes

9. Have you **been seen** by a doctor, physiotherapist, chiropractor or other such person because of low back trouble during **the last 12 months?** ☐
1 ☐ NO 2 ☐ Yes

10. Have you had low back trouble at any time in the **last 7 days?** ☐
1 ☐ NO 2 ☐ Yes

11. a) Sex ☐
1 ☐ Female 2 ☐ Male

b) Year of graduation ________ ☐

c) Age __________ ☐

APPENDIX V – Additional methodology for chapters 3-6

V.I. Population sample

Studies two to five (Chapters 3-6) all used a smaller, more defined population than study one (Chapter 2). Only nursing students in their 2nd and 3rd years of study from the two Western Australian undergraduate nursing courses used in study one were invited to participate. Age restriction for these studies was 18-35 years. This population was chosen based on the LBP prevalence rates from study one, and to allow for ease of follow-up, with these students still likely to be attending university at the 12-month follow-up.

V.II. Sample size

To calculate an appropriate sample size for the primary exploratory prospective study (Chapter 6), data from previous epidemiological studies was considered.

- The incidence of new episodes of LBP in manual workers has been reported at 55% over two years, although only 13% of these were rated as serious (Stevenson et al. 2001).
- Similar incidence new episodes of LBP have been reported in health care workers (40% over 1 year, with 9% of the total subjects experiencing serious low back pain) (Adams et al. 1999).
- Incidence of new episode (not always first time) LBP in nurses has been reported as 38% in 18 months (Smedley et al. 1997).
- Other studies of the general population report first time incidence as 14% in 12 months, (Croft et al. 1996) and 8% in 6 months (George 2002), and new episode incidence (not necessarily first time), as 24% in 12 months (Reigo 2001).
- Studies on adolescent populations report the first time incidence of low back pain as 17% per year (Nissinen et al. 1994), and new episode incidence (not necessarily first time), as 21.5% (Burton et al. 1996).

Therefore a conservative estimate of new episodes of LBP in student nurses was 15% per annum. Effect size data from recent studies for various physical measures in LBP populations (O'Sullivan et al. 2005), and treatment outcomes in specific LBP populations (O'Sullivan et al. 1997), were also utilised in power calculations. Power calculations based on published data suggest a minimum subject population of 100 subjects would be required to produce a significant effect size across a number of variables. An ideal subject population of 200 subjects was targeted to give the prospective study an increased chance of having strong predictive ability. With a conservative back injury rate of 15% as determined above this would ensure 30 subjects would be in the LBP group. This would also assist in increasing effect sizes in some variables for cross-sectional analysis and would also be important to allow for subject dropout over the time frame of the prospective study.

V.III. Screening questionnaires

A modified version of the Nordic Low Back Pain Questionnaire was used to determine LBP history, frequency and severity, and to exclude subjects according to the inclusion / exclusion criteria (Kuornika et al. 1987). Question 2 was added to the questionnaire to gather information regarding postures/activities which aggravate LBP. Question 3 was modified from "*Have you ever had to change job or duties because of low back trouble?*" to a more specific question regarding nursing studies/duties. Question 5 was added to gather information regarding the number of LBP episodes in the past 12-months. Question 10 gathered specific demographic information not included in the original questionnaire. This modified version of the Nordic LBP Questionnaire was pilot tested on 10 health professionals and 10 nursing students to ensure clarity of the revised questions. This pilot testing included discussion of the questions and answers with the subjects after completion of the questionnaire to ensure face validity of the questionnaire.

The Modified Core Network Low Back Pain Medical Screening Questionnaire assessed subject's general health status and screen for confounding medical conditions (Committee 1997). If any responses suggested grounds for exclusion, subjects were questioned further verbally by the investigator prior to continuing with testing.

Modified Nordic Low Back Screening Questionnaire

How to answer the questionnaire: In this picture, you can see the approximate position of the part of the body referred to in the questionnaire as the low back. By low back trouble is meant ache, pain or discomfort in the shaded area, whether or not it extends from there to one or both legs (sciatica).

Please answer by putting a cross in the appropriate box. You may be in doubt as to how to answer, but please do your best anyway.

1. Have you **ever** had low back trouble (ache, pain or discomfort)?

1 ☐ NO 2 ☐ Yes ☐

If you answered NO to Qu. 1, Skip to Qu. 10.

2. What activity/s can hurt your back? (You can mark more than one box)

1 ☐ Bending and/or Lifting ☐
2 ☐ Sitting and/or Driving ☐
3 ☐ Standing and/or Walking ☐
4 ☐ Sudden movements
5 ☐ No specific event

3. Have you **ever** hurt your back associated with your nursing studies or employment in nursing type duties?

1 ☐ NO 2 ☐ Yes ☐

4. How many **episodes** of low back pain have you had during the **last 12 months?**

- ☐ 0
- ☐ 1
- ☐ 2-3

4 ☐ more than 3 ☐

5. Have you taken **any** medication because of low back trouble during **the last 12 months?**

1 ☐ NO 2 ☐ Yes ☐

6. What is the total length of time you have had low back trouble during the **last 12 months**?

- ☐ 0 days
- ☐ 1-7 days
- ☐ 8-30 days
- ☐ more than 30 days, but not every day.

5 ☐ Every day ☐

7. Has low back trouble caused you to **reduce** your activity in the **last 12 months?**

a) Work activity (at home or away from home)?
1 ☐ NO 2 ☐ Yes ☐

b) Leisure activity?
1 ☐ NO 2 ☐ Yes ☐

8. Have you **been seen** by a doctor, physiotherapist, chiropractor or other such person because of low back trouble during **the last 12 months?**

1 ☐ NO 2 ☐ Yes ☐

9. Have you had low back trouble at any time in the **last 7 days?**

1 ☐ NO 2 ☐ Yes ☐

10. a) Sex
1 ☐ Female 2 ☐ Male ☐

b) Year of Study (Eg N1) ________ ☐

c) Age ________ ☐

Modified Core Network Low Back Pain Medical Screening Questionnaire

Code: ______________________________ DATE: _____________

1. Is your general health good? θ Yes θ No

If No, what problems do you have?: _____________________________________

____

____

2. Do you have any ongoing disease processes such as arthritis, osteoporosis, heart disease, arrhythmia, hypertension or cancer? θ Yes θ No

If Yes, please specify:____

____

3. Have you ever been treated for cancer? θ Yes θ No

4. Have you had any recent medical tests (blood test, X-rays etc)? θ Yes θ No

5. Have you lost more than 4kg in the last 6 months? θ Yes θ No

6. Do you have any:

- Numbness/tingling in your buttock or genital region? θ Yes θ No
- Bowel or bladder problems? θ Yes θ No
- Pain, swelling or redness in other joints? θ Yes θ No
- Skin rashes? θ Yes θ No
- Eye discomfort, watery eyes, eye pain with light? θ Yes θ No
- Weakness in your legs? θ Yes θ No
- Balance problems? θ Yes θ No

7. Have you had a:

3 Recent fever or chill? θ Yes θ No
- Recent infection? θ Yes θ No

8. Do you get pain in your legs that is caused by walking and relieved by rest? θ Yes θ No

9. Is your back stiff in the morning for more than 30 minutes? θ Yes θ No

10. Have you ever taken steroids (prednisone / cortisone)? θ Yes θ No

11. Are you currently taking any medication? θ Yes θ No

If Yes, please specify:

____

V.IV. Psycho-social questionnaires

Demographic and social data was collected using a questionnaire based on previous demographic research (Brasic 2003).

The Depression Anxiety Stress Scales (DASS) is a self-administered set of three self-report scales used to measure depression, anxiety and stress.(Lovibond and Lovibond 1995) Back Beliefs Questionnaire (BBQ) is a 14 item self-administered questionnaire which determines individual beliefs regarding the impact of back pain.(Symonds et al. 1996)

The General Short Form 19-item Coping Scale for Adults (CSA) investigates coping and the development of coping strategies.(Frydenberg and Lewis 2004) It provides sub-scale scores for four coping styles; Dealing with the Problem, Non-productive Coping, Optimism, and Sharing. The relationship between coping styles and degree of LBP severity was examined. In addition, four individual items from the questionnaire; Play Sport, I Get Sick, Consciously Block out the Problem, and Worry About What Will Happen to Me, were also tested for relationship with degree of LBP severity. These items were chosen by the authors as they reflected common descriptions of strategies for dealing with painful events described by patients in the clinical setting.

The Pain Catastrophising Scale (PCS)(Sullivan et al. 1995) was used to investigate whether catastrophic thinking was associated with degree of LBP severity. It asks participants to reflect on 13 items regarding past pain experiences using a 5 point scale, and provides a total and three sub-scale scores assessing rumination, magnification and helplessness.

Demographic Questionnaire

1. What is your sex? Male ☐ Female ☐

2. What is your age?
16-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56+ ☐

3. Please write your post code. ________________

4. What is your marital status?
Single ☐ Married ☐ Divorced ☐ Defacto ☐

5. How many children do you have?
0 ☐ 1 ☐ 2 ☐ 3 ☐ 4+ ☐

6. What level of education did you complete?
Year 10 ☐ Year 12 ☐ TAFE / Apprenticeship ☐ University ☐

7. What is your living situation?
By Self ☐ With Parents ☐ With Friends ☐ With Partner / Wife ☐

8. Is your current residence:
Rental ☐ Under Mortgage ☐ Self Owned ☐

9. Is your vehicle:
Leased ☐ Under Mortgage ☐ Work Vehicle ☐ Self Owned ☐

10. What is your yearly salary (Thousands)?
$0-19 ☐ $20-29 ☐ $30-39 ☐ $40-49 ☐
$50-59 ☐ $60-69 ☐ $70-79 ☐ $80 + ☐

11. Do you or any family member/s have a health care card? Yes ☐ No ☐

12. Are you or any family member/s on a pension? Yes ☐ No ☐

13. Do you currently have a worker's compensation claim? Yes ☐ No ☐

14. Have you previously had a worker's compensation claim? Yes ☐ No ☐

15. Do you smoke?
Never ☐ 1-10 Daily ☐ 11-20 Daily ☐ 21-30 Daily ☐
30+ Daily ☐

16. Do you drink alcohol (Standard Drinks)?
Never ☐ 1-5 Weekly ☐ 6-10 Weekly ☐ 11-15 Weekly ☐
16+ Weekly ☐

DASS21. **All students to complete** *Code:*
Date:

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you *over the past week*. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

1	I found it hard to wind down	0	1	2	3
2	I was aware of dryness of my mouth	0	1	2	3
3	I couldn't seem to experience any positive feeling at all	0	1	2	3
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5	I found it difficult to work up the initiative to do things	0	1	2	3
6	I tended to over-react to situations	0	1	2	3
7	I experienced trembling (eg, in the hands)	0	1	2	3
8	I felt that I was using a lot of nervous energy	0	1	2	3
9	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
10	I felt that I had nothing to look forward to	0	1	2	3
11	I found myself getting agitated	0	1	2	3
12	I found it difficult to relax	0	1	2	3
13	I felt down-hearted and blue	0	1	2	3
14	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
15	I felt I was close to panic	0	1	2	3
16	I was unable to become enthusiastic about anything	0	1	2	3
17	I felt I wasn't worth much as a person	0	1	2	3
18	I felt that I was rather touchy	0	1	2	3
19	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3
20	I felt scared without any good reason	0	1	2	3
21	I felt that life was meaningless	0	1	2	3

Back Beliefs Questionnaire (Adapted from Symonds et al 1995) **Code: ______**

We are trying to find out what people think about low back trouble. Please indicate your general views towards back trouble, even if you have never had any.
Please answer ALL statements and indicate whether you agree or disagree with each statement by circling the appropriate number on the scale.

1 = COMPLETELY DISAGREE, 5 = COMPLETELY AGREE

1	2	3	4	5
Completely disagree				Completely agree

Disagree

Agree

1	There is no real treatment for back trouble	1	2	3	4	5
2	Back trouble will eventually stop you from participation in physical activity	1	2	3	4	5
3	Back trouble means periods of pain for the rest of one's life	1	2	3	4	5
4	Doctors cannot do anything for back trouble	1	2	3	4	5
5	A bad back should be exercised	1	2	3	4	5
6	Back trouble makes everything in life worse	1	2	3	4	5
7	Surgery is the most effective way to treat back trouble	1	2	3	4	5
8	Back trouble may mean you end up in a wheelchair	1	2	3	4	5
9	Alternative treatments are the answer to back trouble	1	2	3	4	5
10	Back trouble means long periods of time off school	1	2	3	4	5
11	Medication is the only way of relieving back trouble	1	2	3	4	5
12	Once you have had back trouble there is always a weakness	1	2	3	4	5
13	Back trouble must be rested	1	2	3	4	5
14	Later in life back trouble gets progressively worse	1	2	3	4	5

Coping Scale for Adults (Frydenberg 1996)

GENERAL
SHORT FORM

Coping Scale for Adults

Office use only

1. ID Number: ______________ ☐ ☐ ☐
2. Male: ☐ Female: ☐ — Sex ☐
3. Age: ______________ — Age ☐ ☐
4. Are you at work, engaged in studies or doing something else? ☐
   Please indicate: ______________
5. If at work, what is your occupation? ______________ ☐ ☐
6. If engaged in studies , where do you attend? ______________ ☐ ☐
7. What course? ______________
8. Languages spoken in your home: — Languages
   [From most spoken to least] (1) ______________ ☐ ☐
   (2) ______________ ☐ ☐
   (3) ______________ ☐ ☐

People have a number of concerns or worries, such as work, studies, family, friends, the world and the like. Below is a list of ways in which people cope with a wide variety of concerns or problems. Please indicate the things you do to deal with your concerns or worries by circling the appropriate number. Work down the page and circle 1, 2, 3, 4 or 5 as you come to each statement. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which best describes how you feel.

For example if you **sometimes** cope with your concern by 'Talk to others to see what they would do if they had the problem' you would circle 3 as shown below:

	Doesn't apply or don't do it	Used very little	Used some-times	Used often	Used a great deal
1. Talk to others to see what they would do if they had the problem	1	2	(3)	4	5

Please note that within this scale is one item, designed primarily for clinical purposes, that indicates difficulty with coping. If you don't wish to complete this item you may omit it. The relevant item (highlighted with an asterisk) is item 5.

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		Doesn't apply or don't do it	Used very little	Used some-times	Used often	Used a great deal
1.	Play sport	1	2	3	4	5
2.	Talk to others and give each other support	1	2	3	4	5
3.	Put effort into my work	1	2	3	4	5
4.	Pray for help and guidance so that everything will be all right	1	2	3	4	5
*5.	I get sick; for example, headache, stomach ache	1	2	3	4	5
6.	Work on my self image	1	2	3	4	5
7.	Look on the bright side of things and think of all that is good	1	2	3	4	5
8.	Develop a plan of action	1	2	3	4	5
9.	Try to be funny	1	2	3	4	5
10.	Find a way to let off steam; for example, cry, scream, drink, take drugs	1	2	3	4	5
11.	Improve my relationship with others	1	2	3	4	5
12.	Go to meetings which look at the problem	1	2	3	4	5
13.	Daydream about how things will turn out well	1	2	3	4	5
14.	Blame myself	1	2	3	4	5
15.	Don't let others know how I am feeling	1	2	3	4	5
16.	Consciously 'block out' the problem	1	2	3	4	5
17.	Ask a professional person for help	1	2	3	4	5
18.	Worry about what will happen to me	1	2	3	4	5
19.	Make time for leisure activities	1	2	3	4	5

20. List any *other* things you do to cope with your concern/s

____

____

____

Pain Catastrophising Scale **Code: _____**

Everyone experiences painful situations at some point in their lives. Such experiences may include headaches, tooth pain, joint or muscle pain. People are often exposed to situations that may cause pain such as illness, injury, dental procedures or surgery.

We are interested in the types of thoughts and feelings that you have when you are in pain. Listed below are thirteen statements describing different thoughts and feelings that may be associated with pain. Using the following scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

0 = not at all
1 = to a slight degree
2 = to a moderate degree
3 = to a great degree
4 = all the time

When I am in pain I:

1	I worry all the time about whether the pain will end.	0	1	2	3	4
2	I feel I can't go on.	0	1	2	3	4
3	It's terrible and I think it's never going to get any better.	0	1	2	3	4
4	It's awful and I feel that it overwhelms me.	0	1	2	3	4
5	I feel I can't stand it anymore.	0	1	2	3	4
6	I become afraid that the pain will get worse.	0	1	2	3	4
7	I keep thinking of other painful events.	0	1	2	3	4
8	I anxiously want the pain to go away.	0	1	2	3	4
9	I can't seem to keep it out of my mind.	0	1	2	3	4
10	I keep thinking about how much it hurts.	0	1	2	3	4
11	I keep thinking about how badly I want the pain to stop.	0	1	2	3	4
12	There's nothing I can do to reduce the intensity of the pain.	0	1	2	3	4
13	I wonder whether something serious may happen.	0	1	2	3	4

V.V. International Physical Activity Questionnaire (IPAQ)

The reliable and valid IPAQ, last 7 days self-administered format, was used to record average physical activity levels of subjects (Booth 2000). Subjects estimated average light, moderate and vigorous weekly physical activity across a range of domains including occupational, transport and leisure time. Data were summed across the domains to give weekly averages (hours) of time spent doing vigorous and moderate physical activity as well as total time spent sitting and walking. An example of the individual activity data that were summed to provide a total activity score in the prospective analysis (Chapter 6) is provided in Table V.I. Activity totals were used to examine relationships between physical activity and LBP.

Table V.I. Univariate prospective LBP group comparisons of moderate and vigorous physical activity adjusted for LBP, age and BMI [median (interquartile range)].

Activity Type (hours/week)	No/Mild LBP (n=76)	Significant LBP (n=31)	Odds Ratio	95% CI	p-value
Total moderate physical activity	5.0 (9.9)	7.0 (12.5)	1.08	1.02-1.15	0.009
Moderate job	1.0 (6.0)	3.0 (9.0)	1.07	0.99-1.15	0.100
Moderate household	1.0 (1.88)	2.0 (3.0)	1.12	0.88-1.10	0.129
Moderate garden	0.5 (1.5)	1.0 (2.0)	1.15	0.97-1.36	0.118
Moderate sport	0.0 (1.0)	0.0 (2.0)	1.40	1.01-1.94	0.041
Total vigorous physical activity	3.0 (5.0)	5.0 (11.0)	1.07	1.00-1.14	0.047
Vigorous job	0.0 (2.75)	0.0 (2.0)	1.05	0.96-1.14	0.281
Vigorous garden	0.0 (0.0)	0.0 (0.0)	1.09	0.95-1.24	0.218
Vigorous sport	1.0 (3.0)	1.0 (6.0)	1.14	0.99-1.32	0.077

International Physical Activity Questionnaire

Long Last 7 Days Self-administered Format

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 **last 7 days**. 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 **last 7 days**. **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 travelling 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***

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 travelled 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***

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, shovelling 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***

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***

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**

End of Questionnaire

V.VI. Spinal angle measurements

A range of functional tasks were chosen with consideration of likely repetitive or sustained postures associated with university study and nursing duties. Basic spinal postures measured were; usual sitting and maximal slumped sitting, usual standing, sway standing and maximal forward and backward bending in standing. A series of functional tasks were also measured to replicate various spinal loading tasks specific to replicate common nurse duties. These comprised: 1. Picking up a pen from floor height, 2.Picking up a 5kg box from floor height. 3. Performing lateral (left to right and return across 75cm) transfer of a pillow and 4. Performing lateral transfer of a 5kg box at hospital bed height.

V.VI.I. Sitting posture

1. Subjects were asked to sit on a stool, which was selected to allow their thighs to be parallel with the floor and knees flexed at 90°. No direction of how to sit or an indication of what was being measured was provided. This position was held for 5 seconds and recorded as their usual sitting posture (defined as the sitting posture they would usually adopt during unsupported sitting).
2. Subjects were then assisted into their end of range lumbar flexion sitting posture by an experienced therapist using standardised cues of asking the subject to "slouch" and using hand cues on the lateral shoulder and pelvis to guide posterior pelvic tilting.

V.VI.II Standing postures

1. Subjects were asked to stand comfortably on a designated floor mark. This position was recorded as their usual standing posture (defined as the standing posture they would usually adopt during habitual unsupported standing).
2. Subjects were then asked to bend forwards as far as possible with their knees straight, and a three second recording in this position was defined as maximal forward bending.
3. Similarly, maximal backward bending was measured by asking subjects to then bend backwards as far as possible, keeping their feet stationary.
4. Maximal sway standing posture was defined subject's relaxed standing posture with the pelvis translated anteriorly relative to the trunk. All subjects were guided into this position by the same experienced therapist. Excellent reliability of

positioning subjects in sway posture has been shown previously. (O'Sullivan et al. 2002) All standing posture measures were repeated three times.

V.VI.III. Lifting

1. While in the standing position, a pen was placed in front of subjects and they were asked to pick it up. Subjects were directed to pick up the pen as if they had just dropped their own pen on the floor and needed to retrieve it. This test was performed once.
2. Subjects were then directed to pick up a moderate 5kg load in a box with handles 20cm above floor height. No cues were given regarding how to pick up the box. This test was repeated 3 times.
3. An adjustable bed was then set at a height 10cm above each subject’s superior patella margin as a standardised height. The task involved transferring a pillow from left to right a distance of 75cm, then back to the starting position. Subjects initially stood at the mid point between the box and target position marked on the bed, then were asked to transfer the load, with no specific directions regarding how to lift. This test was repeated 3 times.
4. The task involving transferring a pillow was then repeated using a 5kg box. This test was repeated 3 times.

V.VI.IV. Squatting

Subjects were seated on a stool, with thighs parallel and knees flexed at 90°, and their arms folded across their chest. Subjects were then asked to adopt a squat position with their buttocks just clear of the stool by an experienced therapist using standardised cues. This test was also used for a measure of leg muscle endurance, so only one trial was conducted. Subject’s lumbar spine posture was recorded throughout the squat test, with a three second Fastrak™ data sample taken as their squat posture once their position was stable after rising from the stool. The hold time was measured in seconds using a hand held stopwatch.

V.VI.V. Data management (Sacral, ULx, LLx and TLx angles)

Lumbar spine angles were measured with the 3-Space® Fastrak^{TM} (Polhemus, Kaiser Aerospace, Vermont), using protocol described previously (Dankaerts et al. 2006). This electromagnetic device measures the position and orientation of a sensor in space relative to a source. Data was collected at 25Hz using a customised program in Labview V8 (National Instruments, Texas, USA). Lumbar spine sagittal plane (flexion / extension) angles in degrees between the Fastrak^{TM} skin sensors at T12, L3 and S2 were measured over three separate 5 second trials. The sensors were attached to the skin over the relevant spinous process by the same investigator using double sided tape and Fixomull Stretch tape (Beiersdorf AG, Hamburg, Germany). Sensors were applied with the subject standing in partial lumbar spine flexion with their hands resting on their thighs, to allow comfortable movement into full lumbar flexion and extension without sensor-skin movement during testing.

Calculation of sensor angles was used to provide measures of sacral (S2), upper lumbar (T12- L3), lower lumbar (L3-S2), and total lumbar angles (T12-S2) (FigureV.I.), which have been defined previously and shown to have excellent inter-trial reliability in sitting (Dankaerts et al. 2006). Sagittal extension was assigned a positive value, and flexion a negative value.

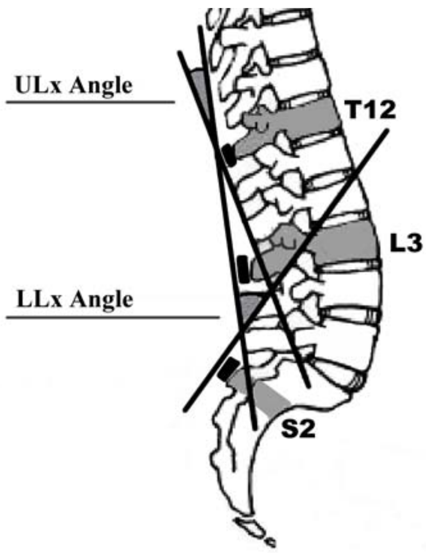

Figure V.I. Spinal model used for the calculation of the angles. LLx = lower lumbar; ULx = upper lumbar. Total lumbar angle is the angle formed between the tangents from the sensors at T12 and S2. Sacral angle is the angle of the S2 sensor relative to the vertical plane.

Fastrak angle outputs were calculated by custom software written in Labview V8. For range of motion, the mean peak angle was calculated from three trials for each of; maximal slumped sitting, sway standing and maximal forward and backward bending in standing. The peak angle was defined as the average angle across the five seconds for which subjects held each peak position. The mean peak sagittal angles were calculated for the functional postures of; picking up a pen, picking up a box, transferring a pillow and a box at bed height, and squatting. As there was no sustained hold during these tasks (except for the squat), the Labview software determined the peak sagittal flexion (or least sagittal extension) angle reached between the start and finish of the task. The start and finish of the task was determined by manually tagging the data at the point of commencement and cessation of motion. Regional differences in sagittal motion between usual sitting and maximal slumped sitting, and usual standing and; sway standing, and maximal forward and backward bending in standing were calculated using the usual posture as the reference posture.

Repeated loading at end of range spinal flexion has been associated with increased low back injury risk (Cholewicki and McGill 1996). The difference between subjects posture during functional tasks and their end of range spinal flexion was calculated due to its potential clinical relevance in this study. The functional tasks measured (lifting from floor and bed height, and squatting) generally involve flexion of the lumbar spine. Therefore the relationship between proximity to end range spinal flexion during functional tasks and low back pain were examined.

Inter-trial reliability for repeated spinal kinematic measures across the 3 trials examined and found to be excellent (Table V.II).

Table V.II. Spinal angle inter-trial reliability of kinematic measures

Posture	LLx ICC (95% CI)	LLx SEM	ULx ICC (95% CI)	ULx SEM	TLx ICC (95% CI)	TLx SEM
Usual sitting	0.926 (0.91-0.94)	2.52°	0.949 (0.94-0.96)	2.00°	0.961 (0.95-0.97)	2.93°
Slump sitting	0.939 (0.92-0.95)	2.30°	0.869 (0.84-0.90)	2.75°	0.989 (0.98-0.99)	1.29°
Usual standing	0.953 (0.94-0.96)	2.17°	0.953 (0.94-0.97)	2.04°	0.957 (0.94-0.97)	2.02°
Sway standing	0.982 (0.98-0.99)	1.80°	0.972 (0.96-0.98)	1.99°	0.960 (0.95-0.97)	2.31°
Backward bending	0.984 (0.98-0.99)	2.54°	0.979 (0.97-0.98)	2.27°	0.973 (0.97-0.98)	2.91°
Forward bending	0.995 (0.99-1.00)	0.52°	0.993 (0.99-1.00)	0.50°	0.995 (0.99-1.00)	0.64°
Lift box	0.955 (0.94-0.97)	1.83°	0.926 (0.91-0.94)	2.29°	0.926 (0.91-0.94)	3.75°
Pick up pen	Single measure					
Pillow transfer	0.927 (0.91-0.94)	2.49°	0.877 (0.85-0.90)	3.06°	0.872 (0.84-0.90)	4.68°
Box transfer	0.959 (0.95-0.97)	1.89°	0.940 (0.92-0.95)	2.17°	0.924 (0.90-0.94)	3.43°
Squat	Single measure					

LLx = Lower lumbar, ULx = Upper lumbar, TLx = Total lumbar.

V.VII. Back muscle endurance

Subject's back muscle endurance was measured using the Sorensen test (Biering-Sorensen et al. 1989). This test has previously been shown to have acceptable reliability and validity (Latimer et al. 1999). Subjects were positioned on a plinth in the prone position. Subject's anterior superior iliac spines were aligned with the end of the plinth, and they rested their forearms on a small stool in front of the plinth. Straps applied to the pelvis and lower legs fixed the subject to the plinth. Subjects were then guided to the test position by the investigator for 5 seconds to learn the required neutral spinal posture. Subjects were then asked to fold their arms across their chest and assume the test position for aslong as possible and to place their forearms back on the stool when they could no longer continue. Only instructions to maintain the neutral spinal posture were given. The length of time in seconds the subject was able to maintain neutral trunk alignment without deviating more than 10° into flexion or extension (measured with a hand-held inclinometer) was recorded during a single trial.

V.VIII. Spinal repositioning sense (Proprioception)

Spinal repositioning accuracy was determined using the 3-Space® Fastrak™. Repositioning accuracy was evaluated with subjects attempting to reproduce a criterion position of neutral lumbar lordosis in sitting, using reliable criteria reported previously (O'Sullivan et al. 2003). This protocol was used due to previous results showing differences in repositioning accuracy between LBP subjects and healthy controls. A demonstration of the testing protocol was given, and the subject was then blind folded and seated on a wooden stool with the hips, knees and ankles at 90°. Subjects were assisted by the investigator to move through their available range of lumbar flexion and extension in sitting three times. They were then positioned into a neutral spinal posture (as determined by the therapist) for five seconds, and instructed to remember the position as they would be asked to find it as accurately as possible during the test trials. Subjects were then instructed to relax into full lumbar flexion for five seconds, before being asked to reproduce the criterion position. The protocol was repeated three times. The subjects were given no feedback as to their repositioning accuracy during testing. Repositioning accuracy in millimetres was recorded as the distance from the criterion position the subject holds during each repositioning trial. Reliability of repositioning accuracy is shown in Table V.III.

Table V.III. Spinal repositioning inter-trial reliability

	Sacral	Lower Lx	Upper Lx
ICC	0.561	0.565	0.495
95% CI	0.44-0.66	0.44-0.66	0.35-0.61

V.IX. Cardiovascular fitness

The Astrand-Rhyming ergometer test is a commonly employed sub-maximal cardiorespiratory fitness test based on the assumption of a linear relationship between heart rate and workload on an ergometer (Astrand and Rodahl 1986). This test has previously been shown to have acceptable reliability and validity (Hodselmans et al. 2008). A resultant VO_2Max score was calculated and then compared to normative values to determine a fitness rating. The test procedure and data collection sheet are provided below.

Astrand-Rhyming Cardiovascular Fitness Test

- Record Subject's weight and age
- Set seat height on bike to allow 5° knee flexion at the lowest pedal position
- 1-2 minute warm-up at 50 RPM and level 2 resistance
- Set resistance according to table below:

	Male	**Female**
Unconditioned	**50 or 100 Watts**	**50 or 75 Watts**
Conditioned	**100 or 150 Watts**	**75 or 100 Watts**

- The subject pedals at this work rate for 6 minutes. The aim is to produce a heart rate of between 125 – 170 bpm.
- Record the HR in the last 15 sec of each minute
- If desired HR is not achieved in minute 5, increase the work rate by 25 or 50 Watts and continue for 2 more minutes
- Give the subject 1-2 minute cool down period at 50 RPM

- Take the average HR of the last 2 minutes
- Find the predicted VO_2 Max score under the appropriate Wattage in the male or female ors Tables
- Correct the VO_2 max value using the age correction table
- Use the value to rate their fitness level according to the classification table

Astrand Fitness Data Collection

Date: ____________

Subject Name: ______________________

Age: ________

Weight: ____________

Resting HR: __________

Initial Work Rate (Watts): ___________

Final Work Rate (If target HR not achieved @ 4:45): _________

0:45 HR _________
1:45 HR _________
2:45 HR _________
3:45 HR _________
4:45 HR _________ (If not above 125 bpm, increase by 25W female / 50W male
5:45 HR _________
6:45 HR _________ (Only if increased work rate)

Average HR of final 2 minutes: _________

Predicted VO_2 max: _________ x Age correction factor: _________

= Corrected VO_2 max: _________

Cardiovascular Fitness Rating: _________

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APPENDIX VI - Gender differences in personal characteristics in nursing students

VI.I. Introduction

Despite generally living healthier lifestyles, having lower body mass index (BMI) and less stressful occupations than males, it is widely reported that females experience more LBP than men (Schneider et al. 2006). Gender differences have been reported in a number of factors that are associated with LBP.

A recent study on sitting posture in healthy individuals showed males sat with more spinal flexion than females, regardless of the chair type (Dunk and Callaghan 2005). Gender differences in standing lumbar curvature (greater lordosis in females) as well as LBP diagnosis have been shown in one clinical study (Norton et al. 2004), while standing spinal posture was also shown to differ between genders in a large adolescent sample (Smith et al. 2008). In terms of back muscle endurance, although some conflicting evidence exists, clear gender differences are commonly reported (Demoulin et al. 2006). Female subjects have repeatedly been shown to have lower lumbar erector spinae muscle fatigability compared to the males (Kankaanpaa et al. 1998; Suuden et al. 2008). Furthermore, there is some evidence to suggest that females with LBP have greater endurance in the Sorensen test compared with healthy controls, which is in contrast to males (Biering-Sorensen 1984).

Gender differences are also recognised in relation to a range of psychological factors and LBP (Gatchel et al. 2007). There is evidence of gender differences in depression (Hyde et al. 2008), pain related anxiety (Robinson et al. 2005), excessive pain behaviours (Dickens et al. 2002) and pain coping strategies (Inman et al. 2004), with females reporting higher scores or more frequent use of these strategies. There is also evidence of gender differences in mechanical spinal loading in response to psychological stress (Marras et al. 2000). Further, gender differences in biochemical factors, such as stress biomarkers and their association with LBP development (Schell et al. 2008), supports the concept of the complex multifactorial nature of LBP.

As there is increasing evidence supporting gender differences in LBP characteristics, the aim of this study was:

- To investigate whether personal social / lifestyle, psychological and physical characteristics differ between female and male nursing students.

VI.II. Methods

Cross-sectional data was collected on 170 female and 24 male undergraduate nursing students. The same personal social / lifestyle, psychological and physical characteristics as outlined in earlier chapters of this thesis were measured.

VI.II.I. Statistical Analysis

All statistical analyses were performed using SPSS Version 13 (SPSS Inc., Chicago: USA). Differences in gender were tested using chi-square analysis and independent t-tests. Non-parametric statistical tests (Mann-Whitney) were used when data was highly skewed and non-amenable to transformation. Adjustment of estimates for age and BMI did not significantly alter results and has not been reported. Significance level was set at 0.05.

VI.III. Results

VI.III.I. Social / lifestyle measures

Results of the social / lifestyle measures in this study showed that amount of alcohol consumption and amount of weekly vigorous physical activity hours were both higher in male nursing students (Table VI.I). This does not appear to be associated with age, BMI or LBP history, however more in-depth analysis of these associations was not conducted.

Table VI.I. Gender comparisons of social and lifestyle variables [mean ± S.D, n (%), or median (IQR)].

	Males (n = 24)	**Females (n = 170)**	**p-value**
Personal Characteristics			
Any History of LBP	18 (75.0 %)	139 (81.8 %)	0.430
Age (yrs)	22.5 ± 3.4	22.5 ± 4.5	0.960
Overweight / Obese	4 (16.7 %)	44 (25.9 %)	0.996
Social / Lifestyle Measures			
Cigarette Smokers	6 (25.0 %)	20 (11.9 %)	0.079
> 5 alcoholic drinks per week	9 (37.5 %)	29 (17.1 %)	**0.018**
Household income			
<AUD 59 000 p/anum	15 (65.2 %)	75 (48.4 %)	0.132
Marital status (% single)	20 (83.3 %)	135 (79.4 %)	0.608
Previous compensation claim	2 (8.3 %)	8 (4.7 %)	0.452
Moderate physical activity (hrs/week)	9.25 (8.8 IQR)	6.75 (10.5 IQR)	0.967
Vigorous physical activity (hrs/week)	6.0 (14.1 IQR)	3.0 (7.5 IQR)	**0.029**
Walking (hrs/week)	9.75 (15.5 IQR)	7.0 (12.3 IQR)	0.150
Sitting (hrs/week)	48.0 (29.0 IQR)	43.0 (17.3 IQR)	0.634

IQR = Interquartile Range.

VI.III.II. Psychological measures

In this sample of nursing students, there were no significant differences between genders in the psychological measures. However, there were trends for higher levels of stress and non-productive coping in the female nursing students (Table IV.II).

Table VI.II. Gender comparisons of psychological variables [mean ± S.D, or median (interquartile range)].

	Males (n = 24)	**Females (n = 170)**	**p-value**
Depression, Anxiety and Stress Scales			
Total (/126)	10.0 (17.0)	14.0 (16.0)	0.357
Depression (/42)	2.0 (4.5)	2.0 (4.0)	0.584
Anxiety (/42)	2.0 (4.0)	4.0 (4.5)	0.950
Stress (/42)	5.0 (9.0)	8.0 (9.0)	0.078
Back Beliefs Questionnaire			
Total (/45)	29.5 ± 6.3	29.7 ± 5.1	0.817
Coping Scale for Adults			
Dealing with Problem (/105)	71.6 ± 13.9	70.4 ± 12.9	0.678
Non-productive coping (/105)	48.8 ± 13.0	53.9 ± 13.2	0.073
Pain Catastrophising Scale			
Total (/52)	6.5 (11.5)	9.0 (13.0)	0.289
Rumination (/16)	3.5 (5.8)	4.0 (7.0)	0.388
Magnification (/12)	1.0 (3.0)	2.0 (3.0)	0.293
Helplessness (/24)	1.5 (7.0)	3.0 (5.0)	0.126

VI.III.III. Physical measures

As outlined in Table IV.III, there were many differences between genders in the physical characteristics measured in this study. Sitting and standing postures as well as functional spinal angles were significantly different between groups. A consistent pattern of males holding more flexed (or relatively less extended) spinal angles across the majority of measures taken was observed. Males also displayed significantly higher leg muscle endurance holding times in the squat test.

Table VI.III. Gender comparisons of spinal angles and physical variables (mean ± standard deviation).

	No/Mild LBP (n = 76)	Significant LBP (n = 31)	p-value
Sitting angles			
Pelvic sit angle (°)	8.1 ± 8.8	-1.3 ± 8.9	**<0.001**
LLx sit angle (°)	-5.3 ± 8.3	4.1 ± 8.8	**<0.001**
ULx sit angle (°)	-6.6 ± 7.7	-1.2 ± 8.8	**0.008**
Pelvic slump angle (°)	16.5 ± 7.6	8.2 ± 8.1	**<0.001**
LLx slump angle (°)	-8.5 ± 7.3	1.6 ± 9.1	**<0.001**
ULx slump angle (°)	-11.2 ± 5.7	-8.5 ± 6.1	0.052
Pelvic sit proximity to EOR(°)	8.4 ± 5.5	9.6 ± 5.7	0.325
LLx sit proximity to EOR (°)	3.2 ± 4.0	2.5 ± 4.0	0.396
ULx sit proximity to EOR (°)	4.7 ± 5.6	7.3 ± 7.0	0.083
Standing angles			
Pelvic stand angle (°)	-20.5 ± 6.9	-26.9 ± 7.4	**<0.001**
LLx stand angle (°)	19.0 ± 10.3	23.4 ± 11.2	0.075
ULx stand angle (°)	12.4 ± 9.3	15.5 ± 9.6	0.130
Pelvic sway angle (°)	-18.3 ± 7.9	-24.3 ± 10	**0.006**
LLx sway angle (°)	26.2 ± 11.9	31.2 ± 13.6	0.089
ULx sway angle (°)	13.9 ± 10.5	17.4 ± 11.9	0.175
Pelvic extension angle (°)	-9.7 ± 13.1	-19.4 ±12.5	**0.001**
LLx extension angle (°)	36.9 ± 15.3	44.0 ± 19.9	0.098
ULx extension angle (°)	28.7 ± 10.6	25.8 ± 15.9	0.397
Pelvic flexion angle (°)	-71.7 ± 13.7	-80.2 ±12.2	**0.002**
LLx flexion angle (°)	-18.3 ± 6.6	-11.8 ± 6.8	**<0.001**
ULx flexion angle (°)	-16.3 ± 5.5	-15.3 ± 5.9	0.421
Functional posture angles			
Pelvic pen angle (°)	-60.1 ± 18.2	62.8 ± 16.5	0.470
LLx pen angle (°)	-15.6 ± 8.2	-8.1 ± 7.2	**<0.001**
ULx pen angle (°)	-14.2 ± 6.7	-12.5 ± 6.3	0.212
Pelvic pen proximity to EOR (°)	11.6 ± 17.1	17.3 ± 17.8	0.135
LLx pen proximity to EOR (°)	3.0 ± 4.3	3.9 ± 3.9	0.342
ULx pen proximity to EOR (°)	2.1 ± 4.6	2.8 ± 5.2	0.492

Pelvic 5kg lift angle (°)	-46.5 ± 14.0	-52.5 ±12.7	**0.035**
LLx 5kg lift angle (°)	-11.2 ± 8.4	-5.3 ± 8.3	**0.001**
ULx 5kg lift angle (°)	-10.4 ± 8.1	-8.5 ± 8.5	0.282
Pelvic 5kg lift proximity to EOR (°)	25.2 ± 13.7	27.8 ± 14.8	0.413
LLx 5kg lift proximity to EOR (°)	7.1 ± 6.4	6.5 ± 5.8	0.670
ULx 5kg lift proximity to EOR (°)	6.4 ± 5.5	7.3 ± 7.7	0.586
Pelvic pillow transfer angle (°)	-39.0 ± 8.5	-47.5 ± 8.0	**<0.001**
LLx pillow transfer angle (°)	-3.0 ± 8.9	3.5 ± 8.5	**0.001**
ULx pillow transfer angle (°)	-7.0 ± 9.0	-4.7 ± 8.3	0.213
Pelvic pillow transfer proximity to EOR (°)	32.7 ± 13.0	32.7± 12.5	0.985
LLx pillow transfer proximity to EOR (°)	15.3 ± 9.4	15.2 ± 7.6	0.956
ULx pillow transfer proximity to EOR (°)	9.3 ± 7.6	10.6 ± 8.1	0.473
Pelvic 5kg transfer angle (°)	-36.7 ± 8.3	-45.9 ± 8.0	**<0.001**
LLx 5kg transfer angle (°)	1.5 ± 8.8	8.4 ± 8.9	**0.001**
ULx 5kg transfer angle (°)	-2.1 ± 10.0	1.7 ± 8.4	**0.043**
Pelvic 5kg transfer proximity to EOR (°)	35.0 ± 16.0	34.3 ± 12.7	0.788
LLx 5kg transfer proximity to EOR (°)	19.8 ± 10.0	20.2 ± 8.6	0.865
ULx 5kg transfer proximity to EOR (°)	14.2 ± 8.2	17.0 ± 8.5	0.133
Pelvic squat angle (°)	-50.3 ± 13.0	-54.7 ±12.2	0.109
LLx squat angle (°)	-8.3 ± 8.2	-3.2 ± 9.0	**0.008**
ULx squat angle (°)	-2.9 ± 9.3	-2.9 ± 9.6	0.984
Pelvic squat proximity to EOR (°)	21.4 ± 15.7	25.3 ± 16.1	0.268
LLx squat proximity to EOR (°)	10.0 ± 5.4	8.8 ± 7.0	0.432
ULx squat proximity to EOR (°)	13.5 ± 9.5	12.3 ± 9.5	0.585
Performance measures			
Squat time (seconds)	58.8 ± 25.9	37.6 ± 20.7	**<0.001**
Sorensen time (seconds)	106.3 ± 48.0	88.9 ± 49.3	0.105
LLx sitting repositioning error (°)	2.7 ± 1.8	3.0 ± 2.3	0.494
ULx sitting repositioning error (°)	3.3 ± 1.9	3.7 ± 2.5	0.476
Fitness rating below average	7 (29.2%)	36 (21.2%)	0.653

LLx = Lower Lumbar, ULx = Upper Lumbar, TLx = Total Lumbar, ROM = Range of Motion, EOR = End of Range flexion angle, Negative lumbar angle = lumbar flexion, Positive lumbar angle = lumbar extension, Negative pelvic angle = posterior pelvic rotation, Positive pelvic angle = anterior pelvic rotation.

VI.IV. Discussion

The results of this preliminary analysis support that gender differences exist in personal social/lifestyle, psychological and physical characteristics in nursing students. The strongest differences were in the physical measures. The relatively small group of males prevented accurate estimation of gender modification effects in this cohort. However, it was concluded that males should be excluded from further analysis in this doctoral research based on the current findings.

The current findings support the need to consider personal characteristics specific to each gender. Characteristics associated with LBP in male nurses, as well as gender differences relative to LBP in nursing students is the subject of separate ongoing research.

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APPENDIX VII - Habitual sitting posture is related to lower lumbar spine posture across a range of functional tasks: clinical implications for low back pain

VII.I. Introduction

Spinal posture is commonly addressed in the clinical management of non-specific LBP patients (O'Sullivan 2005). The direct relationship between spinal posture and LBP remains unclear however, despite extensive investigation.

Clinically, LBP patients report more pain in the lower lumbar (LLx) spinal segments than upper lumbar (ULx) spinal segments (Biering-Sorensen 1983; Beattie et al. 2000). This is consistent with a greater degree of degeneration being evident in the LLx spinal segments with increasing age (Twomey and Taylor 1987), which is thought to be due to the greater proportion of mechanical stress through these segments (Adams et al. 2002). Van Dieen identified the importance of considering the lumbar spine as having separate regions, rather than viewing it as a rigid section, when measuring spinal movement and function (van Dieen et al. 1996). The concept of considering the motion and function of the lumbar spine in terms of LLx and ULx regions has been proposed (Burton 1987), but not widely investigated.

The majority of LBP studies which have not considered lumbar spinal posture in separate regions have failed to show a direct link between spinal posture and LBP (Raine and Twomey 1994). Dankaerts found differences in usual sitting posture between LBP patients and healthy controls (Dankaerts et al. 2006). These differences were only evident however, when the lumbar spine was considered as separate regions (ULx and LLx), and when LBP subjects were sub-classified according to directional pain provocation patterns.

These recent findings raise questions as to whether LLx posture is consistent across a range of functional tasks other than lifting. Further, whether LBP has an influence on regional lumbar spine posture across a range of both static postures and a range of functional tasks warrants investigation.

The aims of this study were:

1. To investigate whether an individual’s regional lumbar spine posture is consistent across a range of functional tasks.

2. To investigate whether having LBP influences the consistency of lumbar spine posture across a range of functional tasks.

VII.II. Methods

VII.II.I. Design

This cross-sectional study was part of a larger prospective study into the development of LBP in nursing students. This study investigated LBP characteristics and spinal kinematics across a range of functional postures of female undergraduate nursing students.

Data was collected on 170 female undergraduate nursing students. A modified version of the Nordic Low Back Pain Questionnaire (Kuornika et al. 1987) was used to determine LBP history, frequency and severity. LBP disability levels were measured by the Oswestry Disability Index (Fairbanks J 1980). A range of functional tasks were chosen with consideration of likely repetitive or sustained postures associated with university study and nursing duties. Basic spinal postures measured were; usual sitting and maximal slumped sitting, usual standing, sway standing, maximal forward and backward bending in standing and squatting. A series of functional tasks were also measured to replicate various spinal loading tasks specific to replicate common nurse duties. These comprised:

1. Picking up a pen from floor height.
2. Picking up a 5kg box from floor height.
3. Performing lateral (left to right and return across 75cm) transfer of a pillow at hospital bed height.
4. Performing lateral transfer of a 5kg box at hospital bed height.

VII.II.II. Statistical Analysis

Paired t-tests examined regional differences in lumbar regional angles across static postures and functional tasks. Pearson's correlation coefficients were used to identify correlations between LLx angles across static postures and functional tasks. Fisher's z-tests were used to compare correlations of LLx angles between LBP groups.

VII.III. Results

Group demographic and LBP characteristics are outlined in Table VII.I. The highest proportion of subjects (48%) was in the Minor LBP group, with Significant LBP being experienced by 31% of subjects and only 21% of the subjects reporting no previous history of LBP. Mean age and BMI were not significantly different between groups.

Table VII.I. Subject Demographics and LBP Characteristics

	No LBP (n = 36)	Minor LBP (n = 81)	Significant LBP (n = 53)
Age (mean + SD, years)	21.7 ± 3.5	22.0 ± 4.2	23.9 ± 5.1
BMI (mean + SD, kg/m^{2})	21.9 ± 2.8	23.3 ± 4.3	23.1 ± 3.4
Lifetime highest VAS (mean + SD, /10)	0	3.9 ± 2.3	6.6 ± 1.6
Annual LBP Duration (range, days)	0	1-7	8-30
Requiring treatment, medication or activity reduction past 12-months (%)	0	44.4	96.2
Oswestry Disability Index (mean + SD)	0	10.4 ± 6.6	21.2 ± 9.2

BMI = body mass index. VAS = visual analogue scale.

VII.III.I. Sitting posture

Over 87% of subjects with any LBP history indicated their LBP was associated with flexion related activities including sitting, bending or lifting. Of these activities, sitting was the most commonly reported (53.4%). Usual sitting posture was therefore chosen as a reference position to compare lumbar spine posture with other functional positions.

In usual sitting across all subjects, there was a strong correlation between LLx angle and sacral angle [r = - 0.72 ($p < 0.001$)]. However, LLx angle in usual sitting did not correlate with ULx angle in usual sitting [r = 0.08 (p = 0.28)]. When patients were sub-grouped according to their LBP severity, there remained no correlation between ULx and LLx angles in usual sitting.

VII.III.II. Correlations across postures

Across all subjects, the LLx spinal angle showed the strongest mean Pearson correlation between usual sitting and other functional postures [r = 0.62 (range =

0.55 – 0.70)], followed by ULx angle [r = 0.43 (range = 0.25 – 0.58)], then sacral angle [r = 0.30 (range = 0.11 – 0.46)]. Considering the strength of the LLx angle correlations across the various tasks, its lack of correlation with ULx angle and the dominance of LLx pain compared to ULx pain in the clinical setting, LLx angle was the focus of more detailed analysis.

Across all subjects, correlations between usual LLx sitting posture and other kinematic LLx measures are rated moderate to good (Portney and Watkins 2000), with the strongest of these correlations being evident with forward bending and lifting tasks. (Table VII.II). When sub-grouped for LBP severity, the correlations change. Compared to all subjects, the strength of all correlations within the "no LBP" group become even stronger, with the most correlations being classified as good to excellent (Portney and Watkins 2000). The strongest correlations again being with forward bending and lifting tasks. The correlations, although still classed as moderate to good, become less strong in the "mild LBP" group, and somewhat weaker again in the "significant LBP" group.

Table VII.II. Correlations between lower lumbar spine angles in usual sitting and other functional postures. Whole group and LBP group comparisons are presented.

Posture	**All Subjects (n = 170)**	**No LBP (n = 36)**	**Mild LBP (n = 81)**	**Significant LBP (n = 53)**	**No LBP v Sig. LBP p-value**
Usual standing	0.58	0.69	0.57	0.52	0.23
Sway standing	0.55	0.66	0.54	0.50	0.27
Backward bending	0.55	0.71	0.52	0.52	0.16
Forward bending	0.65	0.82	0.60	0.58	**0.028**
Lift box	0.70	0.84	0.67	0.62	**0.027**
Pick up pen	0.68	0.88	0.62	0.59	**0.002**
Pillow transfer	0.65	0.80	0.62	0.58	0.051
Box transfer	0.64	0.81	0.59	0.59	**0.046**
Squat	0.64	0.77	0.61	0.57	0.10

VII.III.III. Influence of LBP on posture

Given there were significant differences in LLx angle correlations between pain groups, and as usual sitting was the reference posture, comparisons between subjects with and without LBP in sitting were performed. After sub-grouping all subjects into pain sitting and no pain sitting (taken from Oswestry Disability Index), LLx correlations of subjects with LBP, but not when sitting become much stronger, reflecting similar correlations as those for the no LBP group (Table VII.III).

Table VII.III. Correlations between lower lumbar spine angles in usual sitting and other functional postures. Whole group, and LBP v No LBP in sitting, group comparisons.

Posture	All Subjects (n = 170)	No LBP (n = 36)	No LBP in sitting (n = 98)	LBP in sitting (n=71)	No LBP sitting v LBP sitting (p-value)
Usual standing	0.58	0.69	0.67	0.39	**0.013**
Sway standing	0.55	0.66	0.66	0.32	**0.004**
Backward bending	0.55	0.71	0.66	0.36	**0.014**
Forward bending	0.65	0.82	0.69	0.58	0.25
Lift box	0.70	0.84	0.74	0.62	0.15
Pick up pen	0.68	0.88	0.75	0.53	**0.02**
Pillow transfer	0.65	0.80	0.74	0.47	**0.004**
Box transfer	0.64	0.81	0.74	0.44	**0.002**
Squat	0.64	0.77	0.69	0.55	0.14

VII.IV. Discussion

There is a considerable amount of LBP reported in this relatively young sample of undergraduate nursing students. Although not necessarily disabling, over 30% of the students had pain that would be regarded as clinically significant. Given the known risk for LBP in nurses in relation to bending and lifting duties (Eriksen et al. 2004), this group of nursing students provided a useful cohort for investigation of lumbar posture and the influence LBP has on posture.

Across all female nursing students in this study, sagittal LLx spine angles in usual sitting showed the strongest correlation ("moderate to good" (Portney and Watkins 2000)), with LLx angles in other functional tasks. ULx and pelvic angle correlations across the functional tasks were less strong. When considering only the nursing students with no back pain history, the LLx correlations strengthened to the "good to excellent" range (Portney and Watkins 2000). In this population, sagittal LLx spine posture is often very consistent across a range of functional tasks, particularly in those females with no history of LBP.

This lack of variation of LLx spine posture has also been shown in pain free subjects when commencing lifting, regardless of the lifting technique used (Gill et al. 2007). Movement variation when lifting was found to occur in the ULx and mid thoracic spine. Given the LLx spinal segments are most often the source of LBP (Biering-Sorensen 1983; Beattie et al. 2000), and show the greatest degeneration with increasing age (Twomey and Taylor 1987), posture of these segments may be of greater importance in the development of LBP. Repeated end range tissue loading has been linked with LBP (Cholewicki and McGill 1996), so if the consistent LLx posture held by some individuals is close to end of range flexion or extension, these individuals may be more susceptible to LBP and injury over time.

Sub-classification of LBP according to pain severity and disability levels revealed significant differences in consistency of LLx posture across functional tasks. However, presence of significant pain alone may not fully account for the observed differences. When considering the influence of LBP on spinal posture, mechanism based sub-classification of patients also appears to be important (Dankaerts et al. 2007). Subjects who reported LBP in sitting had significantly weaker LLx spinal posture correlations across most of the functional tasks compared to those without LBP in sitting. Those subjects without LBP in sitting included some 37 subjects who had what was classified as significant LBP in positions other than sitting. These findings may suggest that not just the presence of LBP, but the mechanisms causing LBP in individual patients must be considered to more fully explain the relationship between posture and LBP. This mechanism based approach has been shown to have merit in treating non-specific LBP patients according to their mechanism sub-classification (O'Sullivan et al. 1997; Dankaerts et al. 2007).

This study supports the concept of separate regions of movement and posture within the lumbar spine. LLx posture is not directly related with ULx posture, and knowledge about movement in one region does not provide information about movement in the other. LLx posture is consistent across a range of functional tasks, particularly in those without LBP. The importance of considering regional variance in the lumbar spine is apparent, with perhaps posture variation or lack of variation around the LLx spine being most important.

The presence of LBP appears to influence lumbar posture, particularly when the posture or movement being considered is directly linked with LBP mechanisms of an individual. Regional lumbar posture and its relationship with recurrent or future LBP episodes is the subject of ongoing prospective research.

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APPENDIX VIII - Identification of modifiable personal factors that predict LBP recurrence in female nursing students.

VIII.I. Introduction

In occupational populations, recurrent low back pain (LBP) represents a major challenge. Recurrence rates of around 80% within 12-months of original injury have been reported (Wahlgren et al. 1997). The importance of improving prevention of recurrent LBP is highlighted by the significant proportion of occupational LBP costs being attributed to exacerbation of existing LBP (Marras et al. 2007).

As the best predictor of LBP is a previous history of LBP (Feyer et al. 2000; Hestbaek et al. 2006), clearly investigating what else predicts LBP recurrence is a priority. Whilst, occupational LBP risk factors are widely reported (Burdorf and Sorock 1997), there is also some limited evidence for modifiable personal characteristics also being associated with LBP recurrence (Marras et al. 2007). It is thought that LBP risk factors interact in a cumulative manner (Cholewicki et al. 2005) and a recent review highlights the importance of considering occupational LBP recurrence as a multidimensional problem (Marras 2005).

The aim of this study was:

- To investigate whether personal social / lifestyle, psychological and physical characteristics were associated with recurrence of LBP in female nursing students.

VIII.II. Methods

This prospective study examined the influence of a range of baseline personal characteristics on recurrence of LBP in female undergraduate nursing students during a 12-month follow-up period. The same personal social / lifestyle, psychological and physical characteristics as in earlier chapters of this thesis were measured.

The sample comprised 49 nursing students who had significant LBP at baseline and completed the questionnaires during the 12-month follow-up. Of these, 19 reported no LBP or only mild LBP during follow-up. Thirty subjects reported further episodes of significant LBP during follow-up.

VIII.II.I. Statistical Analysis

Statistical analyses were performed using SPSS Version 13 (SPSS Inc., Chicago: USA). Univariate differences in social/lifestyle, psychological and physical characteristics between subjects with and without significant LBP during follow-up were tested using binomial logistic regression. Age and BMI were included as covariates. A stepwise model for independent predictors of LBP recurrence was developed. To limit the potential of identifying chance variables due to the large number of variables, three variables from each category (social/lifestyle; psychological; physical performance; spinal angles) with the lowest p-values from univariate regression analyses were tested in the model. Alpha probability was set at $p < 0.05$.

VIII.III. Results

Age and BMI were not different between groups. There were also no group differences in any of the social / lifestyle variables on univariate analysis (Table VIII.I).

VIII.III.I. Psychological measures

Of the psychological variables, only the magnification sub-scale of the Pain Catastrophising Scale was different between the groups on univariate analysis. Higher catastrophising was found in subjects reporting significant LBP during follow up (Table VIII.II).

Table VIII.I. Group comparisons of social and lifestyle factors [n (%), or median (interquartile range)].

	No/Mild LBP (n = 19)	Significant LBP (n = 30)	O.R.	95% CI	p-value
Age	23.5 ± 5.6	24.4 ± 5.1	1.03	0.93-1.16	0.555
BMI	22.4 ± 2.9	23.8 ± 3.7	2.67	0.63-11.35	0.184
Household income Below $59 000 AUD (%)	13 (72.2)	14 (48.3)	0.30	0.07-1.23	0.094
Marital status (% single)	13 (68.4)	16 (53.3)	0.98	0.29-3.28	0.971
Previous worker's compensation claim (%)	1 (5.3)	2 (6.7)	0.79	0.06-10.21	0.856
Any family member on a pension (%)	2 (10.5)	4 (13.3)	0.76	0.11-5.26	0.781
> 5 standard alcoholic drinks per week (%)	4 (21.2)	2 (6.7)	0.16	0.02-1.29	0.085
Cigarette Smokers (%)	2 (10.5)	8 (24.1)	2.80	0.48-16.47	0.225
Physical Activity					
Moderate activity (hours/week)	9.0 (18.5)	12.25 (13.4)	0.99	0.93-1.05	0.693
Vigorous activity (hours/week)	6.0 (11.0)	2.25 (9.13)	0.98	0.92-1.05	0.614
Walking (hours/week)	7.5 (15.0)	10.0 (17.25)	1.04	0.98-1.10	0.174
Sitting (hours/week)	43.5 (10.0)	39 (14.88)	1.00	0.96-1.03	0.866

Table VIII.II. Group comparisons of psychological variables [mean ± S.D, or median (interquartile range)].

	No/Mild LBP (n = 19)	**Sig. LBP (n = 30)**	**O.R.**	**95% CI**	**p-value**
DASS Total (/126)	16.0 (16.0)	17.0 (17.5)	1.02	0.97-1.07	0.458
Depression (/42)	1.0 (4.0)	2.0 (6.0)	1.08	0.92-1.27	0.388
Anxiety (/42)	4.0 (4.0)	4.0 (5.0)	0.98	0.87-1.11	0.772
Stress (/42)	10.0 (12.0)	11.0 (9.0)	1.05	0.96-1.15	0.283
Back Beliefs Questionnaire (/45)	28.2 ± 4.6	29.9 ± 6.2	1.06	0.95-1.18	0.284
Coping Scale for Adults					
Dealing with Problem (/105)	69.8 ± 16.5	69.2 ± 9.3	1.00	0.95-1.05	0.915
Non-productive coping (/105)	55.4 ± 15.6	57.9 ±14.3	1.02	0.98-1.06	0.386
Pain Catastrophising Scale (/52)	7.0 (15.0)	10 (17.75)	1.04	0.98-1.11	0.187
Rumination (/16)	3.0 (9.0)	5.0 (8.0)	1.04	0.91-1.19	0.545
Magnification (/12)	2.0 (2.0)	2.5 (3.25)	1.41	1.00-1.99	**0.048**
Helplessness (/24)	2.0 (4.0)	4.0 (7.25)	1.10	0.95-1.27	0.209

VIII.III.II. Physical measures

The difference in pelvic angle between usual standing and sway standing was the only physical variable to reach statistical significance in the univariate analysis. There was less difference in pelvic angle in subjects reporting significant LBP during follow up (Table VI.III).

Table VIII.III. Univariate group comparisons of spinal angles and physical variables adjusted for LBP history, age and body weight (mean ± standard deviation).

	No/Mild LBP (n = 19	**Significant LBP (n = 30)**	**O.R.**	**95% CI**	**p-value**
Sitting angles (°)					
Pelvic sit angle	0.9 ± 10.4	3.2 ± 10.3	0.99	0.94-1.07	0.802
LLx sit angle	2.5 ± 10.0	6.8 ± 9.5	1.04	0.97-1.11	0.245
Pelvic slump angle	-10.0 ± 9.4	-5.7 ± 8.4	1.04	0.96-1.12	0.290
LLx slump angle	-1.9 ± 8.7	4.0 ± 8.7	1.08	1.00-1.17	0.067
Pelvic sit proximity to EOR	10.8 ± 5.7	8.9 ± 6.0	0.95	0.86-1.05	0.336
LLx sit proximity to EOR (°)	4.4 ± 5.2	2.8 ± 3.9	0.92	0.80-1.06	0.260
Standing angles (°)					
Pelvic stand angle	26.2 ± 8.5	27.2 ± 7.1	1.02	0.94-1.10	0.535
LLx stand angle	23.9 ± 12.0	24.9 ± 12.1	1.01	0.96-1.06	0.708
Pelvic sway angle	21.9 ± 10.8	24.6 ± 9.5	1.03	0.97-1.10	0.341
LLx sway angle	29.2 ± 14.7	32.8 ± 13.9	1.02	0.98-1.07	0.368
Pelvic sway angle Diff	4.5 ± 2.6	2.1 ± 3.7	0.78	0.67-0.97	**0.026**
LLx sway angle Diff	5.9 ± 4.4	8.5 ± 5.5	1.10	0.97-1.26	0.144
Pelvic extension angle	16.9 ± 14.2	20.7 ± 13.7	0.98	0.94-1.02	0.327
LLx extension angle	43.6 ± 24.1	42.0 ± 21.0	1.00	0.97-1.02	0.773
Pelvic flexion angle	81.1 ± 15.0	80.0 ± 10.5	1.00	0.96-1.06	0.725
LLx flexion angle	-13.1 ± 5.8	-11.1 ± 7.4	1.04	0.95-1.14	0.354
Functional posture angles (°)					
Pelvic pen angle	66.3 ± 16.6	62.2 ± 18.2	0.98	0.94-1.02	0.259
LLx pen angle	-8.4 ± 7.2	-5.9 ± 8.2	1.05	0.97-1.14	0.256
Pelvic pen proximity to EOR	14.8 ± 21.3	17.8 ± 19.4	1.01	0.98-1.04	0.467
LLx pen proximity to EOR	4.7 ± 5.9	5.3 ± 5.3	1.03	0.92-1.16	0.605

Pelvic 5kg lift angle	58.6 ± 13.8	52.9 ± 11.5	0.95	0.90-1.01	0.081
LLx 5kg lift angle	-6.0 ± 8.4	-3.2 ± 9.8	1.04	0.97-1.11	0.298
Pelvic 5kg lift proximity EOR	22.9 ± 19.5	27.1 ± 15.0	1.02	0.99-1.05	0.370
LLx 5kg lift proximity EOR	7.1 ± 7.4	7.9 ± 6.8	1.02	0.94-1.12	0.607
Pelvic pillow transfer angle	51.0 ± 8.9	47.7 ± 7.4	0.93	0.86-1.01	0.106
LLx pillow transfer angle	3.6 ± 8.5	7.5 ± 9.8	1.05	0.98-1.12	0.161
Pelvic pillow transfer proximity to EOR	14.8 ± 21.4	17.8 ± 19.4	1.01	0.98-1.04	0.467
LLx pillow transfer proximity to EOR	16.7 ± 8.2	18.6 ± 8.2	1.03	0.96-1.11	0.376
Pelvic 5kg transfer angle	49.3 ± 8.0	46.8 ± 6.8	0.94	0.87-1.03	0.194
LLx 5kg transfer angle	9.8 ± 9.3	12.2 ± 9.6	1.03	0.97-1.10	0.324
Pelvic 5kg transfer proximity EOR	31.8 ± 13.8	33.2 ± 12.8	1.01	0.96-1.05	0.682
LLx 5kg transfer proximity EOR	22.9 ± 9.5	23.3 ± 9.0	1.01	0.95-1.08	0.718
Pelvic squat angle	56.9 ± 13.4	58.5 ± 14.1	1.00	0.96-1.05	0.897
LLx squat angle	-3.2 ± 8.3	-1.4 ± 10.6	1.03	0.96-1.10	0.388
Pelvic squat proximity EOR	24.3 ± 16.1	21.5 ± 17.3	1.00	0.97-1.04	0.861
LLx squat proximity EOR	9.8 ± 6.4	9.7 ± 9.4	1.01	0.94-1.09	0.775
Performance measures					
Squat time (seconds)	47.3 ± 23.6	35.8 ± 22.7	0.98	0.95-1.00	0.100
Sorensen time (seconds)	111.9 ±69.2	79.4 ± 47.1	1.01	0.98-1.00	0.087
LLx sit reposition error (°)	3.9 ± 2.8	2.6 ± 2.1	0.81	0.62-1.04	0.099
Predicted VO2 max (L/min)	2.4 ± 0.5	2.3 ± 0.4	0.54	0.13-2.30	0.407

LLx = Lower Lumbar, ROM = Range of Motion, EOR = End of Range flexion angle, Negative lumbar angle = lumbar flexion, Positive lumbar angle = lumbar extension, Negative pelvic angle = anterior pelvic rotation, Positive pelvic angle = posterior pelvic rotation.

VIII.III.III. Multivariate analysis

When including age and BMI as covariates, the final logistic regression model retained higher magnification score as a predictor of significant LBP during follow-up (Table VIII.IV).

Table VIII.IV. Binomial logistic regression model for predicting LBP recurrence.

	Odds Ratio[1]	**95% CI**	**p-value**
Age (yr)	1.05	0.93-1.18	0.449
BMI (kg/m^2)	3.10	0.67-14.29	0.149
Magnification	2.42	1.01-5.80	**0.048**

[1]The Odds Ratio represents the increase in the odds of having significant LBP, holding all other variables constant, for a unit increase (approximating one standard deviation) in the independent variable.

VIII.IV. Discussion

The results of this exploratory analysis showed some evidence that modifiable personal characteristics are associated with recurrence of significant LBP in this cohort of female nursing students.

Notably, higher magnification score (a sub-score of catastrophising) was the strongest psychological predictor of LBP recurrence. This is consistent with psychological factors associated with LBP chronicity (Klapow et al. 1995; Peters et al. 2005), but contrasts with psychological predictors of new-onset LBP.

Clearly the small sample size limits the findings of this analysis. However, these preliminary results suggest further research into modifiable personal characteristics that predict recurrence of LBP is required. Such research could have important implications for reducing the impact of recurrent, and possibly chronic LBP in occupational populations.

VIII.V. References

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