# Low back pain in dance: prevalence and associated factors

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**Statement of Authorship and Sources**

This thesis contains no material that has been extracted in whole or in part from a thesis that I have submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgment in the main text of the thesis. All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where required).

Christopher Swain. 21.8.2018

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# Abbreviations

| | |
|---|---|
| AL LBP | Activity limiting low back pain |
| ANOVA | Analysis of variance |
| AOR | Adjusted odds ratio |
| BMI | Body mass index |
| CI | Confidence interval |
| CV | Coefficient of variation |
| DALYS | Disability adjusted life years |
| ES | Effect size |
| HDS | Harkness discomfort scale |
| IADMS | International Association of Dance Medicine and Science |
| ICC | Intraclass correlation |
| IQR | Inter quartile range |
| LBI | Low back injury |
| LBP | Low back pain |
| LL | Lower lumbar angles |
| LOE | Level of evidence |
| LT | Lower thoracic angles |
| $\eta p2$ | Partial eta squared |
| NSAIDS | Non-steroidal anti-inflammatory drugs |
| NYU | New York University |
| OR | Odds ratio |
| PCS | Pain catastrophising scale |
| ROM | Range of motion |

SD          Standard deviation

TSK         Tampa scale of kinesiophobia

UL          Upper lumbar angles

UT          Upper thoracic angles

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# Abstract

***Introduction*** Low back pain (LBP) is a leading cause of disability worldwide. Dancers, who are often required to perform complex and repetitive movements of the spine, are thought to be vulnerable to LBP. However, there is limited available evidence concerning the prevalence, experience, impact, or factors associated with LBP in this population. Therefore, the overarching aim of this thesis was to investigate the prevalence and factors associated with LBP in dance.

***Methods*** This thesis consists of five discrete but interrelated studies. Study one systematically synthesises the available evidence for the prevalence of, and risk factors for, LBP and injury in dance populations. Studies two and three investigates the prevalence and risk factors for LBP in multiple pre-professional and professional contemporary dance and classical ballet cohorts. Lifetime prevalence of LBP is determined using a cross-sectional study design. Monthly prevalence, duration, and impact of LBP episodes are investigated prospectively. Multivariable logistic regression is used to examine for individual and demographic factors associated with LBP. Studies four and five investigate the interaction between dance, LBP, and spine kinematics. To do so, they employ three-dimensional motion analysis and a multi-segment spine marker set. Posture as well as clinical and functional movement tasks common in LBP assessment are examined in dancers and non-dancers with and without LBP.

***Results*** The systematic review supported that dancers appear vulnerable to the experience of LBP. However, due to the heterogeneous nature of available research, and an absence of multivariable statistical analysis, clarity regarding the prevalence and risk factors for LBP remains limited. The need for multi-site epidemiological studies that employ definitions sensitive to the nature of LBP and that use appropriate statistical methods to investigate

risk factors for LBP within dance populations was identified. The cross-sectional study revealed 74% of pre-professional and professional dancers had a history of LBP. Prospectively, 52% of dancers experienced activity limiting LBP and 24% suffered from LBP that was chronic in duration. Prior experience of LBP preceded the experience of future episodes of LBP (adjusted odds ratio: 3.98; 95% confidence interval: 1.44, 11.00; $p < 0.01$). There was no association between personal or demographic factors and LBP. With respect to spine kinematics, female dancers presented with a flatter upper lumbar spine posture ($p < 0.01$, $\eta p^2 = 0.15$) in the sagittal plane and increased upper lumbar ($p=0.04$, $\eta p^2=0.08$) and lower thoracic ($p=0.02$, $\eta p^2=0.09$) frontal plane range of motion than non-dancers. However, there was no interaction between these measures and LBP. During walking gait, female dancers with recent LBP displayed a moderate reduction in transverse plane ROM for the lower lumbar spine (effect size (ES)=-0.65, 95% CI: -1.24, -0.06, $p=0.03$), and a moderate increase in lower thoracic transverse plane ROM (ES=0.62, 95% CI: 0.04, 1.21, $p=0.04$) compared to asymptomatic dancers.

***Conclusion*** Dancers are vulnerable to the experience of LBP. However, there is considerable variation in the time-course and impact of LBP episodes. History of LBP predicts future episodes, which supports that LBP is rarely limited to a single episode. Beyond this, the factors associated with LBP are complex and not easily discerned. With respect to movement, an altered movement strategy during walking gait suggests that female dancers with LBP may compensate for reduced mobility in painful regions by increasing mobility in other regions. However, these movement strategies are subtle, and the overall number of biomechanical differences was limited. Whether this indicates dance training protects against biomechanical changes normally associated with LBP, or suggests dancers are intrinsically different to non-dancers requires further consideration.

# Chapter One: Introduction and overview

## 1.1. Background

### 1.1.1. Dance and injury

Dance is a physical pursuit that boasts high global popularity. For example, in Australia, it has the highest participation rate for all cultural, sporting and leisure activities amongst girls, and the second highest participation rate for male and female children combined.[1] In the United States, dance accounts for 39% of the total moderate-to-vigorous physical activity achieved by adolescent girls and 23% achieved by boys.[2] Those that participate in dance benefit from increased self-esteem and self-rated health scores,[3][4] cardiorespiratory fitness,[3] muscle size and strength,[3][5] bone mineral density,[6] as well as reduced rates of obesity,[7] depressive symptoms,[8] dementia risk,[9] and long-term illness.[7] Importantly, it is also recognised as enjoyable, a key factor in long-term physical activity maintenance.[10]

Dance can also be a physically demanding activity. Most individuals that pursue dance professionally begin training in early childhood and will participate in multiple dance styles.[11] Full-time pre-professional dance training, which is undertaken during periods of adolescent growth and maturation, is designed to replicate professional dance, and can be comprised of greater physical exposure than other adolescent athletic pursuits.[12] Professional dance is also physically demanding. Australian professional dancers typically spend more than 30 hours per week in class, rehearsal, and performance, which they often manage alongside multiple other roles within the dance industry (e.g. choreography or teaching).[11] By nature, the work entails constant repetition of complex movement and movement patterns, which has been associated with injury risk.[13-15]

Injury in dance is common. In a year-long injury surveillance study conducted within three English pre-professional ballet schools, 76% of ballet students sustained a recordable injury.[12] Each injury resulted in significant time loss (mean = 28 days/injury), up to 60% of injuries required investigation through medical imaging, and 6% required surgery, indicating that some injuries were severe.[12] In Australian professionals, including dancers from companies as well as independent dancers, injury levels were similar. Ninety-seven percent reported experiencing an injury at some point during their career, and 73% reported at least one injury in the last 12 months.[11]

The average annual health costs, including direct disbursements to health care providers as well as insurance premiums, between 1993-1998 for an American ballet company of between 58 to 68 dancers were $550,000 USD, but rose as high as $974,000 USD per annum.[16] For individual dancers, the immediate cost of injury can include loss of professional opportunity and income.[11] Injury may also carry stigmatisation within the dance community and lead to disrupted identity and emotional distress among professional dancers.[17] [18] Longer term, injuries may negatively influence an individual's lifetime physical activity, which has significant implications for their long-term health and risk of chronic illness.[19] [20]

In dance injury literature, low back pain (LBP) is often cited as one of the more prevalent musculoskeletal conditions experienced by dancers.[13] [21] However, there remains a lack of high quality injury studies within dance to confirm this,[22] as well as consensus regarding appropriate injury definitions.[23] [24] The next section will consider what is currently known about LBP, its prevalence and impact, and associated factors.

### 1.1.2. Low back pain definition and burden

Low back pain is a common health problem that can be described as an unpleasant sensory and emotional experience.[25] It is said to be a symptom, rather than an independent disease state, although, as factors associated with LBP are diverse and heterogeneous, the presence of LBP does not necessarily reveal much about its underlying causes.[26] Traditional views of pain, that it represents a reliable marker of tissue damage or disease, have been replaced with the conceptualisation of pain as a perceived need to protect body tissue.[27] Importantly, this contemporary view of pain does not eliminate the role of mechanical or biochemical factors as contributors to pain. Rather, the brain interprets information on the state of the tissues, along with other sensory and contextual information when it generates and modulates pain.[28]

Epidemiological studies demonstrate a high prevalence of LBP across diverse populations.[29] A 2012 systematic review of 165 studies from 54 countries identified a mean point prevalence of 18.3%, a one-month prevalence of 30.8%, a one-year prevalence of 38.0%, and a lifetime prevalence of 38.9%.[29] When considering activity limitation, close to one quarter (23.2%) of the global population will experience an episode of activity limitation each month, while more than one tenth (11.9%) will be experiencing activity limiting LBP at any one time.[29]

It is not surprising that LBP has been identified as the leading cause of disability worldwide.[30] In 2010 the global burden of disease, injuries, and risk factors study estimated that LBP contributed to 58.2 million disability adjusted life years (DALYs). It is the second leading contributor to Australia's disease burden, and associated DALYs increased by 45% between 1990 and 2010.[30] The annual direct costs of treating LBP are £2 billion in the United Kingdom[31] and $50 billion USD in the United States.[32] The combined direct and

indirect cost of LBP to the Australian economy was estimated to be $9 billion AUD in 2001.[33]

Dancers appear to be a population vulnerable to LBP and injury. Prospective studies in pre-professional and professional ballet have identified the lower back as either the second or third most common site of injury.[34 35] In professional ballet, these injuries collectively accounted for the third most time lost due to injury.[34] In pre-professional ballet dancers, a specific lumbar spine injury was identified as the third most severe in terms of time loss.[12] In terms of LBP, cross-sectional studies have identified the lower back as the most common site of musculoskeletal pain in professional ballet dancers,[21 36] and observed a higher prevalence in dance students than non-dance controls.[13] However, determining the precise magnitude of the problem is not straightforward, as dance injury studies have rarely used consistent definitions of pain or injury, and have more often employed cross-sectional study designs, which can be limited by recall bias and are less able to identify risk factors than prospective studies.[22-24 37]

### 1.1.3.  The experience and impact of low back pain

There is significant variation in how LBP is experienced.[38] For some, LBP can be experienced without consequence and resolves without intervention.[39] For others recovery can be slow and symptoms persistent.[39 40] A common approach used to classify LBP is based on the time course of symptoms. For example, acute LBP refers to episodes that can last between a few days to weeks, while chronic LBP lasts 12 weeks or more.[38] Epidemiological studies suggest that about 60% of LBP sufferers experience only acute LBP, while the other 40% develop chronic LBP.[26] However, it is most likely that these classifications represent an over simplification of the time course. For example, Downie,

et al.[39] followed the pain scores of 1585 patients presenting to primary care with acute LBP for 12 weeks. They identified five distinct pain trajectories: complete recovery that was either (1) rapid or (2) slow, (3) incomplete recovery, (4) persistent fluctuating symptoms, and (5) persistent high pain.[39] Recurrent pain is also commonly reported.[40]

Similar variation exists in how people behave when they experience LBP. For instance, not all people experiencing LBP will seek treatment for it, although some will do so multiple times or from numerous health professionals.[41] A meta-analysis of eight studies that reported care seeking for LBP observed that 58% of people who experienced LBP sought care.[42] Medical consultation and treatment represent the largest proportion of health-care costs for LBP.[41]

Individuals with LBP may also consume medication,[43] which is either available over the counter or via prescription.[44] A prospective study of 9544 Danish workers found 21% used over the counter and prescription medication for low back, neck, and hand/wrist pain in a single year.[45] Although medication is recognised as a component of pain management,[46] the evidence in favour of paracetamol and non-steroidal anti-inflammatory medications for the treatment of LBP is mixed,[47 48] with long-term use presenting further health risk.[49]

As with the general population, variation exists in how dancers are impacted by pain and injury. Although many dancers that experience pain or injury will seek help for it, many do not, as evidenced by lower prevalence rates in research methods that rely on a health professional to register a dance injury compared to self-report.[23] The most common reasons for not seeking help for musculoskeletal pain provided by professional dancers is the belief that pain is an inherent part of dancing, an ability to cope with the pain, and fear of consequence.[50] Given there is such variation in the experience and impact of LBP, simply providing a measure of prevalence may not adequately describe the problem.

Epidemiological studies in dance must consider both who experiences the condition as well as the impact it has on the individual.

### 1.1.4. Factors associated with low back pain

A history of LBP has consistently been identified as the greatest risk factor for future episodes.[51] This is, in part, a reflection of the transient nature of LBP. It may also indicate that people with LBP possess a range of characteristics that underlie vulnerability,[52] and that these are present even when pain is not.[53 54] Alternatively, this suggests that pain is a learned experience and past episodes of pain influence future perception.[28]

Demographic factors have also been associated with LBP, implying some populations may be more vulnerable than others.[29] Globally, LBP prevalence appears higher in females compared to males, and peaks in the fifth decade of life.[29] However, this is not always a consistent finding. A meta-analysis of LBP prevalence in children and adolescents observed no difference in LBP prevalence between males and females,[55] whereas self-reported lifetime and point prevalence were higher in males than females in a cross-sectional study of 365 adolescent rowers.[56] In adults, reported LBP prevalence was higher in British males than females for three out of four age categories in a postal survey conducted in 1987-8 (n= 2667), and for all four age categories in a separate survey conducted in 1997-8 (n= 10363).[57] There was no difference in disability due to LBP between sexes.[57]

Age appears to have sigmoidal influence on the prevalence of LBP.[29] Adults aged between 40 and 69 years old appear the most likely to report LBP, and the prevalence of LBP tends to decrease from the sixth decade.[29] This may indicate the role of potential workplace or biological factors in the aetiology of LBP. It may also suggest that people become less

vulnerable to the condition in older age. However, reports of more severe, impactful, and disabling LBP increase in people above the age of 50.[58] It may be that older adults are less impacted by, or less likely to report, more transient episodes of LBP. Yet, they remain more vulnerable to the consequences of LBP or are less likely to respond to treatment, and hence more likely to experience disability, than younger adults.[58] Children and adolescents also experience LBP.[55] Prevalence increases steadily throughout childhood and adolescence, with lifetime prevalence of LBP reaches adult levels by late adolescence.[55]

### 1.1.5. Factors associated with pain and injury in dance

In dance, previous experience of pain and injury may predict future occurrence. In prospective injury surveillance, pre-professional ballet dancers that sustained a recordable injury to any site had a significantly higher prevalence of LBP history compared to their uninjured colleagues.[59] Furthermore, a systematic review of 47 studies interested in risk factors of injury in pre-professional dance found evidence that, alongside insufficient psychological coping skills, a history of injury increases risk for future injury.[22] However, a subsequent cross-sectional study did not find evidence of other risk factors identified during pre-participation evaluations in dancers that had sustained an injury in the past year compared to dancers that had not.[60] Prospective studies are needed to confirm this relationship with respect to LBP.

There is limited evidence that demographic factors may be associated with LBP in dance.[22] A cross-sectional study of 41 individuals that participated in six or more hours of dance per week observed that dancers with LBP were significantly older, taller, and heavier than their pain free counterparts.[61] However, only univariable analysis was performed, precluding adjustment for confounding factors. As age, height, and body mass each increase in a linear

fashion throughout adolescence and early adulthood, it is unclear which of these factors was most relevant. With respect to sex, due in part to traditional gender roles in classical ballet, male dancers are thought to be more susceptible to LBP and injury than their female counterparts.[62] Indeed, common ballet lifts, which are performed exclusively by male ballet dancers, do create loads on the spine that exceed safe working limits for industry.[62] However, whether this results in a higher prevalence of LBP and injury has not yet been confirmed in epidemiological studies.[21] Confirming such a relationship may provide valuable insight into biological and workplace factors associated with LBP.

### 1.1.6. Spine movement and low back pain

Pain impacts movement.[63] In persons with LBP, a spectrum of changes ranging from subtle differences in walking gait or reduced range of motion, to more complete loss of function have been identified.[63-66] These changes are significant, as although not the sole reason why persons with LBP seek care,[41] they do represent a primary contributor to initial and repeat care-seeking behaviour.[67][68] Accordingly, evaluation and treatment of the movement system is a key component of care for patients with pain conditions.[69]

The relationship between LBP and movement is reciprocal as movement changes can be either a cause or effect of LBP.[63] For example, performing lifting tasks with a less mobile spine results in increased load placed onto the spine and prospective research has shown reduced spine mobility may precede the development of more serious first time LBP.[70][71] Similarly, as a major function of pain is protective, when a movement repeatedly generates pain, an individual may anticipate movement-related pain and establish self-protective strategies during motor preparation to avoid pain or to minimise its harmful

consequences.[72] This is evident in experimental studies that have observed a range of movement changes following nociceptive induced LBP.[73]

It is possible that movement factors are of greater importance in populations that are subjected to more complex mechanical demands of the spine.[70] Reviews have described more negative adaptation of spine structures in sporting activities that require faster, more complex end of range spine movements compared to slower paced and smaller ranged activities.[14 74] In addition, a series of experimental animal studies identified a protective paraspinal muscle response to repetitive spine motion that was more pronounced when movements were performed with a higher frequency or combined with load.[75-77] In humans, observational research has documented a decrease in spine kinematic function related to LBP in occupations required to perform repetitive, high velocity tasks in different planes of motion.[15]

There is indirect evidence that dance repertoire and training loads are related to spine pathology and LBP. The prevalence of spondylolysis, a defect caused by alternating full flexion and extension movements,[14] was five times greater in dancers from the Finnish National Ballet than in the general Finnish population.[78] In addition, spinal stress fractures sustained in ballet appear to increase with the total number of weekly dance hours,[79] as does LBP in dance students.[13] Moreover, some factors responsible for moderating spine loads appear to be reduced in contemporary dance students and classical ballet dancers with a history of LBP.[80 81] Given this, it may be reasonable to expect that differences in spine movement associated with LBP are of importance within a dance population.

Importantly, the relationship between LBP and movement is not simple.[69] While some forms of physical exposure have been associated with LBP risk, regular physical activity can also prevent or reduce the risk of developing chronic LBP.[82 83] Furthermore, both

animal and human studies describe an analgesic effect of exercise,[84] as well as an ability of specific exercise types to restore movement of joints, including spine range of motion in persons with chronic LBP.[85 86] In parallel, regular physical activity in healthy adults and athletic populations has been associated with greater pain inhibition and greater pain thresholds.[84 87] Indeed, dancers appear capable of maintaining performance despite the presence of musculoskeletal pain.[50] Moreover, qualitative studies suggest that pain is not always viewed negatively within dance, and that dancing with pain provides some validity to the charisma of the calling.[18] With respect to movement, no association between mobility of the spine in the sagittal plane and the experience of back pain was observed in dance students,[61] counter to what has been seen in non-athletic and sporting populations.[66 70 88] Additionally, a series of studies that examined muscle morphology and motor control found that, unlike non-dance populations, dancers with a history of LBP did not have reduced cross-sectional area of abdominal muscles and did not display increased spine stiffness relative to their pain free counterparts,[5 80] which may suggest dance protects against some changes often associated with LBP. Given this, it should not be assumed that movement factors related to LBP are more pronounced in dancers with LBP.

### 1.1.7. Identifying the research priorities for low back pain in dance

To develop effective prevention and management strategies for LBP in dance, good quality epidemiological data is needed. Currently, in dance, several surveillance studies report the prevalence and incidence of LBP and injury. However, dance injury epidemiology has rarely employed consistent definitions of pain or injury, making interpretation difficult.[23] [24] Moreover, injury surveillance studies within dance have rarely focused solely on the lower back region and more commonly employ cross-sectional study designs that, although

of value, are less suited to the complexities of LBP than prospective studies.[22] [37] Furthermore, as there is considerable variation in the impact of LBP, epidemiological studies need to consider not just who experiences LBP, but also the impact it has on dance participation, and health behaviour.

Prevention and management also requires insight into factors that may increase risk for LBP. Outside of dance populations, history of LBP has consistently been identified as a significant risk factor for LBP.[51] While injury history has been, to some extent, associated with future injury in dance,[22] this has not yet been confirmed with LBP. Age and sex have been associated with LBP vulnerability in the global population,[29] and determining the extent to which these patterns exist within dance would provide valuable insight into biological and workplace factors that may contribute to LBP risk.

Spine movement is often changed in people with LBP, and these changes may either precede first time LBP or contribute to the recurrence of symptoms.[63] While there is evidence that changes in spine function are closely related to more complex occupational tasks,[15] which has direct implications for dance, it is also true that regular physical activity can protect against the development of LBP and is frequently used to restore movement and function.[69] [82] [85] There is a lack of consistent evidence on this issue in dance. Some studies describe a relationship between dance workloads and repertoire and either spine pathology or LBP.[13] [78] [79] Other studies suggest that physical measures able to discriminate between non-dancers with and without LBP are less able to do so within dance.[5] [61] [80] By clarifying this issue in dance, there is potential to improve assessment and treatment of LBP.

**1.2. Research Aims**

The overarching aim of this thesis was to investigate the prevalence and impact of LBP in dance and the associated factors. To achieve this, the following research objectives were identified:

1. To describe and evaluate the available evidence for the prevalence of, and risk factors for, LBP and injury in dance populations.

2. To prospectively determine the prevalence and impact of LBP in a sample of pre-professional and professional dancers.

3. To examine risk factors for LBP in a sample of pre-professional and professional dancers.

4. To investigate the relationship between dance practice, spine movement, and LBP in a sample of pre-professional and professional dancers.

**1.3. Scope, significance, and intended outcomes**

This thesis incorporates and builds on knowledge found in epidemiological and biomechanical research on LBP both inside and outside of dance. This body of work will produce new information concerning a common health problem in a potentially vulnerable population. A greater understanding of the magnitude, variation, and multi-dimensional impact of LBP within a highly specialised population allows for better-informed prevention and intervention strategies. Confirmation of the presence or relative absence of LBP symptoms and impact in dance may provide insight into risk or protective factors for LBP, which will have benefits beyond dance.

## 1.4. Thesis overview

The PhD research is presented as a thesis including published works consisting of seven chapters.

Chapter Two addresses research aim one. It contains study one, which systematically reviews and synthesises the epidemiology on LBP and injury in dance populations. It identifies knowledge gaps concerning the prevalence and incidence of LBP and injury in dance, as well as the associated risk factors. Recommendations for LBP epidemiology in dance are made.

Chapter Three provides information on the conceptual framework and methodological approach used in the subsequent studies of this thesis.

Chapter Four addresses aims two and three and contains two studies. Study two is a cross-sectional study that investigates the lifetime and point prevalence, as well as potential personal and demographic factors associated with LBP prevalence in a sample of pre-professional and professional dancers. Study three prospectively investigates the prevalence, impact, and risk factors for LBP in pre-professional and professional dancers.

Chapter Five addresses aim four and contains one study. Study four analyses spine posture, range of motion (ROM) and movement asymmetry and the experience of LBP in dancers and non-dance controls.

Chapter Six addresses aim four and contains one study. Study five compares frontal and transverse plane spine ROM in dancers with and without recent LBP in two clinical movement tasks and walking gait.

Chapter Seven, the discussion and conclusion, integrates the significant findings of the whole thesis, identifies the strengths and limitations of the research, and highlights future directions.

# Chapter Two: Literature review

## 2.1. Overview of Chapter Two

Chapter One provided an introduction and overview of LBP, with a focus on areas pertinent to dance. It was acknowledged that dancers appear vulnerable to LBP,[21 36] and that personal and demographic factors may increase the risk of LBP.[29 61] However, while numerous studies have commented on this vulnerability, epidemiological studies in dance have often employed heterogeneous definitions of injury that may not be sensitive to the experience of pain,[23 24] and clarity regarding the magnitude of LBP within dance is lacking. In addition, it is unclear what level of evidence exists to support the association between various risk factors and LBP and injury in dance. Therefore, a systematic review of the literature was performed to review and synthesise the epidemiology on LBP and injury in dance populations.

Study one was performed in accordance with the Preferred Reporting Items for Systematic Review and Meta Analyses statement.[89] Prior to commencement, the methods were developed and registered in PROSPERO. The literature search for study one was initially performed in June 2017, which was updated 12 months later. However, to better reflect the sequence of research, the authors' own work (studies two and three from Chapter Four) have not been included in the review. The manuscript for study one has been published in the Journal of Orthopaedic and Sports Physical Therapy:

Swain, C.T.V., Bradshaw, E.J., Ekegren, C. L., et al. The epidemiology of low back pain and injury in dance: a systematic review. ID: 07-18-8609-LR.

## 2.2. Study 1: The epidemiology of low back pain and injury in dance: A systematic review

### 2.2.1. Abstract

***Introduction*** Dance is a physical pursuit that involves loading the spine through repetitive dynamic movements and lifting tasks. As such, low back pain (LBP) and low back injury (LBI) have been identified as common health problems within contemporary dance and classical ballet populations. However, clarity regarding the experience of LBP and LBI in dance is lacking. The purpose of this study was to systematically review and synthesize the epidemiology on LBP and LBI in dance populations.

***Methods*** A comprehensive search of six electronic databases, back catalogues of dance science specific journals, reference lists of relevant articles, and a forward citation search were performed.

***Results*** Forty-eight full text articles were included in the final review. There was considerable methodological heterogeneity amongst the included studies. The median (range) point, yearly, and lifetime prevalence of LBP was 30% (23 – 39%), 70% (41 – 82%), and 37% (17 – 88%) respectively. The lower back contributed to 11% (4 – 22%) of time loss and 11% (5 – 23%) of medical attention injuries.

***Conclusion*** Dancers are vulnerable to LBP and injury. The use of definitions that are sensitive to the complexity of LBP and LBI would facilitate improved understanding of the problem within dance, would inform healthcare strategies, and allow for monitoring of LBP specific intervention outcomes.

### 2.2.2. Introduction

Dance is a physical pursuit that boasts high global popularity. In Australia, it has the highest participation rate for all cultural, sporting and leisure activities amongst girls, and the second highest participation rate for male and female children combined.[1] In the United States, dance is estimated to account for 39% of the total moderate-to-vigorous physical activity achieved by adolescent girls and 23% achieved by adolescent boys.[2] The physically demanding nature of dance has been well documented. Students from pre-professional ballet schools in the United Kingdom complete more training hours than commonly reported by other adolescent athlete populations.[12] Australian professionals, including both company and independent dancers, typically complete in excess of 30 dance hours per week in class, rehearsal, and performance, which they often manage alongside multiple other roles within the dance industry.[11] Moreover, it has been established that dancers are vulnerable to a high degree of musculoskeletal pain and injury,[22 90 91] a significant proportion of which includes pain and injury in the lower back.[36]

Cross-sectional studies have documented high prevalence rates of low back pain (LBP) in professional ballet dancers.[21 36] Furthermore, LBP and low back injury (LBI) have been identified as a common and often severe cause of time loss injury in both pre-professional and professional dancers.[12 34] This problem has been attributed to the unique and highly physical movement demands of dance.[92 93] Indeed, spinal pathologies such as spondylolysis, a defect caused by alternating full flexion and extension movements,[14] are more common in ballet dancers than the general population.[78] Further, the incidence of spine stress fractures in professional ballet dancers appears to increase with dance hours completed.[79]

Due to the heterogeneous injury definitions and reporting methods used in dance-injury surveillance studies,[22 24 94] and the complexities of assessing pain and chronic injury outcomes,[37] determining the extent to which LBP and LBI are a problem in dance is not straightforward. Therefore, to advance the understanding of LBP and LBI in dance, the primary aim of this review was to systematically assess the available evidence on the prevalence and incidence of LBP and LBI in pre-professional and professional dance populations. A secondary aim was to identify any risk factors in these populations for LBP and LBI.

### 2.2.3. Methods

This systematic review is structured in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[89] The review was registered via PROSPERO (ID: CRD42017073428) prior to commencement.

*Search strategy*

A systematic review of the literature was performed to identify peer-reviewed articles examining the epidemiology and risk factors of LBP and LBI in dance students and professionals. Relevant publications were identified through systematic searches of the following six electronic databases up until June 25th, 2018: MEDLINE, SPORTDiscus, Web of Science, EMBASE, CINAHL and the ProQuest Performing Arts Periodicals Database. The search strategy included a combination of controlled vocabulary (e.g. Medical Subject Headings of the National Library of Medicine) and free text terms (**Table 2.1**). In addition, the Online Dance Medicine and Science bibliography, back catalogues of dance specific journals including the (Journal of Dance Medicine and Science and Medical Problems of Performing Artists), and reference lists from comprehensive reviews and

identified studies were hand-searched for possible references not otherwise found. Forward citation searching via Google Scholar was also performed. The search was limited to those articles published in English, but no date limits for publication were set.

**Table 2.1. Example of electronic search strategy used for each online database**

| Data Source | Search Strategy | Number of Hits |
|---|---|---|
| Medline Complete (EBSCO) | 1. Dancing (MeSH) OR Danc* OR Ballet | 13850 |
| | 2. Back pain (MeSH) OR Low back pain (MeSH) OR Spinal Injuries (MeSH) OR Athletic injuries (MeSH) OR Wounds and Injuries (MeSH) OR Back ache OR Lumbar pain OR Spin* pain OR Lumbago OR Sports Injur* | 142841 |
| | 3. 1 AND 2 | 377 |
| | 4. Limit to English Language | 330 |

*Inclusion/ exclusion criteria*

Cohort, case-control, or cross-sectional studies were included if they examined the prevalence and incidence of LBP and/or LBI in dancers, or risk factors for LBP/ LBI in dancers, and met all subsequent inclusion criteria. Studies of both sexes including children of all ages participating in a structured dance programme, as well as adults dancing either at a tertiary or professional level were eligible, but to control for current exposure, studies with only retired dancers were not. To ensure consistency in the type of physical exposure, dance styles including ballet, contemporary, modern, and dance theatre or similar were eligible, whereas other forms of artistic dance (e.g. Irish dancing, Salsa, break dancing or hip hop), or social forms of dance (e.g. weddings and parties) were excluded. All possible

definitions of pain and injury were considered (e.g. presence of any complaint, medical consult, disabling/ time-loss) and duration (e.g. acute, chronic). However, the studies had to clearly report outcomes for the low back or lumbar spine region. As such, studies reporting pain and injury to the 'back', 'spine', or 'lumbopelvic region' were excluded. A risk factor was defined as any pre-existing factor that may increase the potential for LBP or LBI in dancers, which was identified through a prospective research design. Studies investigating factors associated with LBP/ LBI cross-sectionally, that were unable to describe whether the risk factor preceded the episode of pain were excluded from this component of the review. Studies that reported risk factors for injury but did not delineate the site of the injury were also excluded.

*Data extraction and risk of bias assessment*

Two reviewers (CS & EB) independently checked the titles and/or abstracts of all studies returned by the search results. Studies that were clearly not relevant were excluded. The full texts of all subsequent studies were assessed to determine if the selection criteria were met. Any disagreement between review authors was resolved through discussion. Data extraction and risk of bias assessment were performed by two reviewers (CS & DW) using a standardised, pre-piloted form. Extracted information included: study details (authors, year, country, design, duration), participant information (dance style, level, sex, age, sample size), definition of pain/injury used, collection methods, LBP/ LBI estimates (prevalence, incidence, etc.), exposure variables (i.e. risk factors), reported significance of associations between risk factors and LBP/ LBI, and risk factors not significantly associated with LBP/ LBI. The risk of bias (ROB) assessment was performed using the risk of bias in prevalence studies tool (**Appendix B**). This tool contains 10 items that address external validity (selection and non-response bias) and internal validity (measurement and analysis

bias).[95] Risk of bias assessment was performed in relation to the assessment and reporting of LBP and LBI outcomes.

## 2.2.4. Results

A summary of the results of the literature search is presented in **Figure 2.1**. The literature search returned a total of 4119 articles. Following duplication removal, and a review of titles and abstracts, 146 full texts were screened, with 98 subsequently excluded. Forty-eight studies were included in the final review.
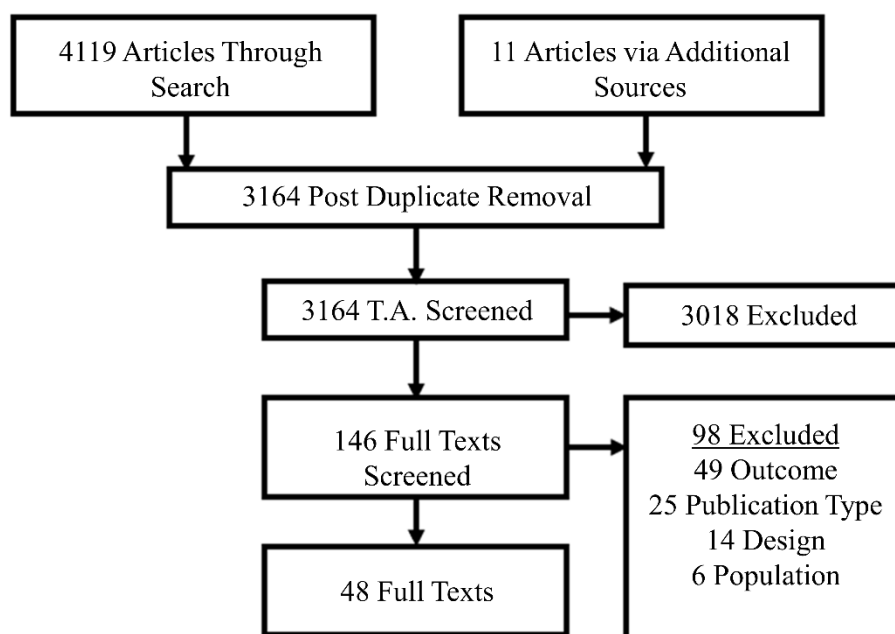


**Figure 2.1. PRISMA Chart**

T.A = Title and abstract

*Description of the studies*

Of the studies included in this systematic review, 21 were cross-sectional in design, 19 were retrospective, and 8 were prospective. Thirty studies presented data collected from a

single cohort or single medical centre, and 18 included multiple cohorts. Ballet was the predominant style for 31 studies, contemporary or modern for six studies, musical theatre for two, and either a combination or non-exclusive style was featured in nine studies. Twenty-two studies featured exclusively professionals, 17 featured non-professionals, and nine had a mix of professional and non-professional dancers. Descriptive data extracted from the included studies are represented in **Tables 2.2** and **2.3**.

*Risk of bias*

The median ROB score was 4.5/10. Four studies were judged to have a low risk of bias (deemed as ≤ 3/10), which equated to 8% of the studies included in the final review. Studies with a low risk of bias commonly incorporated a tool with established reliability and validity to measure pain or injury (ROB Item 7), provided an adequate anatomical description of the low back (ROB Item 6), and obtained a sample that was judged to reflect a national dance population (ROB Item 1).

**Table 2.2. Prevalence of low back pain in dance**

| Authors, Year | Study type (duration) | LOE | ROB | Country | Cohort description | N (% female) | Age [years] mean ± SD (range) | Definition of LBP | Collection methods | LBP prevalence estimates (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Drężewska and Śliwiński [96], 2012 | Cross-sectional | IV | 6.5 | Poland | 1 ballet school | 71 (63) | 16.5 (15-18) | Pain measured via visual analogue scale | Self-report | Period unclear: 62 |
| Gamboa, et al. [59], 2008 | Prospective (LBP acquired cross-sectionally) | IV | 4 | USA | 1 ballet school | 359 (80) *prevalence data available for n=198. | 14.7 ± 1.9 | 'Subjective history with specific focus on LBP' | Part of medical history pre-screening | Lifetime: 33 |
| Grego Muniz de Araújo, et al. [97], 2013 | Cross-sectional | IV | 2 | Brazil | 1 dance festival. Ballet and other. Professional and other. | 163 (77) | 28.7 ± 9.8 | Nordic musculoskeletal questionnaire | Self-report | Last 7 days: All: 39 F: 39 M: 38 |
| Liederbach, et al. [98], 1997 | Cross-sectional | IV | 6 | USA | Schools and companies. Classically trained. | 947 (65) | (18-35) | 'A history of chronic or recurrent LBP' | Self-report | History of chronic/ recurrent LBP: All dancers: 17 Dancers w/ scoliosis: 23 |
| Nunes, et al. [99], 2002 | Cross-sectional | IV | 6 | Canada | 2 dance studios. Young dance students. | 31 (100) | | Pain identified on a body chart. | Self-report | Last month: 8.3 |
| Ramel and Moritz [21] | Cross-sectional | IV | 1 | Sweden | 3 ballet companies | 128 (59) | F: 27 (18-43) M: 28 (17-47) | Nordic musculoskeletal questionnaire | Self-report | Past 12 months: 70  Time loss in last 12 months: 25  Past 7 days: 27 |
| Ramel, et al. [36], 1999 | Cross-sectional | IV | 2 | Sweden | 3 ballet companies | 51 (67) | 32 (28-37) | Nordic musculoskeletal questionnaire  Major injury defined as one that stopped dance for more than one month | Self-report | Past 12 months: 82  Time loss in last 12 months: 33  Past 7 days: 37 |

| Study | Design | LOE | ROB | Country | Population | n (%) | Age | LBP definition | Measurement | Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Major LB injury history: 19.6 |
| Roussel, et al. [100], 2009 | Prospective (LBP acquired cross-sectionally) | IV | 4 | Belgium | 1 pre-professional dance programme | 32 (81) | 20 ± 2 | Unspecified. | | History: 63 |
| Roussel, et al. [101], 2013 | Cross-sectional | IV | 4 | Belgium | 1 pre-professional dance programme | 40 (95) | 20.3 ± 2.4 (17-26) | LBP for at least 2 consecutive days. | | Past 12 months: 41 |
| Seitsalo, et al. [78], 1997 | Cross-sectional | IV | 4.5 | Finland | 1 ballet company | 60 (58) *prevalence data available for n=50. | 28 (21-43) | Any LBP. Lumbago Sciatic pain. Non-specific LBP. | Self-report | History: Any LBP: 88 Lumbago: 12 Sciatic Pain: 10 Past 12 months: 76 |
| Thomas and Tarr [102] | Cross-sectional | IV | 5.5 | UK | Student, professional, retired, and other. Predominantly contemporary dancers. | 204 (86) | | Pain (subjective) Injury: participation impact. | Questionnaires and semi-structured narrative interviews | 'Recent' LBP 29.9 Current LB Injury: 8.3 Past LB Injury: 32.4 |
| Wojcik and Siatkowski [103], 2015 | Cross-sectional | IV | 2.5 | Poland | Ballet students at the primary, junior high, and high school level. | 237 (Sex distribution not reported). | Primary: 11.2 ± 0.8 Junior: 14.0 ± 0.8 High:17.0 ±0.8 | Pain: a numeric rating scale | Self-report | Pain 'Now' All: 23.2 Primary: 12.5 Junior: 16.1 High: 46.9 Pain 'Before' All: 36.7 Primary: 18.8 Junior: 33.3 High: 64.1 |

LBP = Low Back Pain; LOE = Level of evidence. ROB = Risk of bias.

**Table 2.3. Low back pain and injury in dance**

| Authors, Year | Study type (duration) | LOE | ROB | Country | Cohort description | N (% Female) | Age [years] mean ± SD (range) | Definition of LBI | Collection methods | LBI estimates |
|---|---|---|---|---|---|---|---|---|---|---|
| Allen, et al. [34], 2012 | Prospective (1 year) | II | 3.5 | UK | 1 professional ballet company | 52 (49) *Injury analysis for 50 dancers only | F: 25 ± 6 M: 23 ± 5 | Time loss | Physiotherapist | Incidence (n, %) All: 47, 13.2 F: 26, 15.1 M: 21, 11.5<br><br>Incidence (/1000 dance hrs) F: 0.63 M: 0.55 |
| Baker, et al. [104], 2010 | Cross-Sectional/Retrospective (9.5 months) | III-b | 5.5 | UK | 1 contemporary dance school (first years) | 57 (83) | F: 20 ± 2.5 M: 21 ± 3 | Time loss | Self-report and physical therapist records | Incidence (n, %) All: (6, 8.6) F: (3, 5.4) M: (3, 21.4)<br><br>Physiotherapist recorded: All: (9, 14.3) F: (8, 15.4) M: (1, 9.1) |
| Berlet, et al. [105], 2002 | Prospective (7 months) | II | 5.5 | USA | 1 ballet company | 13 (62) | F: 26.89 ± 2.98 M: 28.83 ± 3.31 | Time loss/ medical attention grading | Self-report | Prevalence (%) All: 15% F: 25% M: 0% |
| Bowerman, et al. [35], 2014 | Prospective (6 months) | II | 5.5 | Australia | 1 ballet school | 46 (65)<br><br>Four dropouts (1 F, 3 M). | 16 +/- 1.58 | Time loss | Physiotherapist | Incidence (n, %) 13, 22.0<br><br>Incidence (/1000 dance exposures) 0.78<br><br>Incidence (/1000 dance hours) 0.53 |
| Byhring and Bo [106], 2002 | Prospective (19 weeks) | II | 4.5 | Norway | 1 ballet company | 41 (66) | F: 26 +/- 5.7 M: 27 +/- 4.6 | Combined time loss/ medical attention | Physiotherapist | Incidence (%) ~7.5-8.5 |
| Caine, et al. [107], 2016 | Cross sectional- | III-2 | 3.5 | Canada | 1 ballet school | 71 (62) | F: 16.41 M: 17.37 | Time loss | Self-report | Incidence (n, %) All: 4, 3.5 |

| Study | Design | Level | Score | Country | Setting | N (%) | Age | Injury definition | Data source | Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | retrospective (8.5 months) | | | | | | All: (11 – 23) | | | F: 2, 2.8 M: 2, 4.7 |
| Costa, et al. [108], 2016 | Cross-sectional | III-2 | 5 | Brazil | 2 professional ballet companies and controls | 53 (59) [57 controls] | F: 34.2 ± 6.3 M: 34.1 ± 7.3 | Injuries. Regardless of time loss/ medical attention. | Self-report | Prevalence (%) Dancers: All: 22.6 F: 6.5 M: 45.5 Controls: 5.3 |
| DiPasquale, et al. [109], 2015 | Prospective (four-months) | II | 6.5 | USA | 1 modern dance university programme (non-audition based) | 46 (89) | 19.61 +/-1.31 | Time loss | Self-report | Incidence n (%) 5, 10.9 |
| Ekegren, et al. [12], 2014 | Prospective (one academic year) | II | 3.5 | UK | 3 ballet schools | 266 (58) | 17.2 +/- 1.21 (15-23) | Time loss | Physiotherapists | Incidence (n, %) 36, 9.5 |
| Evans, et al. [110], 1998 | Cross-sectional | III-b | 3.5 | UK | Multiple west end productions | 58 (64) | F: 25.8 +/- 5.4 M 25.0 +/-5.4 | Injuries. Regardless of time loss/ medical attention. | Self-report | Prevalence (%) 18.5 |
| Fulton, et al. [111], 2014 | Retrospective (three years) | III-b | 4.5 | USA | Summer dance intensive. Modern and other styles. Recreational to professional. | 321 that sought care | (12 to (approx.) 50) | Medical attention | Clinic records | Incidence (n, %) 41, 10 (years 2-3, year 1 not provided). |
| Garrick [112], 1986 | Retrospective (five year) | III-b | 5 | USA | 1 sports medicine clinic. Primarily treats professional and preprofessional ballet dancers. | 1055 Injuries treated | No age restrictions. | Medical attention | Physician/ Sports medicine clinic records | Incidence (n, %) ~63, 6 [95 (9) involved the spine. Two thirds were the lumbar spine.] |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Garrick and Requa [113], 1993 | Retrospective (three years) | III-b | 5 | USA | 1 professional ballet company | ~70 contracted dancers and 12 apprentices<br><br>~200 students covered for injuries sustained during performances/ rehearsals with the company. | | Medical expenses | Insurance documents and medical records. | Incidence (n, %) 71, 23 |
| Garrick and Requa [114], 1997 | Retrospective (17 years) | III-b | 3.5 | USA | 1 sports medicine clinic with medical responsibilities for 2 professional companies and 1 pre-professional ballet school. | 3960 injuries treated. (75) | | Medical attention | Physician/ Sports medicine clinic records | Incidence (n, %) All: 293, 7.4 F: 200, 6.5 M: 93, 10.6 |
| Garrick [115], 1999 | Retrospective (two years) | III-b | 4 | USA | 1 ballet school | 59 | (13-18) | Medical attention | Clinic records | Incidence (n, %) 9, 4.6 |
| Klemp and Learmonth [116], 1984 | Retrospective (10 years) | III-b | 4 | Sth Africa | 1 ballet company | 47 (64) | 27.8 yrs (19-47) | Injuries. Regardless of time loss/ medical attention. | Workers compensation records | Incidence (n, %)<br><br>Ligament injuries: 6, 8.5<br><br>Tendon injuries: Nil<br><br>Muscle injuries: Not possible to discern. |
| Krasnow, et al. [117], 1999 | Cross-sectional | IV | 5.5 | Canada | Females from modern, ballet, and gymnastics. | 65 (100) 35 dancers, 30 gymnasts | $15.5 \pm 0.5$ (12-18) | Injuries. Regardless of time loss/ medical attention. | Self-report | Incidence (%) Ballet: 12 Modern: 21 Gymnast: 18 |
| Leanderson, et al. [118], 2011 | Retrospective (7 years) | III-b | 4 | Sweden | 1 ballet school. | 476 (62) | (10-21) | Medical attention | Medical records | Incidence (n, %) F 23 (5.3) |

| Study | Design | Level | Score | Country | Population | n (%) | Age | Injury definition | Data source | Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | M 22 (5.1)<br><br>[of LBP diagnosis of all injuries] |
| Nilsson, et al. [119], 2001 | Retrospective/ Prospective (5 years) | II – III-b | 4.5 | Sweden | 1 ballet company | 98 (51) | 28.3 (17-47) | Medical attention | Physician records | Incidence (n, %) All: 60, 15 |
| Quirk [92], 1983 | Retrospective (15 years) | III-b | 6 | Australia | 1 professional ballet company and a ballet school | 664 (71) | Not available | Medical attention | Physician records. | Incidence (n, %) 180, 8.5 |
| Ramkumar, et al. [93], 2016 | Retrospective (10 years) | III-b | 4.5 | USA | 1 professional ballet company | 153 (53) | 27.5 | Combined time loss/ medical diagnosis | Workers compensation and physician diagnosis | Incidence (n, %) 117, 20 |
| Rovere, et al. [120], 1983 | Retrospective (9 months) | III-b | 4 | USA | Ballet and modern dancers from 1 tertiary dance programme | 218 (74) | Not provided | Medical attention | Physician records | Incidence (n, %) 43, 12.2 |
| Shah, et al. [121], 2012 | Cross sectional | IV | 3.5 | USA | National survey of professional modern dancers | 184 (73) | 30.1 ± 7.3 (18-55) | Time loss | Self-report | Incidence (n, %) 40, 17 |
| Sobrino, et al. [122], 2015 Sobrino and Guillen [123], 2017 | Retrospective (5 years) | III-b | 4.5 | Spain | 4 professional ballet and contemporary ballet companies. | 145 (52) | All: 25.8 ± 5.7 F: 26.3 ± 5.9 M: 25.2 ± 5.4 | Medical attention | Insurance records | Incidence (n, %) 49, 13.4 |
| Solomon and Micheli [124], 1986 | Cross-sectional | IV | 5 | USA | Multiple modern dance companies. | 164 (77) | 26.15 +/- 6.43 (16-48) | 'Debilitating' Injuries. Regardless of time loss/ medical attention. | Self-report | Incidence (n, %) All: 45, 15.3 Cunningham: 9, 14.3 Graham: 10, 16.3 Horton: 8, 21.6 Humphrey-Weidman: 2, 6.1 Limon 16, 15.4 *Some injuries were counted* |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *more than once if a dancer studied multiple dance styles* |
| Solomon, et al. [125], 1995 Solomon, et al. [126], 1996 Solomon, et al. [16], 1999 | Retrospective-Prospective (5 years) | II - IIIb | 3.5 | USA | 1 ballet company | Year 1: 70 (57) Year 2: 60 (Not reported) Year 3: 60 Year 4: 60 Year 5: 59 | All: (17 – 35) | Reported injury that may or may not have required medical attention. | Company records | Incidence (n, %) Yr 1: 12, 8 Yr 2: 12, 8.4 Yr 3: 13, 13 5 yr Average: 14, 12 |
| Stracciolini, et al. [127], 2015 Yin, et al. [128], 2016 | Retrospective (9 years) | III-b | 4.5 | USA | 1 sports medicine clinic. Paediatric dancers. | 181 (95) 171 (100) | 14.8 ± 2 | Medical attention | Random sampling of medical charts of a sports medicine clinic. | Incidence (%) 11.5 11.7 |
| Wanke, et al. [129], 2012 | Retrospective (17 years) | III-b | 3.5 | Germany | 6 professional ballet companies and one state ballet school | Occupational accidents: 291 (63) | All: 30.1 F: 29.5 M: 30.8 | Time loss injuries attributed to dance floors. | Work accident reports | Incidence (%) F: 4.2 M: 14.1 |
| Wanke, et al. [130], 2012 | Cross-sectional | IV | 5 | Germany | 1 musical theatre school | 37 (46) | All: 21.3 ± 2.2 F: 21.1 ± 2.2 M: 21.5 ± 2.2 | Injuries. Regardless of time loss/ medical attention. | Self-report | Incidence (n, %) All: 12, 13.2 Acute: 3, 6.1 Chronic: 9, 21.4 |
| Wanke, et al. [131], 2013 | Retrospective (17 years) | III-b | 3.5 | Germany | 3 ballet companies | Occupational accidents: 745 (48) | All: 28.7 ± 5.3 F: 28.9 ± 5.2 M: 28.5 ± 5.4 | Time loss | Work accident reports | Incidence (%) All: 8.5 F: 9.8 M: 17.3 |
| Wanke, et al. [132], 2014 | Retrospective (2 years 17 years apart). | III-b | 3.5 | Germany | 3 ballet companies | Occupational accidents: 241 (46) | 1994/95: All: 28.0 F 28.3 M 27.7 2011/12: All: 29.5 F: 29.5 M: 29.5 | Time loss | Work accident reports | Incidence (%) 1994/95: 5.8 2011/12: 20.3 |
| Washington [133], 1978 | Cross-sectional | IV | 7 | USA/ international | International survey of dancers as well as medical and support staff. | Not reported | Not reported | Injuries. Regardless of time loss/ medical attention. | Self-report | Incidence (n, %) Individual reports: 52, 12 Group reports: 81, 6 |

LBI = Low Back Injury; LOE = Level of evidence. ROB = Risk of bias.

*Prevalence of low back pain*

Twelve studies [21 36 59 78 96-103] that reported LBP prevalence met the inclusion criteria for this review. All of these were cross-sectional in design. Multiple tools and LBP definitions were used. Five studies reported point prevalence as 'pain now',[103] 'recent pain',[102] or pain experienced in the last seven days.[21 36 97] These studies reported a median (range) prevalence of 30% (23 to 39%). Four studies reported LBP experienced for a full calendar year.[21 36 78 101] These studies had a median (range) prevalence of 73% (41 to 82%) for any LBP, and 29% (25 to 33%) for LBP that was associated with activity limitation or disability. The lifetime history reported by five studies ranged between 17 and 88% and had a median value of 37%.[59 78 98 100 103]

*Prevalence of low back injury*

Five studies reported the prevalence of LBI in dancers.[36 102 105 108 110] These used a range of designs, definitions, and time periods. The point prevalence of LBI that limited participation was 8% in a single study of predominately professional contemporary dancers.[102] During a seven-month season, 25% of professional female dancers and 0% of male dancers experienced a LBI, although this was based on a sample of 13 dancers (eight female).[105] Nineteen percent of West-End performers (theatre district in Central London) reported experiencing a LBI during their current production, albeit with varied time periods of each production.[110] History of LBI in professional contemporary and ballet dancers was reported by two studies and history of major LBI (causing more than one month away from dance) was reported by one. These values were 23%,[108] 32%,[102] and 20%,[36] respectively.

*Incidence of low back injury*

Only two studies reported incidence of LBI using a dance exposure or dance hour denominator. Incidences of 0.78 per 1000 dance exposures and 0.53 per 1000 dance hours

were observed in ballet students.[35] Reported incidence in professional ballet dancers was 0.63 and 0.55 per 1000 dance hours in females and males, respectively.[34]

*Low back pain and injury as a percentage of all injuries experienced by dancers*

Thirty-three studies reported the percentage of all injuries sustained by dancers that were to the lower back. Of these, 11 studies (12 estimates) used a time or activity loss definition,[12 34 35 93 104 106 107 121 129 131 132] 16 studies (12 estimates) used a medical attention or medical cost definition,[16 92 111-115 118-120 122 123 125-128] and six used a definition that was not dependent on time loss or medical attention.[109 116 117 124 130 133] The median percentage (range) was 11% (4 to 22%) for studies that used a time loss definition, 11% (5 to 23%) for studies that used a medical attention definition, and 12% (6 to 21%) for studies defined injury using separate criteria.

The percentage of all injuries accounted for by the lower back was higher in studies that used exclusively professional cohorts than pre-professional cohorts. In pre-professional dancers, the median percentage (range) was 10% (4 to 22%) in studies using a time loss definition,[12 35 104 107] and 8% (5 to 12%) in studies applying a medical attention injury definition.[115 118 120 127 128] In professionals, the median (range) was higher at 13% (6 to 20%) for time loss definitions,[34 93 106 121 131 132] and 14% (12 to 23%) for medical attention definitions.[16 113 119 122 123 125 126]

*Risk factors for LBP and injury*

No studies assessed risk for LBP and adjusted for confounding variables. Included studies performed only univariable analysis and lacked consistency in reporting the significance of associations between risk factors and LBP, or delineated LBP and injury outcomes based on a potential risk factor but did not perform statistical analysis on these variables.

Fifteen studies examined sex as a risk factor for LBP and LBI, or delineated outcomes based on sex (**table 2.4**).[21 34 78 97 104 107 108 114 122 123 125 126 129-131] No sex-related differences were reported in eight studies. [21 78 97 107 122 123 125 126 130] One study observed a higher percentage of self-reported and lower percentage of physiotherapy reported low back injuries in male dancers compared to female.[104] Four injury studies observed that male dancers experienced a greater percentage of injuries to the low back than female dancers.[108 114 129 131] One study observed a higher incidence of LBI in female dancers, although significance was not reported.[34]

Additional exploration of risk factors included age and anthropometric data (e.g. height, body mass). The prevalence of LBP or proportion of LBI increased as the age of dancers increased in three studies.[96 103 114] Higher prevalence of LBP history was observed in dancers with scoliosis, although statistical analysis was not performed.[98] A body mass index (BMI) lower than 18.5 was associated with higher risk of LBP in one study.[96]

**Table 2.4. Low back pain and low back injury and sex in dance**

| Authors, year | Observation | Reported Significance | Confounders controlled for |
|---|---|---|---|
| Allen, et al. [34], 2012 | M < F (11.5% vs 15.1%; 0.55/1000 dance hours vs 0.63/1000 dance hours). | Not reported. | No |
| Baker, et al. [104], 2010 | Self-report: M > F (21.4% vs 5.1%)<br>Physiotherapist records: M < F (9.1% vs 15.4%) | Not reported. | No |
| Caine, et al. [107], 2016 | M = F (2.8% vs 4.7%) | Not reported | No |
| Costa, et al. [108], 2016 | M > F (45.5% vs 6.5%) | p < 0.01 | No |
| Garrick and Requa [114], 1997 | M > F (10.6% vs 6.5%) | Not reported | No |
| Grego Muniz de Araújo, et al. [97], 2013 | M = F (39% vs 38%) | Not reported | No |
| Ramel and Moritz [21], 1994 | M = F. Delineated values not presented. | 'No significant difference in pain locations in men vs women' P-Value not reported. | No |
| Seitsalo, et al. [78], 1997 | Spondylolysis prevalence: M = F (40% vs 26%) | P = 0.08 | No |
| Sobrino, et al. [122] Sobrino and Guillen [123], 2015, 2017 | M = F (24% vs 25%) | Not reported | No<br>No |

| | | | |
|---|---|---|---|
| Solomon, et al. [125] Solomon, et al. [126], 1995, 1996 | M = F (9% vs 10%) | Not reported | No |
| Wanke, et al. [130], 2012 | M = F. Delineated values not reported. | "No statistically significant gender (sic) differences in the location of acute injuries were found." P-Value not reported. | No |
| Wanke, et al. [129], 2012 | M > F (14.1% vs 4.2%) | P = 0.02 | No |
| Wanke, et al. [131], 2013 | M > F (17.3% vs 9.8%) | "Significant gender (sic) specific differences were observed in the spine region … particularly with the more than twice affected lumbar spine in male dancers". P-Value not reported. | No |

LBP = Low back pain; M = Male; F = Female

### 2.2.5. Discussion

*Findings*

The purpose of this systematic review was to synthesize the epidemiology on LBP and LBI in pre-professional and professional dance populations. The median point (30%), yearly (73%) and lifetime (37%) prevalence of LBP observed in dancers were similar or above rates that have been previously reported in the global population (18%, 48%, and 49%, respectively),[29] and in a meta-analysis of sub-elite through to elite participants in Olympic sports (24%, 55%, and 61%, respectively).[134] These findings must be interpreted with caution, as significant methodological heterogeneity was present amongst the included studies. Specifically, there were inconsistencies in targeted populations, sex balance, study designs, time periods, anatomical definitions, and statistical reporting (highlighted by higher median yearly prevalence than lifetime prevalence). Regardless, the results of this systematic review do provide confirmation that dancers are vulnerable to the experience of LBP.

Comparisons between studies that report LBP and those that report LBI is difficult. LBP studies used prevalence statistics more frequently than injury studies that most often presented the frequency of LBI as a percentage of all injuries experienced by dancers. Nonetheless, studies included in the review indicated that approximately 73% of dancers will experience at least one episode of LBP each year; however, the lower back will only be identified as the cause of time loss or medical attention for 11% of cases. This disparity may be indicative of two realities. First, dancers experience many injuries at sites that do not include the lower back,[22] which in effect may lower the relative contribution of LBI to the total injury count. Second, the impact of an episode of LBP will often fall short of a

time loss threshold,[21][36] and many dancers may be able to maintain a high level of performance even in the presence of pain.[50] In this respect, traditional definitions of injury are only capable of providing a partial overview of the problem. This finding is consistent with recent observations in both sport and dance populations. For example, in a sample of volleyball players, although a time loss injury definition described a low injury risk, self-report revealed a high prevalence of pain.[37] In dance, compared to self-report, a medical attention and/ or time loss definition registered by a health professional underestimated the burden of dance injuries.[23]

Consistent with previous reviews of pain and injury in dance,[22][90][91] significant heterogeneity of definitions amongst the studies included was observed. For example, for time loss injuries, collection methods included self-report,[104][121] as well as health professional registration[12][34][35][104][129][131][132] and the minimum threshold for registration included activity modification or partial absence,[35][104][106][107][121] complete absence for at least one day,[12][34][93] or time limiting incident without a threshold defined.[129][131][132] Furthermore, the interpretation of severity varied between studies that used a time loss definition. For instance, Bowerman, et al. [35] used three levels to classify injury severity in pre-professional ballet students: 1) modified class, 2) off class for up to 3 days, 3) off class for more than 3 days. In contrast, in professional ballet dancers, Allen, et al. [34] categorised injuries as transient (return within 7 days), mild (return within 7 to 28 days), moderate (return within 29 to 84 days), and severe (return after 84 days).

A second aim of the review was to identify risk factors for LBP and LBI. Overall, there were few studies that deliberately focused on risk factors for LBP and LBI in a dance population. Consequently, no studies included in this review performed multivariable analysis, which allows adjustment for confounding variables. The prevalence of LBP and percentage of all injuries located in the lower back appeared to increase with age and dance

level.[96 103 114] As a relationship with age and dance level may provide important information about biological or workplace factors that contribute to LBP and injury in a dance population, multivariable statistical analyses is needed to confirm a significant relationship between age, years of training, or dance level and LBP. There was mixed information describing sex as a risk factor and, again, multivariable analysis is needed. Previously, it has been suggested that male dancers may be more vulnerable to LBP and LBI, due in part, to the lifting demands required of men in ballet.[62] While this still may be the case, both males and females from ballet and contemporary dance are exposed to a variety of physical factors beyond lifting that may increase risk of LBP and LBI. In addition, it is important to acknowledge that as well as physical factors, biological and psychosocial factors contribute to the initiation, maintenance, and perception of pain,[69] and these factors are pertinent to both males and females.

*Recommendations*

Definitions that are sensitive to the nature of LBP in dance are needed. This is not simple. Pain is a subjective experience that fluctuates within and between individuals.[38 135] It need not be associated with identifiable tissue damage to be valid,[25 136 137] and although the impact can be severe, many dancers who experience pain are able to maintain their ability to perform.[50] Given this, the injury definition endorsed by the International Association of Dance Medicine and Science (IADMS), which considers injury as an anatomic tissue-level impairment as diagnosed by a health care practitioner that results in full time loss from activity for one or more days beyond the day of onset,[24] may not be best suited for determining the prevalence of LBP. However, an initial intent of the measurement of the IADMS definition was to encourage the standardisation of measurement of risk factors and injury reporting,[24] which the current review endorses. To achieve this in LBP epidemiology, Dionne, et al.[138] proposed a minimal definition ('In the past 4 weeks, have

you had pain in your low back?') that should be combined with a minimum severity criterion ('was this pain bad enough to limit your usual activities for more than one day'). Where possible, a description of the lower back area ('the posterior aspect of the body from the lower margin of the 12th ribs to the lower gluteal folds') should accompany this definition.[138] In sports medicine, the Oslo Sports Trauma Research Center questionnaire has been identified as a sensitive and valid tool capable of documenting patterns of injury and illness in athletic populations,[139] and has also been proposed as a suitable tool for dance epidemiology.[23] These tools, either on their own or in combination with other measures, may be of value.

As a key function of surveillance is to assess the effectiveness of an intervention,[140] outcomes that are specific to the site of pain and injury are needed. For the lower back, prevalence, which refers to the proportion of the population with the condition at a given time,[141] should be used.[37] Due, in part, to high childhood and adolescent prevalence of LBP,[55] as well as the recurrent nature of LBP and LBI,[40 142] the incidence of first time or new episodes of LBP is often difficult to determine. Furthermore, reporting the percentage of all injuries experienced by a cohort located in the lower back area may be influenced by the total number of other injuries, as well as multiple injuries experienced by a single dancer at the same site, meaning this outcome has less value for assessing outcomes of site-specific interventions.

Multi-site studies are needed to reduce risk of bias, increase the external validity of individual studies, and to obtain statistical power appropriate for multivariable analysis. There is a distinction between asking what the problem is in dance and asking the same question in a single dance company or school. Single site studies may be more sensitive to site specific effects (e.g. dance style and repertoire, touring, dance floors, injury reporting cultures, etc). In addition, as dance schools and companies are composed of highly

specialised populations, they are limited in numbers of potential participants. Multi-site studies are more likely to recruit and retain a sufficient number of participants to facilitate multivariable statistical analysis, allowing more valid conclusions. Furthermore, as LBP symptoms are prevalent in non-dance populations,[29][55] including control groups in future studies will allow researchers to determine what proportion of LBP symptoms observed can be attributed to dance participation or how the experience of LBP in dancers is unique.

Finally, prospective studies that investigate LBP are needed. No prospective investigations of LBP prevalence were found in the literature search. Compared to cross-sectional studies, prospective study designs minimise recall bias, allow for improved examination of risk factors, and are more able to provide information on the duration and impact of LBP symptoms.

*Limitations*

To limit the focus and clarity of the review, studies that reported results that were not specific to the lower back or lumbar spine, or studies that used general language to describe the site of injury were not included. As such, some studies investigating 'back' pain or injuries in dancers were not eligible for inclusion.[13] Furthermore, inclusion criteria were limited to peer review. Although this is a strength of the study, several national reports were subsequently excluded (e.g. Safe Dance reports I-IV).[11][143-145] It is also possible that relevant studies were not included due to the English language restriction and search terminology employed. Finally, due to the range of definitions used, a meta-analysis of reported data was not possible.

**2.2.6. Conclusion**

Low back pain and injury are common within dance and in line with levels observed in athletic populations. Multisite prospective cohort studies that employ definitions suitable to capture LBP and LBI, with outcomes clearly reported, would enable improved comparison with non-dance populations. It would also facilitate improved identification of risk factors to better identify dancers who may need injury prevention or pain management strategies, inform dance appropriate clinical management, and allow for monitoring of low back specific interventions within dance.

# Chapter Three: Methodology and design

## 3.1. Chapter Three overview

Chapter One established the need to obtain information on the prevalence, impact, and risk factors for LBP in dance as a research priority. Chapter Two systematically reviewed the available epidemiological evidence for the prevalence, incidence and risk factors for LBP and injury in dance. Chapter Three provides information on the conceptual framework and methodological approach used in this thesis. A rationale and detailed description of the specific methods used, which is presented at a level that allows replication, is presented in the subsequent studies. As such, the content contained within Chapter Three exists as a supplement to the subsequent studies.

## 3.2. Conceptual framework

The World Health Organisation's approach to public health includes a four-step model for investigating the causes of conditions and preventing their occurrence (**Figure 3.1**).[146] Step one aims to define the problem through the systematic collection of information about the magnitude, scope, characteristics and consequences. Step two aims to establish causes and correlates for health problems, as well as the factors that could be modified through intervention. Step three aims to determine the effective preventative strategies by designing, implementing and evaluating interventions. Step four concerns the implementation and ongoing evaluation of these strategies.[146] This approach has been adapted by sports medicine and underlies many current preventative initiatives within the field.[37 140] The principles of the approach present a useful framework for the investigation of LBP in dance.
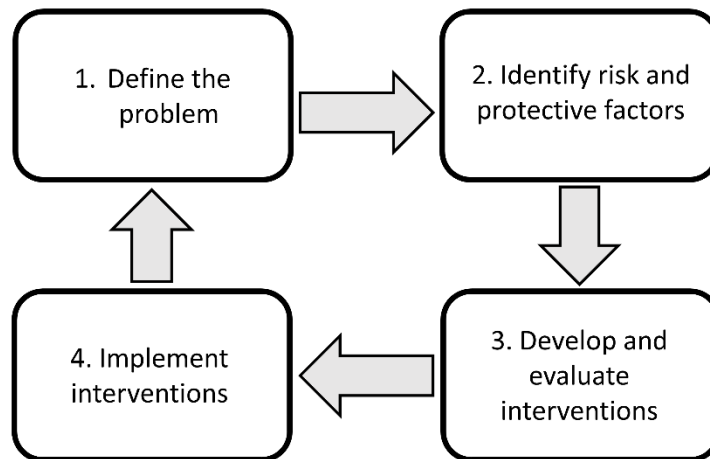
**Figure 3.1. The public health approach.** Adapted from World Health Organisation, 2018.[146]

This thesis specifically addresses steps one and two of the public health model. Research aims one (describe and evaluate the available epidemiological evidence for LBP and injury in dance populations) and two (determine the prevalence and impact of LBP in dance) were devised to collect new information concerning the magnitude, characteristics and consequences of LBP in dance. Research aims three (to examine risk factors for LBP in dance) and four (to investigate the relationship between dance practice, spine movement, and LBP in dance) were developed to establish a greater understanding of causes and correlates for LBP in dance.

### 3.3. Research design

The research design of studies two and three in Chapter Four was informed by dance medicine, sports injury, and LBP literature.[22 29 55 95 147] Both cross-sectional and prospective approaches are used to obtain new information regarding the experience of LBP in dance. The cross-sectional approach in study two facilitated collection of new information regarding the magnitude (i.e. lifetime and point prevalence) and associated factors (personal and demographic factors) of LBP in dance. The prospective approach in study three facilitated collection of new information related to the magnitude (prevalence), characteristics (e.g. pain duration, intensity), consequences (e.g. activity limitation, care-seeking, and medication use), and risk factors (e.g. personal factors) of LBP in dance. Content from the initial and monthly questionnaires are presented in **Appendix C** and **Appendix D**. Information concerning the development and sourcing of specific content, as well as the distribution of the questionnaires is presented in sections **4.2.3** and **4.3.3**. Additional discussion concerning the psychometric properties of the questionnaires is presented in section **4.4.5**.

The collective aim of studies four and five in Chapters five and six is to provide the new information regarding the interaction of dance, spine biomechanics, and LBP. The research design of these studies was informed by spine biomechanics commentary,[14 26] a prior systematic review of LBP and spine kinematics investigation,[66] as well as additional investigations of spine kinematics in athletic and LBP populations.[88 148-152] To provide a complete description of LBP, multi-dimensional information on the LBP experience was collected. This included information on the LBP experience, perceived triggers of LBP,[56] and assessment of factors that may predict LBP outcomes,[41 153] or influence of kinematic changes on pain.[154 155] As study five was completed at The Harkness Center for Dance Injuries, New York, the selection of instruments was also influenced by current practice at

the Harkness Center and NYU Health. These items are outlined in sections **5.2.3** and **6.2.3** and presented in **Appendix E** (study four) and **Appendix F** (study five).

To quantify spine kinematics, optoelectric motion capture was used. These systems are highly sensitive, non-invasive, and capable of capturing movement during fundamental static tasks as well as more complex dynamic movements.[150 151 156] This method provides an indirect measure of spine movement, using reflective landmark markers placed onto the skin. The method displays a high level of agreement with radiological investigation techniques,[157-159] and several previous investigations, including analysis of spine movement, have demonstrated acceptable test-retest reliability on the same day and different occassions.[149 151 160] The setup and calibration methods of the motion capture systems used in studies four and five followed manufacturer guidelines.[161 162]

A multi-segment spine marker set was used to model the upper and lower thoracic as well as the upper and lower lumbar spine segments. A previous version of this marker set was first used to investigate lumbar spine kinematics in studies with nurses, as well as elite female gymnasts.[163 164] The marker set was subsequently expanded to include the thoracic spine segments for investigation of sit to stand performance and walking gait in patients with chronic LBP.[148 149] Based on the description of the marker set provided by Christe, et al.,[149] a bespoke Visual 3D model was developed. Further rationale and outline of the advantages of this marker set is provided in section **6.2.2**. A detailed description of the marker set is provided in sections **5.2.3** and **6.2.3**.

Movement tasks and kinematic variables assessed included postural assessment, maximum range of motion (ROM), and movement asymmetry (study four), as well as maximum ROM and ROM during walking gait (study five). These assessments were selected based on: (i) their previous association with LBP in non-dance populations,[64-66 70 88 148 150 151] (ii) their

potential influence on the distribution and magnitude of spinal loads,[14 26 71] and (iii) previous findings in dance medicine literature that indicate these measures may be either unique or pertinent in dancers.[5 61 80 165] A detailed rationale for these assessments is provided in section **5.2.2** and **6.2.2**. A detailed description of the assessment procedures is presented in sections **5.2.3** and **6.2.3**, as well as **Appendix G**.


### 3.4. Sampling procedure

The sampling procedure in this thesis was guided by recommendations from study one, the Risk of Bias in Prevalence Studies Tool (**Appendix B**),[95] as well as additional systematic reviews of LBP epidemiological and kinematic investigations.[29 55 66] To obtain a sample that was representative of the national dance population for studies two and three in Chapter Four, five dance schools, five universities or tertiary dance programmes, and nine companies from Australia and New Zealand were contacted regarding research participation. Of the cohorts contacted, two dance schools, two universities and one company provided permission for their dancers to be approached. To achieve a census, all dancers from participating cohorts were invited to participate. A representative sample from one dance school was not achieved (less than 15% response rate), and this school was subsequently excluded from the studies.

For studies two through five, to ensure the sampling frame was representative of the target population, pre-professional dance schools and universities were recruited from cohorts that had audition-based selection of students and an established history of producing professional dancers. In studies four and five, the selection criteria also allowed for participation of recent dance graduates and professionals dancers from small companies as well as the independent dance sector. Dance style was limited to contemporary dance and

classical ballet to ensure consistency in loading patterns, without restricting the potential sample size.

For study four, the inclusion criteria for dancers with and without LBP was adapted and modified from a prior study of spine kinematics in tennis players.[88] The modifications made included removing tennis specific criteria (LBP aggravated by tennis serving), limiting the time-period for LBP to 12-months (compared to 15-months), and removing the need for radiological identified damage, as this information was not available and is not necessary for pain to be valid.[25] In addition, informed by results from study three, treatment was considered to include both care-seeking and medication use. For study five, the inclusion criteria for the LBP group was limited to dancers that had experienced LBP with reported impact on their dance practice in the last two-months. The reasons for this distinction include preliminary results from study four (as noted in section **6.1**) and preference of Harkness Center and NYU Langone Health clinical professionals.

### 3.5. Data analysis

For research aim two, which is addressed in studies two and three, prevalence is used to describe the proportion of dancers with LBP relative to the total number of dancers participating. The use of prevalence, rather than incidence, is consistent with recommendations from study two, reviews from sports medicine,[37] and current practice in the LBP literature.[29] The calculation of prevalence is outlined in sections **4.2.3** and **4.4.3**.

For research aim three, which is addressed in studies two and three, multivariable logistic regression was used to examine factors that may be associated with LBP. Multivariable logistic regression is well suited for describing and testing relationships between a categorical outcome variable and multiple predictor variables.[166] As it allows for control

and adjustment of confounding variables, this analysis complies with recommendations from study one, as well as reviews in the dance medicine and LBP literature.[22][82]

For research aim four, which is addressed in studies four and five, statistical tests that examine a difference in group means were used. This is consistent with prior kinematic investigations of LBP and multi-segment spine kinematics in both athletic and non-athletic populations.[88][148] As study four examined the effect of two independent variables (dance and LBP) on one dependent variable (spine kinematics), two-way ANOVA analysis was used. As study five examined the effect of one independent variable (LBP) on one dependent variable (spine kinematics), independent t-tests were used. In addition, to provide an indication of the magnitude of an effect, effect size statistics are also reported.[167] By nature, a multi-segment spine marker set requires multiple analyses, which can increase the likelihood of a type I error.[168] As such, the use of a Bonferroni correction was considered within the research group and discussed with a statistical consultant. However, as a Bonferroni correction increases the likelihood of a type II error,[168] this adjustment was not employed. Rather, as per the recommendations of Feise,[168] the magnitude of effect and comparison of findings from other studies was used to balance statistical significance results.

# Chapter Four: Prevalence and risk factors for low back pain in dance

## 4.1. Overview of Chapter Four

The systematic review presented in Chapter Two supports that dancers appear vulnerable to the experience of LBP. However, due to the heterogeneous nature of available research, and an absence of multivariable statistical analysis, clarity regarding the prevalence and risk factors for LBP remains limited. As such, new data is required to confirm the prevalence of LBP in dance, and to describe the experience of LBP in terms of severity, chronicity, and impact. Furthermore, investigation of risk factors that controls for confounding factors is needed. Chapter Four focusses on the second and third aims of this thesis, which are to determine the prevalence and impact of LBP and to examine risk factors for LBP in dance. It contains studies two and three.

Study two uses a cross-sectional design to examine the lifetime and point prevalence of LBP in a sample of pre-professional and professional dancers, as well as multivariable logistic regression to examine the association between individual and demographic factors and LBP. It adheres to each item on the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement.[169] The manuscript containing study two been published as:

Swain, C. T. V., Bradshaw, E. J., Whyte, D. G., et al. Life history and point prevalence of low back pain in pre-professional and professional dancers. *Phys Ther Sport* 2017;25:34-38.

## 4.2. Study 2: Life history and point prevalence of low back pain in pre-professional and professional dancers

### 4.2.1. Abstract

*Introduction* Although LBP is often cited as a common condition amongst dancers, limited information exists regarding the extent to which it is experienced in this population. The purpose of this study was to investigate lifetime history and point prevalence of low back pain (LBP) in pre-professional and professional dancers and to identify any demographic or physical factors associated with LBP in dancers.

*Methods* Lifetime and point prevalence of LBP were investigated cross-sectionally. Participants included male and female classical ballet and contemporary dancers aged 12 years old and above. They were recruited from one pre-professional ballet school, two pre-professional university dance programs, and a professional nationally touring ballet company. Multivariable logistic regression was used to examine potential risk factors for LBP.

*Results* A total of 110 (n=19 male) dancers (mean (SD) 17.8 (2.9) years old) participated in the study, which represented 50% of the population invited to participate. A 74% lifetime prevalence of LBP was reported by dancers. Point and 12-month prevalence were 24 and 64%, respectively. No significant association was observed between LBP and any demographic or physical variables.

*Conclusion* Pre-professional and professional dancers have an increased vulnerability to LBP. The development of LBP within this population is complex and may not be associated with individual factors measured in this study.

### 4.2.2. Introduction

Low back pain (LBP) is a common and potentially disabling condition that creates significant personal, social and economic loss.[30] Populations engaged in daily activities that require prolonged cyclic spine movements are reported to be the most vulnerable to the development of LBP.[170] When these movements are performed with repetition, at high velocities, in multiple planes of motion, and when handling heavy loads, the risk of developing LBP increases significantly.[15,75] Dance is a physically demanding pursuit that involves complex spine movements performed with high repetition, at varying velocities, and as a component of intense training programmes. Therefore, LBP is often cited as one of the most common musculoskeletal conditions among dancers. However, this information is largely anecdotal, with very little data existing to demonstrate that such a relationship between dance and LBP actually exists.

A number of previous studies have demonstrated that low back injuries commonly occur in dance. Large injury surveillance studies have identified the low back as the third or fourth most common site of injury in pre-professional and professional dance,[34,59] and self-reported data from professional dancers indicate the low back as the second most common site of chronic injury.[143] Low back injuries often result in a prolonged time away from dance. Indeed, specific lumbar injuries, such as disc injuries, facet joint dysfunction and nerve root pathologies, require the third longest time for dancers to return to full activity,[12,34] indicating the impact on practice is significant. However, these studies have all employed injury definitions that overlook pain and thus likely underestimate the problem. There have been few attempts to quantify the prevalence of LBP in dance. Prior investigations into musculoskeletal pain reported between 70%[21] and 82%[36] of professional ballet dancers had experienced some form of low back pain in the previous 12 months. A retrospective study

of dance students found that 49% of female and 59% of male dancers reported at least one prior episode of back pain during their lifetime,[13] although the study employed broad definitions of both 'back pain' and 'dancer'. A more recent study noted that 62% of ballet students reported some form of lumbosacral pain, however it was unclear what time period this represented.[96]

To help mitigate the risk of LBP in dancers, demographic or physical factors that may be associated with increased LBP need to be identified. For instance, due to traditional gender roles and subsequent lifting demands associated with ballet, it has been suggested that male dancers are particularly prone to LBP.[62] However, this has not yet been confirmed in epidemiological studies. Outside of dance, higher LBP prevalence has been more commonly seen in females rather than males.[29] The relationship between age and LBP risk in dance also requires further investigation. Due to early commencement of training and specialisation, many dance students are required to sustain high levels of physical exposure during periods of growth and maturation, which may further increase LBP vulnerability. Studies have shown that injury incidence in dance students increases as training progresses,[12 118] and LBP risk may also increase with age.[29 55 147] Confirming any such relationship would be of undoubted clinical value.

The risk of LBP in dance is perceived to be high; however, there is a lack of data regarding the prevalence of LBP in dancers. The purpose of this study was to determine the lifetime and point prevalence of LBP within pre-professional and professional dance settings, using accepted definitions of LBP,[138] and to identify any demographic or physical factors associated with LBP lifetime and point prevalence.

### 4.2.3. Methods

Using a cross-sectional design, male and female contemporary and classical ballet dancers and dance students aged 12 years and over were recruited from a pre-professional ballet school, two pre-professional university dance programs, and a professional nationally touring ballet company. Based on curriculum outlines, weekly dance activity was estimated to begin at 13-18.5 hours, for school students depending on year level, and to be around 24 hours for university students. These estimations do not account for performances, extra-curricular classes, workshops and supplemental training that are available to students. Prior to participation, all volunteers were provided with information about the study and given the opportunity to ask questions before providing written informed consent/ assent, as well as parental consent when required. Ethical approval was granted by the Australian Catholic University Human Research Ethics Committee (2015-187H).

Participants completed a single online questionnaire (Qualtrics) that was developed using recommendations from LBP, sport medicine, adolescent, and dance injury literature. To determine lifetime history of LBP, participants were asked "have you ever experienced pain in your lower back?", which was accompanied by a diagram of the posterior aspect of the body and highlighted the region between the lower margin of the 12th ribs and the gluteal folds.[138] Participants who had previously experienced an episode of LBP were then asked when they last experienced LBP (currently experiencing LBP, within the last 3 months, within the last 12 months or more than 1 year ago). In addition, the questionnaire contained items concerning descriptive data (age, height, body mass) and dance background (age started dancing) and from these, BMI and years dancing were calculated. For females, questions on menstrual function were included (have you had a period, how old were you when you first had a period, how many periods have you had in the last 12 months, are you

currently taking female hormones).[171] Further, for dance school participants aged below 18 years, Tanner scales were used to assess maturation. However, following discussion with participating cohorts, questions concerning menstrual function and maturation were made optional. The online collection methods allowed participants to complete the questionnaires anonymously and in their own time, minimising social pressure, or discomfort. The initial questionnaire is presented in **Appendix C**.

The sample was described using frequencies and percentages for categorical variables and means (standard deviation) for continuous variables. Univariable associations between demographic, physical and dance factors and LBP lifetime and point prevalence were examined using chi-square and t-tests for the entire sample and for females separately (to account for unique variables collected in females only). Multivariable logistic regression was used to determine demographic and physical variables with predictive value for LBP experience (including lifetime and point prevalence) for the entire sample, as well as females separately. Variables that showed significant association following univariable analyses ($p<0.25$), as well as likely confounding variables, age and gender, were entered into the model. A backward stepwise approach was planned whereby non-significant variables were removed from the model individually ($p<0.05$) and the reduced model compared with the initial model using likelihood ratio tests.[166] The resulting odds ratios (ORs) and associated 95% confidence intervals (CIs) were reported. Allowing for a minimum of 10 participants for each of the eight covariables relevant to all participants, an expected lifetime prevalence of LBP of 50-60% (which is above the prevalence observed in the global population[29] and similar to values previously observed in dancers[13]), a sample size of 160 to 200 was required for sufficient statistical power.[172] All statistical analysis was performed using SPSS software for Windows (version 22.0, SPSS Inc., Chicago, IL, USA).

### 4.2.4. Results

In total, 91 female (mean (SD) age, 17.9 (2.6) years) and 19 male (17.1 (3.7) years) dancers agreed to participate in the study, which represented 48% of the invited population. Participants had a mean (SD) BMI of 20 (2.6) and had commenced dancing at 7.9 (4.8) years of age. Descriptive data are presented in **Table 4.1**. Of the dancers who participated in this study, 73.6% (n=81) indicated they had a history of LBP, 23.6% (n=26) were currently experiencing LBP, while 46.4% (n=51) and 63.6% (n=70) had experienced at least one episode in the last three and 12 months, respectively.

Factors with significant univariable associations with lifetime prevalence were entered into the lifetime prevalence multivariable model. These included sex, age, height and body mass for the entire sample, and menarche age and use of oral contraceptive for the female sample. Factors with significant univariable associations entered into the point prevalence multivariable model included cohort type (school, university or company), age, body mass, BMI and years dancing for the entire sample, and period commenced (yes/no) for the female sample. Following multivariable analyses (**Tables 4.2 and 4.3**), no variables were found to be significantly associated with LBP in dancers.

**Table 4.1. Participant descriptive data.** Results are reported as mean (standard deviation) for continuous variables and frequencies (percentage) for categorical variables.

| Population descriptor | Female (n=91) | Male (n=19) |
|---|---|---|
| Age (years) | 17.9 (2.6) | 17.1 (3.7) |
| Height (cm) | 165.1 (7.5) † | 175.2 (9.8) ‡ |
| Body Mass (kg) | 54.1 (8.5) † | 65.1 (13.3) ‡ |
| BMI (kg/m²) | 19.8 (2.4) † | 21 (3.1) ‡ |
| Age Started Dancing (years) | 7.6 (4.7) ‡ | 9.3 (4.8) |
| Years Dancing (years) | 10.4 (5) ‡ | 7.8 (6.2) |
| Period Commenced n (%) | 69 (84) ‖ | - |
| Age of Menarche (years) | 13.4 (1.5) § | - |
| Number of periods in the last 12 months | 10.4 (2.5) ‖ | - |
| Taking Oral Contraceptive n (%) | 32 (40) § | - |

† Data missing for n = 6 cases; ‡ Data missing for n = 2 cases; § Data missing for n = 10 cases; ‖ Data missing for n = 9 cases; BMI, body mass index

**Table 4.2. Identified associations with low back pain from univariable and multivariable analysis**

| Population Descriptor | Point Prevalence | | | | Lifetime History | | | |
|---|---|---|---|---|---|---|---|---|
| | Univariable Analysis | | Multivariable Analysis | | Univariable Analysis | | Multivariable Analysis | |
| | Mean(SD)/ n (%) | P | AOR (95% CI) | P | Mean(SD)/ n(%) | P | AOR (95% CI) | p |
| Age (years) | 18.9 (2.3) | **0.14** | 1.06 (0.76,1.48) | 0.71 | 17.86 (2.7) | 0.85 | 1.11 (0.91,1.40) | 0.31 |
| Male n(%) | 3 (15.8) | | 1.00 (ref) | | 15 (78.9) | | 1.00 (ref) | |
| Female n(%) | 23 (25.3) | 0.35 | 1.20 (0.19,7.69) | 0.85 | 66 (72.5) | 0.66 | 1.18 (0.26,5.39) | 0.83 |
| Height (cm) | 167.2 (8.6) | 0.84 | | | 167.8 (8.5) | **0.06** | 0.97 (0.89,1.06) | 0.48 |
| Body Mass (kg) | 58.9 (9.2) | **0.09** | 1.02 (0.92,1.13) | 0.71 | 56.9 (10.5) | **0.14** | 0.97 (0.90,1.10) | 0.49 |
| BMI (kg/m²) | 21 (2.6) | **0.03** | .79 (0.55,1.15) | 0.26 | 20.1 (2.6) | 0.50 | | |
| *Cohort type* | | | | | | | | |
| School n (%) | 2 (6.1) | **0.02** | 1.00 (ref) | 0.60 | 22 (66.7) | 0.60 | | |
| University n (%) | 19 (31.2) | | 3.31 (0.22,57.29) | 0.41 | 47 (77.1) | | | |
| Company n (%) | 5 (31.3) | | 0.99 (0.21,4.84) | 0.99 | 12 (75) | | | |
| *Dance background* | | | | | | | | |
| Age Started Dancing (years) | 7.5 (5.6) | 0.64 | | | 8 (5) | 0.76 | | |
| Years Dancing (years) | 11.4 (5.8) | **0.11** | 0.94 (0.85,1.05) | 0.30 | 9.9 (5.3) | 0.92 | | |

AOR, Adjusted odds ratio; CI, confidence interval; BMI, body mass index; Bold indicates $p<0.25$

**Table 4.3. Identified associations with low back pain from univariable and multivariable analysis for female dancers**

| Population Descriptor | Point Prevalence | | | | Lifetime History | | | |
|---|---|---|---|---|---|---|---|---|
| | Univariable Analysis | | Multivariable Analysis | | Univariable Analysis | | Multivariable Analysis | |
| | Mean(SD)/ n (%) | p | AOR (95% CI) | P | Mean(SD)/ n (%) | P | AOR (95% CI) | p |
| Age (years) | 18.7(2.1) | **0.14** | 1.00(0.68,1.48) | 0.99 | 18.1(2.5) | 0.52 | 1.16(0.82,1.65) | 0.41 |
| Height (cm) | 166.2(8.1) | 0.48 | | | 166.3(7.4) | **0.02** | 0.92(0.80,1.06) | 0.23 |
| Body Mass (kg) | 56.5(5.7) | **0.08** | 1.02(0.9,1.15) | 0.78 | 55.1(8.6) | **0.07** | 0.91(0.76,1.09) | 0.29 |
| BMI (kg/m²) | 20.3(1.9) | **0.22** | 0.96(0.63,1.45) | 0.85 | 19.9(2.4) | 0.51 | | |
| *Cohort type* | | | | | | | | |
| School n (%) | 2(8.7) | **0.12** | 1.00 (ref) | 0.80 | 14(60.9) | 0.39 | | |
| University n (%) | 16(30.2) | | 2.20(0.09,55.53) | 0.63 | 41(77.4) | | | |
| Company n (%) | 5(33.3) | | 0.90(0.17,4.79) | 0.91 | 11(73.3) | | | |
| *Dance background* | | | | | | | | |
| Age Started Dancing (years) | 7.3(5.3) | 0.75 | | | 7.6(4.9) | 0.88 | | |
| Years Dancing (years) | 11.4(5.4) | 0.29 | 0.95(0.84,1.07) | 0.40 | 10.6(5.0) | 0.58 | | |
| *Menstrual function* | | | | | | | | |
| Commencement of Period n (%) | 20(87) | **0.11** | 0.53(0.04,7.86) | 0.64 | 54(81.8) | **0.20** | 1 | |
| Age of Menarche (years) | 13.6(1.4) | 0.63 | | | 13.3(1.5) | **0.20** | 1.24(0.79,1.96) | 0.35 |
| Number of periods in the last 12 months | 10.3(2.6) | 0.82 | | | 10.6(2.5) | 0.27 | | |
| Taking Oral Contraceptive n (%) | 10(43.5) | 0.75 | | | 28(42) | **0.12** | 0.64(0.14,2.85) | 0.56 |

AOR, Adjusted odds ratio; CI, confidence interval; BMI, body mass index; Bold indicates p<0.25

### 4.2.5. Discussion

The aim of this study was to determine past history as well as present status of LBP in pre-professional and professional dancers from both classical ballet and contemporary dance settings. High lifetime history (73.6%), 12-month prevalence (63.6%), and point prevalence (23.6%) were reported by dancers. The proportion of dancers who reported LBP in the past 12 months was similar to the levels previously reported in professional Swedish ballet dancers (70%)[21] but lower than levels observed in a subsequent follow up (82%).[36] Both LBP in the past 12 months and lifetime history were notably higher than previously observed in Australian dance students (38% and 52% respectively).[13] However, the dance students in the prior study did report higher lifetime history than aged matched controls, as well as an increased risk when more than 30 hours of physical activity per week were devoted to dance.[13] Similarly, a 62% prevalence of lumbosacral pain was reported by ballet students,[96] however, it is unclear what point in time this represents or what, if any, cut-off scores were used to classify those with LBP, making meaningful comparison with the current study difficult.

Both lifetime history and point prevalence were greater in the current study than those calculated in a large meta-analysis of LBP prevalence in children and adolescents (39.9% history and 12% point prevalence),[55] as well the mean prevalence reported in a systematic review of the global population (38.9% lifetime and 18.3% point prevalence).[29] Furthermore, the prevalence of LBP reported in the current study was above levels previously seen in university level [173 174] and elite athletic populations,[147 175-177] although history and point prevalence were notably lower than those recently observed in school-level male (93.8% history and 64.6% point prevalence) and female (77.9% history and 52.8% point prevalence) adolescent rowers.[56] Nonetheless, the findings indicate increased

vulnerability to LBP for pre-professional and professional dancers, reinforcing previous findings that suggest a higher risk exists in populations required to perform repetitive or prolonged movements of the spine.[75]

A secondary aim of this study was to use a multivariable approach to determine if there were any demographic or physical factors associated with LBP lifetime and point prevalence. In this sample, no such variables were found to have any predictive value for LBP when potentially confounding factors were accounted for. This may be because LBP results from complex interactions between structure, injury biomechanics and personal factors that were not captured in this questionnaire. Regardless, it is still important to consider the implications of these findings. For instance, in respect of gender, it has previously been suggested that male dancers may experience high risk for LBP due to the lifting requirements of ballet.[62] There was no evidence of this in the current study, although some caution in interpretation is required, given the number of males who responded and the inclusion of both ballet and contemporary dancers. Importantly, traditional gender roles are not present to the same extent in contemporary dance as ballet, and regardless of style, female dancers are required to perform many end-of-range spine movements, often at high velocities, which increases vulnerability to LBP. In the general population, significantly higher median and mean prevalence of LBP has been seen globally among females;[29] however this has not always been a consistent or statistically significant finding and studies with athletes have observed the opposite.[55] [56]

No significant associations with age or years of training and either lifetime history or point prevalence of LBP were found. This outcome was unexpected as prior research has indicated the risk of LBP increases with age in both the general and athletic populations,[55] [147] and that the overall injury rate in dance students increases as training progresses.[12] [118]

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However, high rates of LBP are common during adolescence and a systematic review on the global prevalence of LBP found no statistically significant difference in prevalence between adolescents and young adults aged between 20-29 years.[29] Likewise, the lifetime and point prevalence of male and female adolescent rowers did not increase with age and the youngest age group (14 years) reported the highest prevalence.[56] As dancers begin training at a young age, initial exposure to spine movements and LBP risk would occur early. The youngest participants were aged 12 years. As LBP may start before age 12, any survey of dancers aged 12 or older will not capture the true age when LBP began.

The high rates of LBP in a relatively young sample are of potential concern, as the experience of LBP in adolescents has been associated with poorer mental and physical quality of life, as well as the establishment of care seeking behaviours, medication use and activity modification.[43] Furthermore, the single greatest risk factor for future LBP is prior history.[178] In Irish dancers, levels and severity of pain, as well as several other biopsychosocial parameters, were predictive of future pain and injury that resulted in time loss,[179] while LBP history has been seen as a precursor for the development of other types of musculoskeletal injury in pre-professional ballet students.[59] The latter of which may be explained, in part, by the presence of numerous physical deficits that persist in persons with LBP history.[53] Longer term, injuries sustained during sport and recreation may also negatively influence an individual's lifetime physical activity, which has significant implications for their long-term health and risk of chronic illness.[19] Given this, efforts to establish a greater understanding of the interaction between pain and longitudinal health and well-being are warranted.

There are a number of limitations that need to be considered when interpreting the data from the current study. First, the study may be limited by a potential response bias, with

dancers who have experienced LBP possibly being more willing to participate, which in turn may have resulted in an overestimation of LBP prevalence. In addition, although self-reported measures represent the most appropriate assessment for pain experience, there is the possibility in that by drawing attention to the pain site, they may exacerbate the problem.[180] Furthermore, as pain experiences and perceptions change across the lifespan, it is possible that the threshold for reporting pain may differ between younger students and university or professional level dancers. The cross-sectional design of the study cannot determine whether the observed high prevalence is due to the nature of dance activity, levels of exposure involved in dance training and practice, or other environmental factors associated with dance. Most likely, the pain results from a complex interaction of both environmental and personal factors.

The multivariable analysis performed in the current study was underpowered, and it is possible that the contribution of some of risk factors that were investigated have been obscured. This was due, in part, to sample size, as we were limited to a convenience sample of a highly specialised population, as well as a higher than expected lifetime prevalence. Furthermore, due to the personal nature of a number of the questionnaire items (i.e. menstrual status and Tanner scales) these questions were made optional and therefore the ability to investigate maturation and biological age was reduced. Nonetheless, this was a secondary aim of the paper, and the interpretation that LBP aetiology is complex is consistent with current perspectives on spinal pain.[181]

### 4.2.6. Conclusion

The prevalence of LBP in pre-professional and professional dancers is higher than commonly observed in the general and athletic populations. No differences were observed

in any demographic or physical related factors, indicating the onset of initial LBP experiences may occur at a young age, and that the causes of LBP episodes are complex and not easily discerned.

## 4.3. Linking section

Via cross-sectional design, study two indicated that the lifetime and point prevalence of LBP in pre-professional and professional dancers is higher than the prevalence observed in the general populations and several athletic populations. There was no identifiable relationship between the individual or demographic factors measured and LBP prevalence.

To provide new information on the experience of LBP in dance, study three uses a prospective design to determine the prevalence and impact of LBP in a sample of pre-professional and professional dancers over a nine-month period. The prospective study design allows for greater examination of the duration and impact of LBP episodes as well as investigation of risk factors for LBP in dance. It adheres to each item of the STROBE statement.[169] The manuscript for study three been published as:

Swain, C. T. V., Bradshaw, E. J., Whyte, D. G., et al. Life history and point prevalence of low back pain in pre-professional and professional dancers. *Phys Ther Sport* 2018;30:8-13.

## 4.4. Study 3: The prevalence and impact of low back pain in pre-professional and professional dancers: a prospective study

### 4.4.1. Abstract

***Introduction*** There is limited information concerning the prevalence, impact, and factors associated with low back pain (LBP) in dance. The purpose of this study was to determine the prevalence of LBP in pre-professional and professional dancers and its impact on dance participation, care-seeking and medication use.

***Methods*** Prevalence and impact of LBP was measured prospectively. Participants included male and female dancers from one pre-professional ballet school, two pre-professional university dance programs, and a professional ballet company. An initial questionnaire collected demographic and LBP history data. The monthly prevalence of LBP (all episodes, activity limiting episodes and chronic LBP) and impact (activity limitation, care-seeking, and medication use) was collected over a nine-month period.

***Results*** 119 dancers participated, which represented 54% of those invited. Activity limiting LBP was reported by 52% of dancers, while chronic LBP was reported by 24%. Seventeen percent of all episodes of LBP resulted in some form of dance activity being completely missed. One-third of the sample reported care-seeking and one-fifth of the sample used medication. A history of LBP was associated with activity limiting LBP (p<0.01; adjusted odds ratio: 3.98; 95% confidence interval: 1.44, 11.00).

***Conclusion*** LBP in dancers was common and had multiple impacts. This study reinforces the need for dancer access to healthcare professionals with expertise in evidence-based LBP prevention and management.

### 4.4.2. Introduction

Low back pain (LBP) is the leading cause of disability worldwide and represents significant personal and social cost.[38] It is often first experienced in childhood, with lifetime prevalence reaching adult levels by late adolescence.[55] Dance, which is a rigorous physical pursuit that boasts the highest participant rate for all cultural, sporting and leisure activities amongst Australian girls and the second highest for Australian male and female children combined,[1] has been associated with a high prevalence of LBP.[13 143 182] There is a strong rationale underlying this correlation. For instance, epidemiological evidence shows that engaging in work with high physical demands is a risk factor for the initial onset of LBP,[51] while specific spine movements such as repetitive bending and twisting, which are integral to dance, are associated with increased reports of LBP as well as functional loss and spine injury.[15 51]

Accordingly, epidemiological studies of dance injuries have identified the low back as the third most common site of injury in both pre-professional and professional classical ballet dancers,[12 34] and the second most common site of chronic injury in Australian professional dancers.[143] In adolescent ballet dancers aged between 9 and 20, LBP history has been associated with future musculoskeletal injury.[59] Two previous LBP studies in dancers, both cross-sectional in design, have observed higher rates of LBP in dancers than controls,[13] as well as lifetime and point prevalence rates surpassing those seen in global adolescent and adult populations.[182] These findings endorse LBP as a common health issue in young, as well as professional dancers and, being well above that of the general population, warranting more attention.

Importantly, there is considerable variability in how LBP manifests in individuals,[183] and simple measures of prevalence can only provide a partial overview of the problem. Little

is currently known about the impact of LBP on dancers, as previous studies have focussed on how much LBP is experienced, rather than the extent to which it disrupts dance practice or incites care-seeking and medication use. In addition, little is known about the factors associated with LBP in dance, which limits the capacity to develop targeted prevention strategies. This study had three aims: 1) to investigate, via prospective cohort design, the prevalence of LBP in pre-professional and professional dancers, 2) to determine the impact of LBP on dance participation, care-seeking and medication use, and 3) to determine factors associated with the experience of LBP.

### 4.4.3. Methods

A prospective cohort study was conducted over a nine-month period. Classical ballet dancers from a pre-professional ballet school (n=95, aged 11-18), and a professional nationally touring ballet company (n=29, age range unavailable) as well as contemporary dancers from two pre-professional university dance programmes (n=77 and n=19, aged 17-25) were invited to participate. Acceptance into each cohort is via an audition process, ensuring a threshold of ability. Volunteers were eligible for inclusion in this study if they were aged 12 years or more. No incentives were offered in return for participation. After providing informed consent/assent, participants provided their email addresses to researchers to allow distribution of online questionnaires. Ethical approval was granted by the Australian Catholic University Human Research Ethics Committee (2015-187H).

Questionnaires were developed following review of the LBP, sport, and dance injury literature. Participants received an initial online questionnaire (Qualtrics, USA) via email at the commencement of the study, followed by a questionnaire sent at the end of each month during the study period (**Appendix D**). A single reminder email was sent to

participants that had not completed the questionnaire within seven days. All collected data were de-identified, with participants creating their own login identification to allow for individual tracking.

The initial questionnaire collected demographic, dance and LBP history data, which have been reported previously.[182] Subsequent questionnaires determined the monthly prevalence of LBP, asking 'In the past month, have you had pain in your lower back?' and were accompanied by a diagram of the posterior aspect of the body, highlighting the region between the lower margin of the 12th ribs and the gluteal folds.[138] Participants who indicated they had experienced LBP were then asked whether the episode was new (i.e. not present in the previous questionnaire), how intense the pain was (a numeric scale of 0-10), and whether they were currently experiencing LBP. To determine the impact of LBP, participants were asked the total amount, as well as percentage, of dance activity they had to either modify or miss due to their pain, and whether they consulted a health professional (yes or no) or used medication for their pain (yes or no). To provide a measure of dance participation, all participants were asked for information about their dance activity for the past month, including the type (class, rehearsal, or performance) and style (classical, contemporary, or other), as well as the number and average duration of each activity.

The prevalence of LBP (aim 1) was reported for the entire study period and for each month of the study period, proportional to survey respondents. Episodes of LBP were defined as 'any LBP episode', which included all episodes of LBP, 'activity limiting LBP', which was an episode of LBP that resulted in some form of missed or modified practice, and 'chronic LBP', which occurred when participants indicated that they experienced three consecutive episodes of LBP that were not new in a three-month period. Point prevalence was calculated

as the proportion of responders that indicated they were currently experiencing LBP at the time of completing the questionnaire.

To determine the impact of LBP (aim 2), the proportion of LBP episodes requiring activity-modification was calculated as a proportion of all LBP episodes. The proportion of the sample that engaged in care-seeking or medication use was calculated as a proportion of the entire sample as well a proportion of those that experienced LBP. Spearman correlations were used to examine the relationship between reported pain-intensity of LBP episodes and these outcomes. Significance was set at $p < 0.05$.

To determine factors associated with the experience of LBP (aim 3), exposure variables including age, sex, body mass index (BMI), age started dancing, cohort type (dance school, university, or company), and LBP history were described using frequencies and percentages for categorical variables and means (standard deviation) for continuous variables. Chi square analyses and independent t-tests were used to examine univariable associations between exposure measures and the presence or absence of LBP (i.e. i) 'any LBP episode', ii) 'activity limiting LBP' and iii) 'chronic LBP'), followed by multivariable logistic regression to adjust for confounders. Variables that showed significant association following univariable analyses (p<0.25) were entered into the multivariable model. A backward stepwise approach was planned, whereby non-significant variables were removed from the model individually (p<0.05), and the reduced model compared with the initial model using likelihood ratio tests. The resulting adjusted odds ratios (AORs) and associated 95% confidence intervals (CIs) were reported. Multivariable models for any episode of LBP and chronic LBP were underpowered and therefore, only the model for activity limiting LBP is presented. To assess for a relationship between dance participation and LBP prevalence, Pearson (for parametric data) and Spearman (for non-parametric data)

correlations were performed between monthly prevalence for all LBP episodes with the mean number of dance activities (class, rehearsal, and performance) and dance hours (number of each activity type multiplied by the average duration of each corresponding activity) for each month. All statistical analyses were performed using SPSS software for Windows (version 22.0, SPSS Inc., Chicago, IL, USA).

### 4.4.4. Results

Out of 220 individuals invited, 168 agreed to participate. The email addresses of three individuals were invalid, necessitating their exclusion from the study. Two individuals completed only the initial questionnaire and were excluded from the final analysis. The initial questionnaire as well as at least one subsequent monthly questionnaire were returned by 119 participants (54% of the sample invited, n=100 females). Participant demographic data are presented in **Table 4.4**. Five hundred and eighty-five total monthly questionnaires were collected throughout the course of the study. Twenty-two dancers completed all 10 questionnaires, 50 completed between five and nine, and 47 completed four or less. The highest response rate was obtained for the first monthly questionnaire (62%) and the lowest was recorded for the final questionnaire (22%). Sixty-three percent of monthly questionnaires were completed within five minutes and 87% within 10 minutes.

Ninety-three (78%) participants reported at least one episode of LBP over the course of the study, while 62 (52%) experienced an episode that resulted in some form of activity limitation, and 29 (24%) experienced chronic LBP (**Table 4.4**). The point prevalence of LBP was between 8 and 25%, with the highest rate observed in the third month (**Figure 4.1**). Monthly prevalence (**Figure 4.1**) ranged from 19 to 58%, and 11 to 34% for all episodes of LBP and activity limiting LBP, respectively.

**Table 4.4. Participant descriptive data.** Results are reported as mean (standard deviation) for continuous variables and frequencies (percentage) for categorical variables.

| Population descriptor | Entire cohort | | Any LBP | | Activity limiting LBP | | Chronic LBP | |
|---|---|---|---|---|---|---|---|---|
| | Male | Female | Yes | No | Yes | No | Yes | No |
| | (n=19) | (n=100) | 93 (78) | 26 (22) | 62 (52) | 57 (48) | 29 (24) | 90 (76) |
| Male n (%) | … | … | 15 (79) | 4 (21) | 8 (42) | 11 (58) | 6 (32) | 13 (68) |
| Female n (%) | … | … | 78 (78) | 22 (22) | 54 (54) | 46 (46) | 23 (23) | 77 (77) |
| Age (yrs) [†] | 17.1 (3.7) | 17.9 (2.7) | 18.0 (2.8) | 16.8 (2.9) | 18.3 (2.8) | 17.1 (2.9) | 18.2 (2.8) | 17.6 (2.9) |
| Height (cm) [‡] | 175.2 (9.8) | 165.1 (7.6) | 167.7 (8.6) | 163.4 (9.2) | 167.6 (8.8) | 166.1 (8.9) | 168.0 (8.6) | 166.4 (8.9) |
| Body mass (kg) [§] | 65.1 (13.3) | 54.0 (8.6) | 56.9 (10.5) | 52.0 (9.3) | 56.8 (9.8) | 54.9 (11.1) | 58.3 (11.2) | 54.9 (9.9) |
| BMI (kg/m²) [¶] | 21.0 (3.1) | 19.7 (2.4) | 20.1 (2.7) | 19.3 (2.0) | 20.2(2.5) | 19.7 (2.6) | 20.6 (2.9) | 20.6 (2.9) |
| Age started dance [#] | 9.3 (4.8) | 7.4 (4.6) | 7.6 (4.9) | 8.0 (4.1) | 8.3 (5.2) | 7.1 (4.0) | 8.2 (5.1) | 7.5 (4.6) |
| Years dancing [#] | 7.8 (6.2) | 10.4 (5.0) | 10.4 (5.3) | 8.4 (5.3) | 10.0 (5.4) | 9.9 (5.2) | 10.0 (5.7) | 10.0 (5.2) |
| School n (%) | 10 (53) | 27 (27) | 24 (65) | 13 (35) | 13 (35) | 24 (65) | 7 (19) | 30 (81) |
| University n (%) | 8 (42) | 59 (59) | 57 (85) | 10 (15) | 37 (55) | 30 (45) | 18 (27) | 49 (73) |
| Company n (%) | 1 (5) | 14 (14) | 12 (80) | 3 (20) | 12 (80) | 3 (20) | 4 (27) | 11 (73) |
| History of LBP n (%) [†] | 15 (79) | 65 (74) | 70 (82) | 10 (46) | 50 (86) | 30 (61) | 28 (96) | 52 (66) |
| Used healthcare n (%) | 5 (26) | 29 (29) | 34 (37) | 0 | 31 (50) | 3 (5) | 13 (45) | 21 (23) |
| Used medication n (%) | 3 (16) | 22 (22) | 25 (27) | 0 | 20 (32) | 5 (9) | 12 (41) | 13 (14) |

[†]Data missing for n = 11 cases; [‡]Data missing for n = 20 cases; [§]Data missing for n = 21 cases
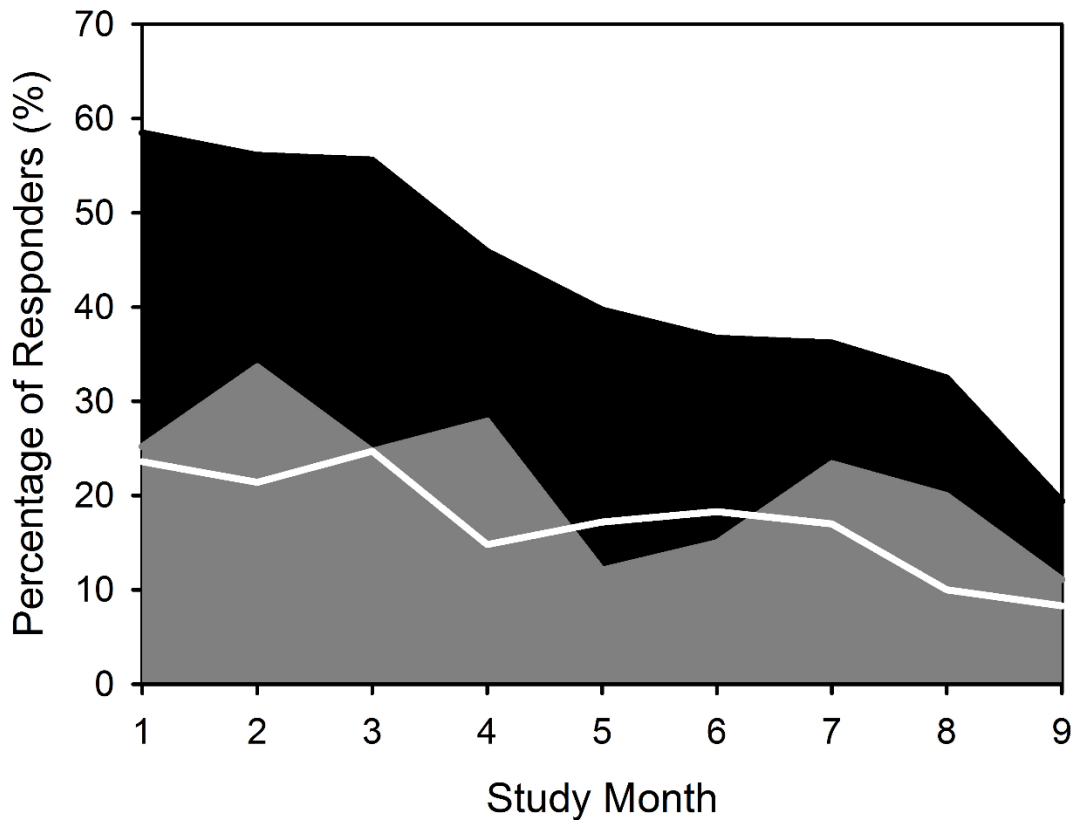
**Figure 4.1. Monthly experience of low back pain.** The black area represents all episodes of LBP, the grey area represents episodes of activity limiting LBP and the white line represents the point prevalence of LBP.

For each LBP episode, 49% resulted in no modification to dance activities, 46% resulted in up to half of dance activities being modified and the remaining 5% resulted in modification of more than half of dance activities. Seventeen percent of LBP episodes resulted in some portion of training being completely missed. A median pain intensity score of 4/10 (Interquartile range (IQR) = 3-6) was observed for all episodes of LBP and 5/10 (IQR = 3-7) for episodes of activity limiting LBP. Of the 62 individuals that experienced activity limiting LBP, 48% reported multiple episodes over the course of the study.

Thirty-four (29%) participants reported seeking health care for their LBP. Physiotherapists were the most commonly seen professionals (seen by n=16), followed by, Pilates instructors (n=5), chiropractors (n=5), and medical professionals (n=4). Medication use was reported by 25 (21%) participants, with 17 reporting the use of non-steroidal anti-inflammatories (NSAIDS), and 14 reporting the use of paracetamol on at least one occasion. Other medication reported included 'pain killers' or undisclosed (n=2). Of the medications reported, one (Celebrex®, n=1) is available as prescription medication only. A median intensity score of 5/10 (IQR = 4-7) was observed for LBP episodes that resulted in care-seeking and 6/10 (IQR = 5-7) for episodes resulting in medication use. There were significant, medium sized, positive correlations between the intensity of each episode of LBP and care seeking (r = 0.31, p<0.01), as well as medication use (r = 0.38, p<0.01) each month.

The mean number of dance activities reported per month ranged from 35.5 to 60.2 (SD range: 14.0-24.9). No significant relationship was identified between monthly dance activities and the monthly prevalence of any LBP (r= 0.29, p= 0.45) or activity limiting LBP (r= 0.38, p= 0.32). The mean dance hours per month ranged between 49.9 to 85.3 (SD range: 21.4 to 44.4). No significant relationship was identified between monthly dance hours and the monthly prevalence of any LBP (r= 0.48, p= 0.19) or AL LBP (r= 0.57, p= 0.11). Large variability was evident in the dance participation measures even when cohorts were considered separately (standard deviations for dance hours ranging from 5.1 to 85.9 hours per month), and when subgroups (e.g. year group) within cohorts were considered.

Exposure variables significantly associated with activity limiting LBP were entered into a multivariable model (**Table 4.5**). These included histories of LBP, age, age started dancing, and cohort type (school, university, and company). After adjusting for confounding

variables, lifetime history was the only significant predictor of activity limiting LBP (p=0.01).

**Table 4.5. Univariable and multivariable associations with activity limiting low back pain**

| Population descriptor | Univariable analysis | | Multivariable analysis | |
|---|---|---|---|---|
| | Mean (SD)/ n (%) | p | AOR (95% CI) | P |
| Age (yrs)[†] | 18.3 (2.8) | 0.05 | 0.99 (0.76, 1.29) | 0.93 |
| Age started dancing (yrs)[‡] | 8.3 (5.2) | 0.20 | 1.04 (0.95, 1.14) | 0.40 |
| Cohort Type | | **0.01** | | |
| School n (%) | 13 (35) | | 1.00 (ref) | |
| University n (%) | 37 (55) | | 0.14 (0.01, 1.33) | 0.09 |
| Company n (%) | 12 (80) | | 0.34 (0.07, 1.59) | 0.17 |
| History of LBP n (%)[†] | 50 (86) | **<0.01** | 3.98 (1.44, 11.00) | **<0.01** |

AOR, adjusted odds ratio; [†]Data missing for n = 11 cases; [‡]Data missing for n = 14 cases; Bold indicates p< 0.05

### 4.4.5. Discussion

The purpose of this study was to determine the prevalence and impact of LBP in pre-professional and professional dancers. In this cohort, LBP was common. The proportion of dancers that experienced an episode of activity limiting LBP (52%) during the nine month study period was above the yearly prevalence observed in the global adolescent (34%)[55] and adult populations (38%),[29] and within the yearly prevalence ranges observed in a systematic review of Olympic sport disciplines (24-66%).[134] The monthly prevalence of activity limiting LBP ranged from 11-34%, which is slightly higher than that seen in elite rowers (6-25%);[147] although, the mean (22%) was similar to the monthly prevalence seen in the global population (23%).[29] Mean point prevalence (17%) was above that seen in the global adolescent population (12%),[55] similar to the adult population (18%),[29] and at the lower end of the range observed in Olympic sports (18-65%).[134] However, observations of

Olympic sports included both current episodes and episodes in the last seven days in their point prevalence definition, which potentially inflated the results.

Similar to patterns seen in other populations,[183] there was large variation in how LBP was experienced by individuals. Of those that reported at least one episode of pain, one third experienced no activity limitation and close to a third experienced only a single episode, compared to a quarter that experienced chronic LBP. These results highlight that disability as a result of LBP is not inevitable; however, nor is rapid recovery. They also indicate a simple description of prevalence provides only a partial insight into the problem.

The degree to which LBP incites care seeking can provide perspective on the impact of the condition. Close to one third of the entire sample and half of those that experienced activity limiting LBP reported seeking professional help. The moderate correlation between pain intensity and care seeking seen here is consistent with non-athletic populations,[41] and indicates dancers are more likely to consult for episodes they perceive as more severe. In addition, previous studies have identified a link between emotional distress and consumption of health care for LBP, which emphasises the necessity for health professionals who have expertise in managing dance conditions. Many dancers who experienced LBP did not seek help, which is consistent with patterns in the general population,[38] reinforces the proposal that many episodes of LBP recover with minimal intervention,[183] and further highlights the variation in the experience of LBP. Notably, the proportion that did pursue health care was lower than that seen in Western Australian adolescents.[43] This may suggest episodes in dance are less severe or that dancers are able to cope with some level of pain.[50] It may also indicate reluctance amongst dancers to acknowledge their pain, potentially as a product of cultural expectations, or through fear of possible implications.[18 50]

More than one-fifth of the dancers in this sample reported the use of analgesic medication for their LBP. Current consensus statements do support analgesic use as a component of pain management in athletic populations,[46] although, the effectiveness of analgesics as a treatment for LBP is unclear,[47 48] and prolonged use can increase the likelihood of long-term sickness absence.[45 49] Dancers were more likely to use pain medication for episodes that were more intense, or if they experienced activity limiting or chronic LBP. While a complete understanding of the factors that influence the decision to consume analgesics in this sample is not available, these results indicate that dancers do want some form of pain relief. The use of over-the-counter medications may indicate a level of self-management in the pain-relieving process. If so, this would indicate the importance of providing dancers with the appropriate education and resources to play an active role in pain management.[184]

Consistent with previous studies, past history of LBP predicted the experience of activity limiting LBP.[51] This may reflect the recurrent nature of the LBP experience,[38] or the influence of past experience on pain perception.[28] It is also possible that individuals who experience LBP possess a range of underlying factors that increase their vulnerability to LBP, which may persist across the lifespan.[185] As such, a history of LBP should be included in dance health screening, and can be used to identify at-risk populations who may be suitable for clinical intervention.

The current study was unable to find any overall association between the experience of LBP and the participation data collected; although, these findings should be interpreted with caution, as the self-reported participation data had a high degree of variability. In epidemiological studies, documenting a link between physical exposure and LBP is difficult, particularly given the complexities of spinal loading as well as the subjective nature of the pain experience. This difficulty does not imply the lack of a causative

relationship,[186] as industry-based studies that have described exposure using precise quantitative measures have shown much greater ability to predict loss in spine function related to pain,[15] and cross sectional research in pre-professional dancers has observed higher LBP prevalence in dancers with higher weekly dance hours.[13] Nonetheless, it is also important to consider other factors that influence pain. For instance, prior research with Irish dancers found the severity of pain and injury was more closely linked to biopsychosocial factors than the mechanical measures collected.[179]

Monthly LBP, activity limiting LBP, and point prevalence steadily declined over the course of the study. There are several possible explanations for this finding. That LBP prevalence was lowest in the final month may partially reflect a seasonal effect. At this time, the two university cohorts had finished their final performances, while the school had completed its major performance three months earlier and the final term was close to conclusion. The findings may also indicate that an improvement in both fitness and movement ability occurred during the study period, increasing the capacity for dancers to manage the physical demands placed upon them. Alternatively, it is possible that continued participation in the project led to an upward shift in the individual threshold for reporting pain; however, the opposite may also be true, and ongoing participation may be just as likely to increase one's awareness of LBP and its impact. The attrition rate should be considered as a potential factor that contributed to the decline in prevalence, yet, dropout occurred in both individuals who experienced and did not experience pain, and a prior surveillance study found a decline in injury rate was not associated with a change in the response rate.[187]

The major limitation of this study was the response and attrition rate. To counter the expected attrition, we used multiple cohorts and communicated the purpose to each individual in person, although we were unable to offer any significant incentive. Self-report

based surveillance studies that have achieved higher participation have often featured a collection of highly disciplined elite athletes,[139 147] more persistent and personalised follow up that may be linked to medical care,[139 187] or researchers with a status that participants may admire.[179] The monthly questionnaire was designed to present minimal burden for participants; however, it was more complex than the tool used by Clarsen, et al.[139] and it is possible this contributed to the attrition. Reassuringly, available evidence does not suggest that a lower response rate in epidemiology studies automatically implies low validity or the presence of substantial bias,[188 189] although the exact age range and sex distribution for each cohort was not attainable, and application to the wider dance community may not be automatically assumed.

While the questionnaire used was not formally validated or tested for reliability, the initial and monthly questionnaire were discussed with dance education and health professionals from more than one cohort and reviewed by a dance science professional outside the research team as well as a group of senior ballet school students. The questionnaires were confirmed to have face validity. The definition of LBP, which was accompanied by a diagram, is consistent with the standardised definition of LBP for use in prevalence studies[138] and a meta-analysis of LBP prevalence studies in children and adolescents indicated that one month and point period prevalence are less affected by publication bias than recall periods greater than one month,[55] which supports monthly distribution of questionnaires. The dance participation data component of the questionnaire was modelled on the tool used by Newlands, et al.,[147] which although not validated, did successfully demonstrate a relationship between monthly training load and LBP in junior and senior elite rowers. This was modified so that the participation data matched the dance exposure categories (class, rehearsal, performance) described by an IADMS standard measures consensus statement.[24]

Importantly, LBP is not a homogenous condition. While this study describes the prevalence and impact of LBP in pre-professional and professional dancers, it is likely that the mechanisms responsible for LBP development within the sample are vast. For instance, repetitive application of complex loads to the spine, combined with aspects of growth and maturation, may predispose young dancers to specific spine injuries.[190] [191] Similarly, the physical, social, and personal contexts would differ greatly between a university level contemporary dancer and a professional ballet dancer, and these may influence pain.

Clinically, as a history of LBP was identified as a predisposing factor to the experience of activity limiting LBP, reducing the incidence of first time LBP in young dancers could have long term health benefits. Furthermore, as dancers appear to be a population at risk, efforts to provide them with the skills and resources to play an active role in responding to pain would be appropriate. Future research would do well to investigate factors that contribute to LBP in dance, as well as dancers' knowledge of available pain management.

### 4.4.6. Conclusion

Results from this study support the assertion that pre-professional and professional dancers are vulnerable to experiencing LBP and there is suggestion of a seasonal effect in this population. Low back pain history increases future risk, and for a significant portion of dancers, pain is ongoing, interferes with dance participation and provokes care-seeking and medication use. Accordingly, dance students and professionals need access to healthcare professionals with expertise in the management of LBP and its consequences. Artistic and education staff should be sensitive to the complexities of pain, and its interaction with dance participation.

# Chapter Five: The relationship between dance, LBP, and spine kinematics

## 5.1. Overview of Chapter Five

Chapters Two and Four have provided epidemiological information about the magnitude, scope, and characteristics of LBP in dance. It has been confirmed that dancers are vulnerable to the experience of LBP, that the impact of LBP in dance is multi-dimensional, and a history of LBP may predict future episodes. Furthermore, as no interaction between individual or demographic factors and LBP was identified, it should be assumed that all dancers are vulnerable to LBP. This epidemiological data was needed to better understand LBP in dance and to place the problem into perspective.

Chapter Five moves on to the fourth aim of this thesis, which is to investigate the relationship between dance practice, spine movement, and LBP. Although mechanical factors are often proposed as key contributors to the experience of LBP in dance, the evidence in support of this remains inconsistent. Studies that describe a relationship between dance exposure and LBP and injury support the importance of mechanical factors in this population.[13 78 79] However, studies that have had only limited ability to discriminate between dancers with and without LBP using physical assessment may suggest otherwise.[5 61 80] Accordingly, further insight into this relationship was identified as a research priority.

Study four used three-dimensional motion analysis and a multi-segment spine marker set to examine postural and movement tasks in a sample of female dancers and non-dancers with and without LBP. The postural and movement assessments that were selected are common in clinical investigation of LBP and influence the magnitude and distribution of

loads sustained by spine structures. The manuscript for study four has been accepted for publication in Gait & Posture.

Swain, C.T.V., Whyte, D. G., Ekegren, C.L., et al. Multi-segment spine kinematics: relationship with dance training and low back pain. ID: GAIPOS_2018_578.

## 5.2. Study 4: Multi-segment spine kinematics: relationship with dance training and low back pain

### 5.2.1. Abstract

*Introduction* Spine posture, range of motion (ROM) and movement asymmetry can contribute to low back pain (LBP) and may be influenced by physical exposure to spinal loads during movement. These variables may have greater influence in populations required to perform repetitive spine movements, such as dancers; however, there is limited evidence to support this. The purpose of this study was to examine the influence of dance and LBP on spine kinematics.

*Methods* In this cross-sectional study, multi-segment spine kinematics were examined in 60 female participants, including dancers (n = 21) and non-dancers (n = 39) with LBP (n = 33) and without LBP (n = 27). A nine-camera motion analysis system sampling at 100Hz was used to assess sagittal standing postures, as well as frontal and transverse plane ROM and movement asymmetry. A two-way ANOVA was performed for each of the outcome variables to detect any differences between dancers and non-dancers, or individuals with and without LBP.

*Results* Dancers had smaller upper lumbar sagittal plane angles when standing ($p< 0.01$, $\eta p^2 = 0.15$), and achieved greater frontal plane ROM for the upper lumbar ($p=0.04$, $\eta p^2=0.08$) and lower thoracic ($p=0.02$, $\eta p^2=0.09$) segments. There were no differences between dancers and non-dancers for transverse plane ROM or movement asymmetry ($p>0.05$). There was no main effect for LBP symptoms on any kinematic measures, and no interaction effect for dance group and LBP on spine kinematics ($p>0.05$).

***Conclusion*** The number of segments and tasks that differentiated dancers from non-dancers was limited, and no relationship was observed between LBP and spine kinematics. This suggests that these simple, static posture, ROM, and asymmetry measures often used in clinical practice are not sensitive enough to detect any impact LBP may have on spine movement in either dance or non-dance populations.

### 5.2.2. Introduction

Alongside biological and psychosocial factors, biomechanical factors can contribute to the initiation and persistence of low back pain (LBP).[69] Prospectively, a flatter standing posture as well as reduced spine mobility have been seen to precede more serious episodes of first time LBP.[70] Furthermore, individuals with existing LBP commonly present with reduced lumbar spine range of motion (ROM), as well as more asymmetrical spine movement, compared to persons without.[66] [150] Accordingly, assessment of spinal posture and movement is a common component of clinical examination for LBP patients and can inform treatment strategy.[192] [193]

It is possible that the contribution of biomechanical factors on the development of LBP is of greater importance in populations with large movement demands.[70] Performing movements with a less mobile spine is associated with increased spine loading.[71] Tennis players with LBP have shown reduced ROM of the lower lumbar spine as well as a more laterally tilted pelvis than their asymptomatic counterparts.[88] Spine kinematics may also be influenced by this type of physical exposure. Cross-sectional research has documented increased prevalence of rotation related deficits and spine movement asymmetries in individuals that participate in rotation related sports.[152] Furthermore, longitudinal research has shown decreases in spine kinematic function in occupational work that involves more dynamic physical exposures,[15] which may have implications for athletic populations that perform similar movements. However, while a relationship between participation in athletic activity and LBP has been identified, there is only limited research into movement patterns in people with LBP participating in these activities.[194]

Dancers, who are required to perform many complex and repetitive movements of the spine, often to extreme ranges of motion, represent an ideal population to study spine

kinematics and LBP. Cohort studies have confirmed dancers experience LBP at least as much as, if not more than, general and sporting populations.[182 195] Research documenting high prevalence of spondylolysis in ballet dancers,[78] as well as an association between dance hours and spinal stress fractures or LBP support a relationship between dance exposure and spine health.[13 79] Evidence also supports a unique spine profile in this population, with dancers presenting with flatter spine postures and greater sagittal plane spine mobility than non-dancers,[61] as well as a prevalence of trunk asymmetries (measured with a scoliometer) and asymmetrical trunk muscle morphology.[5 165]

Despite this, the relationship between dance, spine kinematics, and LBP remains unclear. One previous kinematic study did not find an association between sagittal plane mobility and LBP in dance students,[61] an observation which is counter to those from both athletic and non-athletic populations.[66 70 88] However, this study used a broad definition of dancer, considered only the sagittal plane, and modelled the lumbar and thoracic spine as single segments,[61] which may be less able to provide accurate descriptions of spine kinematics compared to a multi-segment model.[196] Elsewhere, unlike non-dance populations, measures including trunk stiffness and thickness of select paraspinal muscles did not discriminate between ballet dancers with or without LBP.[5 80] As such, kinematic differences should not be automatically assumed. Evaluating differences between dancers and non-dancers in simple measures of spine kinematics that have previously been associated with LBP and that are common in clinical practice may provide insight into the interaction of dance, spine movement, and LBP. Therefore, the purpose of this study was to analyse spine posture, maximum ROM, and movement asymmetry in dancers and non-dancers with and without LBP.

### 5.2.3. Methods

Female professional and student dancers aged 15 years old and above, from both classical ballet and contemporary dance styles were recruited. Dance students were eligible for inclusion in this study if they were enrolled in senior level full-time training at a ballet school, a tertiary dance programme, or had recently (<1 year) completed an equivalent programme. Dance professionals were eligible for this study if they were either dancing with a company or as an independent professional. Non-dancers were recruited to match the age and sex of the dancers. They were recruited from university and community settings. Dancers and non-dancers were allocated to the LBP group if they had experienced a minimum of two episodes of LBP in the past 12 months that resulted in activity modification, consultation with a health professional, or the use of medication. They were allocated to the No-LBP group if they had not experienced any episode of LBP in the past 12 months. Exclusion criteria for all groups included known spinal deformities, pregnancy, or the presence of injury in any body region other than the lower back resulting in a modified training load or compromised spine kinematics at the time of testing. Ethical approval was granted by the Australian Catholic University Ethics Committee (2016-213E). All participants above the age of 18 (n = 50) provided written informed consent prior to participation in the project. Participants below the age of 18 (n = 10) provided informed parental/ guardian consent as well as participant assent.

Prior to testing, participant height (cm) and body mass (kg) were collected using a stadiometer (SECA) and scales (A&D HW-PW200), respectively. For all participants, age (years), current and past medical history, as well as current and past LBP status were collected by questionnaire (**Appendix E**). Information on dance practice (e.g. current dance level, primary style, dance hours) and physical activity (e.g. moderate and vigorous activity

type, weekly frequency, weekly hours) was collected for dancers and non-dancers, respectively using a standardised questionnaire. Participants with LBP indicated their current, average, and worst pain intensity on a visual analogue pain scale and completed the Tampa Scale for Kinesiophobia (TSK) and Pain Catastrophizing Scale (PCS).[197][198]

Spinal kinematics were measured using a nine camera three dimensional Vicon Nexus motion analysis system (six MX13+ and three T20-S cameras, Nexus 2.2 software, Vicon, Oxford, UK) sampling at 100Hz. A multi-segment spine marker set that has previously identified kinematic differences between individuals with and without LBP was used.[149] Seventeen (12mm) reflective markers were attached to the pelvis, lumbar spine and thoracic spine of each participant, as previously described.[149] Five central markers were placed on the spinous processes of T1, T6, L1, L3 and L5, which were identified via palpation. Eight lateral markers were placed 5cm either side from the midpoint of the central markers. Four markers were placed on the right and left posterior superior iliac spines and the anterior superior-iliac spines (**Figure 5.1**).
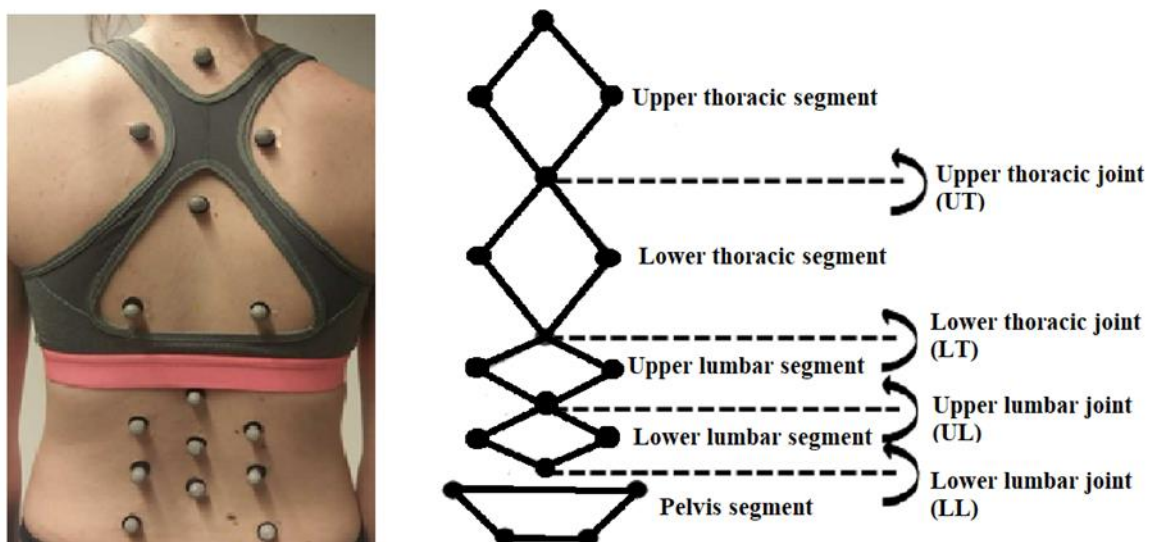


**Figure 5.1. Multi-segment spine marker set.**

After marker placement, trials of fundamental (normal) standing posture, frontal plane range of motion (ROM) in standing and transverse plane ROM in sitting were completed. For each task, a demonstration and standardised verbal instructions (**Table 5.1**) were provided to all participants. All tasks were performed in the same order, and at the participants own pace, to ensure that the most reliable measure of trunk motion was obtained.[151] [199] Multiple practice attempts were provided, and two successful captures of each task were completed.

**Table 5.1. Verbal instructions for movement assessments**

| Trial | Verbal Instructions |
|---|---|
| Standing Posture | Stand relaxed how you would normally stand. Feet shoulder-width apart, knees straight and arms hanging freely, look forward. |
| Trunk Rotation | With your arms crossed over your chest (hands on shoulders) and keeping both sit bones on the stool, rotate your trunk to one side as far as you can, look over your shoulder, return to the starting position. |
| Side Bend | With your feet positioned pelvis width apart, easily bend to your (direction) side as far as you can, sliding your arm along your leg, return to the starting position. |

Gap filling was completed in the Vicon Nexus software and then the motion capture data was subsequently exported as C3D files. Kinematic parameters were quantified using Visual 3D (C-Motion, Inc. MD, USA) after marker data were filtered using a low-pass Butterworth filter at a cut-off frequency of 6Hz to eliminate motion artefact. As described by Christe, et al.,[149] the trunk was divided into a series of five segments, including the

pelvis, lower lumbar, upper lumbar, lower thoracic, and upper thoracic spine segments. For each task, lower lumbar angles (LL) were defined as the angles between the lower lumbar and pelvis segments, the upper lumbar angles (UL) as the angles between the upper lumbar and lower lumbar segments, the lower thoracic angles (LT) as the angles between the lower thoracic and upper lumbar segments and the upper thoracic angles (UT) as the angles between the upper thoracic and lower thoracic segments. To calculate ROM in the movement tasks, the peak angles to the left were added to the peak angles to the right for each segment. To calculate asymmetry, the maximum absolute values to the left were subtracted from the maximum absolute values to the right then divided by the total ROM and multiplied by 100.[151]

All statistical analyses were performed using SPSS software for Windows (version 22.0, SPSS Inc., IL, USA). Statistical significance was set at $p < 0.05$ for all tests. The Shapiro-Wilk test was used to determine whether the data were normally distributed. Frontal plane ROM variables for UL and LT as well as the asymmetry variables for the LL, UL, and UT in the frontal plane and LL, LT and UT in the transverse plane were not normally distributed and thus log-transformed prior to any further analysis. Levene's Test was used to assess equality of variance. A two-way analysis of variance (ANOVA) was performed for each of the outcome variables to detect whether there were any differences between dancers and non-dancers, or individuals with and without LBP. Dance (two levels: dancer and non-dancer) and LBP (two levels: LBP and no LBP) were entered as fixed factors. Partial eta squared ($\eta p^2$) was obtained for all significant findings as a measure of effect size.

### 5.2.4. Results

Twenty-one female dancers (LBP n = 15) and 39 female non-dancers (LBP n = 18) volunteered to participate. Dancers started dancing at a mean (SD) age of 5.6 (2.5) years old and had 14.9 (5.7) years of dance experience. The mean (SD) weekly dance hours completed by dancers at the time of testing was 20.5 (9.8). In contrast, non-dancers reported completing 4.4 (3.3) weekly hours of moderate to vigorous physical activity in a variety of activities. There were no significant differences in age or height between dancers and non-dancers, but dancers had significantly lower body mass and BMI than non-dancers (**Table 5.2**). For the participants with LBP, there were no differences in current (mean (/10) ± SD; dance = 2.1 ± 2.7, non-dance 0.9 ± 0.9, p = 0.15), average (dance = 3.8 ± 1.6, non-dance 4.2 ± 2.2, p = 0.55) or worst pain intensity (dance = 6.7 ± 1.9, non-dance 6.6 ± 1.8, p = 0.68). Nor were there differences kinesiophobia (mean (/52) ± SD; dance = 24.9 ± 5.7, non-dance 23.4 ± 5.7, p = 0.50) between dancers and non-dancers; however, dancers reported significantly higher PCS scores than non-dancers (mean (/52) ± SD; dance = 17.1 ± 9.2, non-dance 8.9 ± 6.5, p = 0.01).

**Table 5.2. Participant demographic data**

| Population descriptor | Dancers (n=21) | Non-Dancers (n=39) | p |
|---|---|---|---|
| Age (years) | 21.5 (6.4) | 22.9 (5.8) | 0.42 |
| Height (cm) | 165.6 (8.35) | 165.2 (6.2) | 0.85 |
| Body Mass (kg) | 53.2 (7.5) | 60.9 (8.6) | **< 0.01** |
| BMI | 19.5 (2.7) | 22.3 (2.8) | **< 0.01** |

BMI = Body mass index; Bold indicates p<0.05.

For posture, there was a significant main effect for dance on the UL ($F_{(1,56)} = 9.78$, $p<0.01$, $\eta p^2=0.15$), with dancers demonstrating significantly smaller angles in the sagittal plane, suggesting a flatter standing posture. There was no main effect for LBP on posture for any segment. There was no interaction effect for dance and LBP on posture. For ROM, significant main effects of dance on UL ($F_{(1,56)}=4.49$, $p=0.04$, $\eta p^2=0.08$) and LT ($F_{(1,56)}=5.09$, $p=0.02$, $\eta p^2=0.09$) were observed in the frontal plane, with dancers achieving greater ROM compared to non-dancers. There was no main effect of dance on transverse plane ROM or any measure of movement asymmetry for any segment. There was also no main effect of LBP symptoms on ROM or movement asymmetry, nor was there any interaction between dance and LBP symptoms for these measures. Mean and significance values for standing posture, ROM, and movement asymmetry are presented in **Table 5.3**.

**Table 5.3. Mean (SD) values and significance from the Two-Way ANOVAs**

| Assessment | Angles | Dancer | Non-Dancer | p | LBP | No-LBP | p | Interaction p |
|---|---|---|---|---|---|---|---|---|
| Standing posture (degrees) | LL | 7.02 (8.15) | 5.76 (10.34) | 0.50 | 5.87 (10.32) | 6.60 (8.77) | 0.60 | 0.60 |
| | UL | 7.40 (9.16) | 14.26 (8.29) | **<0.01** | 11.97 (9.05) | 11.72 (9.42) | 0.29 | 0.48 |
| | LT | 1.23 (10.22) | -3.73 (6.46) | 0.10 | -0.33 (8.78) | -4.03 (7.17) | 0.16 | 0.49 |
| | UT | -17.48 (6.43) | -19.18 (8.26) | 0.27 | -19.20 (7.37) | -17.84 (8.06) | 0.30 | 0.59 |
| Frontal plane ROM (degrees) | LL | 16.10 (6.94) | 16.74 (7.17) | 0.69 | 16.45 (7.67) | 16.59 (6.31) | 0.69 | 0.72 |
| | UL | 27.61 (10.20) | 23.73 (6.24) | **0.04** | 25.42 (8.16) | 24.72 (7.97) | 0.53 | 0.15 |
| | LT | 41.15 (9.50) | 35.25 (7.35) | **0.02** | 38.66 (9.30) | 35.69 (7.42) | 0.52 | 0.85 |
| | UT | 26.55 (6.02) | 24.10 (5.89) | 0.15 | 26.55 (5.55) | 22.98 (6.07) | 0.19 | 0.11 |
| Frontal plane asymmetry [(R-L)/ (R + L)] * 100 | LL | 6.66 (2.48) | 7.25 (2.40) | 0.96 | 5.81 (2.64) | 8.87 (2.03) | 0.10 | 0.90 |
| | UL | 5.83 (2.55) | 6.27 (2.27) | 0.53 | 6.09 (2.55) | 6.15 (2.14) | 0.60 | 0.20 |
| | LT | 6.30 (3.30) | 8.00 (4.10) | 0.28 | 6.78 (3.70) | 8.19 (4.07) | 0.21 | 0.47 |
| | UT | 4.87 (2.77) | 7.49 (1.86) | 0.09 | 5.95 (2.57) | 7.13 (1.79) | 0.65 | 0.96 |
| Transverse plane ROM (degrees) | LL | 9.55 (5.30) | 9.31 (4.99) | 0.51 | 9.41 (5.40) | 9.37 (4.73) | 0.45 | 0.13 |
| | UL | 14.44 (4.06) | 15.97 (5.00) | 0.28 | 15.31 (4.37) | 15.62 (5.19) | 0.99 | 0.99 |
| | LT | 35.41 (12.14) | 33.73 (9.05) | 0.75 | 35.67 (11.53) | 32.68 (8.07) | 0.34 | 0.93 |
| | UT | 20.94 (10.87) | 19.90 (8.79) | 0.28 | 18.82 (7.42) | 21.92 (11.31) | 0.12 | 0.60 |
| Transverse plane asymmetry [(R-L)/ (R + L)] * 100 | LL | 18.14 (1.97) | 9.41 (5.40) | 0.24 | 16.24 (2.27) | 16.78 (2.32) | 0.90 | 0.92 |
| | UL | 14.38 (10.27) | 15.31 (4.37) | 0.54 | 13.70 (9.60) | 16.50 (10.95) | 0.45 | 0.37 |
| | LT | 6.01 (2.50) | 35.67 (11.53) | 0.74 | 5.74 (3.00) | 6.66 (1.92) | 0.62 | 0.72 |
| | UT | 13.43 (2.76) | 18.82 (7.42) | 0.27 | 11.83 (2.63) | 12.57 (2.95) | 0.78 | 0.47 |

Bold indicates p <0.05.

### 5.2.5. Discussion

The purpose of this study was to examine the relationship between dance, LBP, and multi-segment spine kinematics. In our sample of female participants, dance had a significant relationship with fundamental posture and spine ROM for select segments and tasks. The dancers presented with a smaller upper lumbar angle when standing, indicating a flatter posture at this segment in the sagittal plane. In addition, dancers displayed significantly increased frontal plane ROM at the upper lumbar and lower thoracic segments compared to non-dancers. Dance explained between 8 – 15% of the variation observed in these measures. No relationship between LBP and spine kinematics was observed, and no interaction between dance and LBP with spine kinematics was observed.

Similar to previous research, there were differences in posture and ROM in dancers compared to non-dancers.[61] However, the total number of differences between dancers and non-dancers was small and these were limited to the upper lumbar and lower thoracic segments. Furthermore, although differences in frontal plane ROM were observed, there was no difference between dancers and non-dancers in transverse plane ROM. Therefore, the differences should collectively be viewed as modest, and, overall, measures such as posture and spine mobility appear to have limited ability to discriminate between trained dancers and non-dancers. With respect to asymmetry, previously, ballet students have exhibited a higher prevalence of trunk asymmetries measured with a scoliometer and ballet professionals have possessed asymmetrical trunk muscle morphology that is not evident in non-dancers.[5 165] Using three-dimensional motion capture and a multi-segment marker set, the current study did not observe any differences in movement asymmetry between dancers and non-dancers. While we did not measure muscle morphology, the implication of the

current study is that these characteristics may not necessarily translate into more movement asymmetry than non-dancers.

The findings should also be considered in the context of previous studies examining physical activity types, spine posture, and movement patterns. Teaching bipedal motion in animals precedes the development of a lordotic curve,[200] which supports the notion that spine posture is influenced by activity type. Furthermore, participation in repetitive rotation related sports has been linked to specific movement adaptations that can be detected in clinical assessment.[152] However, while former elite gymnasts presented with a flatter thoracic posture than controls, there were no differences between spine mobility between gymnasts and non-gymnasts.[201] Similarly, in young dancers, gymnasts, and figure skaters, sagittal plane extension did not change as training progressed.[201 202] In the current study, select differences were observed between dancers and non-dancers, although the number of differences was small. This suggests that dance activity may just be one of the many contributors to habitual posture and spine mobility.

The present study did not find an association between spine posture, ROM, or movement asymmetry and LBP. Although non-neutral postures and reduced spine segment ROM have been associated with LBP,[66 203] an absence of clear differences between groups with and without LBP is not without precedent.[204] In a three-year prospective study, reduced spine mobility was a significant predictor of more serious first time LBP, but it was not associated with transient LBP and only able to explain 2.1% of the variation in all the serious LBP experienced.[70] Previous results regarding movement asymmetry and LBP have been varied. Two kinematic studies that used similar movement tasks to the current study observed more asymmetrical spine movement in people with LBP.[150 151] In contrast, in clinical assessment, spine movement asymmetries were not associated with LBP unless the movement of a limb

was involved.[152] Collectively, the relationship between LBP and movement does not appear simple or stereotypical.[205] In support of this, the present study suggests that generic interpretation of the simple clinical assessments used may be of limited value for LBP in dance and non-dance populations.

There was no interaction effect for dance and LBP on spine kinematics. Recent studies have shown that measures previously able to discriminate between people with and without LBP, such as trunk muscle cross-sectional area or spine stiffness, are less able to discriminate between dancers with and without a history of LBP,[5 80] suggesting dancers may be resistant to changes often associated with LBP. However, the current study did not see an interaction between LBP and spine kinematics in non-dancers either. Thus, the present results cannot support the hypothesis that dancers are resistant to changes associated with LBP. Rather, despite the use of three-dimensional motion analysis, it is more likely that the simple posture, ROM, and movement asymmetry measures used were not sensitive enough to provide insight into movement changes associated with LBP. As such, adequate assessment of spine movement changes associated with LBP may require use of more probing kinematic assessment and functional or dance specific tasks.

No differences in current, average, or worst pain intensity were observed between dancers and non-dancers with LBP, which suggests the current results were not influenced by fluctuations or severity of pain symptoms. Previous research that has identified altered spine kinematics in LBP patients who were pain free at testing suggests that an absence of current pain does not impair the ability to identify kinematic deficits.[149 206] This also raises the issue as to whether kinematic assessment is sensitive to changes in pain symptoms, which is an area for future research.

Several methodological limitations should be considered when interpreting these findings. First, the cross-sectional nature of this study is unable to determine whether the small number of differences observed are caused by dance or merely reflect a selection bias within it. Second, this study was limited to a convenience sample of a well-trained, highly specialised population, for whom LBP is common,[182 195] which limited the statistical power of the analysis and prevented subgrouping or adjustment for confounding. Third, although there were no significant differences between participants for age, sex, and height, dancers had significantly lower body mass. Due to the traditional builds preferred in classical ballet, obtaining a control group matched for body mass was not achievable. In addition, while there were no differences between dancers and non-dancers with LBP in pain intensity or kinesiophobia, dancers with LBP displayed increased pain catastrophising than non-dancers with LBP.

### 5.2.6. Conclusion

The number of segments and tasks that differentiated dancers from non-dancers was limited and no relationship between LBP and spine kinematics was observed. These findings suggest that simple, static posture, spine ROM, and movement asymmetry assessments often used in clinical practice do not generate measures sensitive enough to provide generic information on the experience of LBP symptoms in dance or non-dance populations.

# Chapter Six: Spine kinematics in dancers with and without low back pain

## 6.1. Overview of Chapter Six

Chapter Five was the first chapter to investigate the relationship between dance practice, spine movement, and LBP in a sample of dancers and non-dancers with and without LBP. Examination of spine posture, ROM, and movement asymmetry revealed a small number of select measures that were able to differentiate between dancer and non-dancers. However, in the sample studied, these assessments did not provide clear or generalisable information about LBP.

Chapter Six again addresses research aim four. It is distinct from Chapter Five as it only examines differences in dancers with and without LBP. In addition, to improve the ability to identify changes associated with LBP, dancers with LBP had to have experienced LBP in the past two-months to be eligible. Walking gait, which has previously been used to identify kinematic deficits in people with LBP was also examined.[148]

Study five was completed in collaboration with the Harkness Center for Dance Injuries, which is part of the New York University Langone Center, New York, USA. The collaboration was facilitated by an Endeavour Research Fellowship, issued by the Australian Department of Education and Training. The manuscript for study five has been accepted with minor changes by Gait & Posture.

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## 6.2. Study 5: Multi-segment spine range of motion in dancers with and without recent low back pain

### 6.2.1. Abstract

***Introduction*** Reduced spine mobility has been identified as both a risk factor and a consequence for low back pain (LBP). However, it is not known if this biomechanical marker applies in athletic populations such as dancers, who are required to perform repetitive multi-planar spine movements. This study compared frontal and transverse plane spine range of motion (ROM) in dancers with and without recent low back pain (LBP), in two clinical movement tasks and walking gait.

***Methods*** Fifty-nine pre-professional and professional dancers (Female (F): 47, Male (M): 12) either with LBP in the past two months (F = 26, M = 9) or no LBP in the past 12 months (F = 21, M = 3) participated in this study. A multi-segment spine model was used to obtain thoracic and lumbar spine ROM during standing side bending, seated rotation, and walking gait. Independent t-tests were used to identify differences in mobility between groups. Analyses were performed on the entire sample, as well as the females separately.

***Results*** No significant differences were observed between groups when males and females were analysed together. When females were analysed separately, dancers with LBP displayed reduced upper lumbar transverse plane ROM in seated rotation (Effect Size (ES)= -0.61, 95% Confidence Interval (CI): -1.20, 0.02, p=0.04), as well as reduced lower lumbar transverse plane ROM (ES=-0.65, 95% CI: -1.24, -0.06, p=0.03) in gait. However, there was increased lower thoracic transverse plane ROM (ES=0.62, 95% CI: 0.04, 1.21, p=0.04) during gait. There were no frontal plane differences.

***Conclusion*** Despite evidence of an altered movement strategy in female dancers with recent LBP, the collective ability of segmental spine ROM measures to discriminate between dancers with and without LBP was limited.

### 6.2.2. Introduction

Dancers are vulnerable to the experience of low back pain (LBP). The point prevalence of LBP is estimated to range between 8-25% in pre-professional and professional dancers, and in this population, LBP is associated with activity limitation, care-seeking, and medication use.[195] Although it is acknowledged that multiple factors contribute to LBP, recent evidence suggests that physical factors, such as posture and spinal range of movement (ROM), contribute to the experience of LBP.[88][181] Therefore, an understanding of how these factors relate to LBP in a population exposed to repetitive, end-range spine movements is needed.

Research on non-dancer populations has shown that people with LBP move differently than those without LBP. For example, reduced spine mobility has been identified as a risk factor for serious first time LBP,[70] and people with less spine mobility sustain greater spine stresses during lifting tasks.[71] Movement inhibition may also represent a protective strategy in people with LBP.[63] Studies that have induced LBP via a nociceptive stimulus in healthy volunteers support this.[155] A protective response is not necessarily positive and, if it persists, may have long term consequences.[63]

Mechanical factors, such as spine mobility, may be of increased importance within a population such as dancers because the end range, multiplanar spine movements typical of dance increase the potential number and magnitude of physical stresses the spine may experience. In support of this, dancers with a history of LBP display impaired trunk damping, which suggests an impaired ability to control spine movement is related to LBP in this population.[80] However, other mechanical properties of the spine system, such as trunk stiffness, did not differ between dancers with and without LBP,[80] and, unlike non-dancers, sagittal plane spine mobility was not associated with LBP in dance students.[61]

Given these contrasting findings, there is scope for more detailed investigations of spinal mobility in dancers with LBP.

Assessment of maximum spine range of motion (ROM) and walking gait have been used to identify spine kinematic impairment associated with LBP in athletic and non-athletic populations.[65 66 88 148] However, methods previously used to examine spine kinematics relative to LBP have been less than optimal. First, many prior studies have used only a single segment model to assess spine kinematics.[65 66] As movements of the whole lumbar spine display high variability both within and between individuals,[14 164 207] and as regional spine segments display distinct patterns of movement across different tasks,[164] these measures are limited in their ability to accurately describe lumbar spine kinematics. In contrast to a single segment model, a multi-segment model of the lumbar spine was able to detect kinematic differences between males and females during a sit to stand task.[196] In addition, during gait, studies that have used a multi-segment spine model have detected ROM differences between persons with and without LBP that were not detected in studies that modelled the trunk as a single segment.[64 65 148] Second, many previous investigations of spine kinematics have been limited to the lumbar spine. More recently, differences in lumbar-thoracic kinematics have differentiated between LBP patients and healthy controls,[149 156] which implies that modelling the thoracic as well as lumbar segments may provide unique information about spine movement changes associated with LBP. Third, the few studies that examined kinematic variables in clinical and functional tasks have predominantly focused on the sagittal plane.[156 164] As spine movements involving lateral bending or axial rotation have been associated with increased stresses distributed across different structures of the spine,[208] as well as LBP outcomes,[15] knowledge of the frontal

and transverse planes is required, particularly in individuals with high multi-planar mobility demands, such as dancers.

The aim of this study was to use a multi-segment spine model to examine differences in spine ROM in the frontal and transverse planes in both clinical movement tasks and walking gait in dancers with and without LBP. It was hypothesised that dancers with recent LBP would have reduced spine segment ROM in the transverse and frontal planes during both clinical movement tasks and gait.

### 6.2.3. Methods

Female and male pre-professional (students enrolled in a tertiary dance programme) and professional (including full time, part time, and independent professionals) dancers aged 18 – 40 years with and without LBP were recruited from around the New York Metropolitan area via a series of posters, social media posts, and information sessions. Low back pain was defined as pain experienced in the posterior aspect of the body from the bottom of the 12th rib to the lower gluteal folds.[138] Dancers with LBP had experienced at least one episode of LBP that had an impact on their dance practice (i.e., more than a transient episode) during the last two months. Dancers without LBP had not experienced any form of LBP in the last 12 months. Exclusion criteria were the presence of a separate injury that prevented participation in dance activity or impacted kinematics, known spinal deformities, a spinal curvature greater than 7° (measured with a scoliometer by a physical therapist), a history of spinal or abdominal surgery or current pregnancy. Fifty-nine volunteers, including 35 with LBP in the past two months (Female (F): 26, Male (M): 9) and 24 with no LBP in the past 12 months (F: 21, M: 3), met the inclusion criteria for this

study. All volunteers provided written informed consent and ethics approval was obtained from the NYU School of Medicine's Institutional Review Board (study number 17-00490).

Participants attended a single data collection session at the at the Harkness Center for Dance Injuries, NYU Langone Medical Center. Participants completed a questionnaire that contained items relating to demographics (e.g. age, sex), dance participation (e.g. style, dance level, training background), LBP (e.g. impact, burden), and, to obtain a more complete description of the LBP experience, psychosocial factors (e.g. emotional distress,[209] Harkness Discomfort Scale (HDS),[210] and the Tampa Scale for Kinesiophobia (TSK)[197]). Emotional distress was determined using two valid and reliable 11-point scales relating to the experience of anxiety and depression in the past week that were taken from the Orebro Musculosketal Pain Questionnaire.[209] The HDS is a validated outcome measure which provides a score reflecting the frequency and severity of six painful body regions.[210]

Spinal kinematics were captured using a previously described multi-segment spine kinematics model.[148] [149] Five reflective markers (12.7mm, B & L Engineering, USA) were placed on the spinous processes of T1, T6, L1, L3 and L5, which were identified via palpation, eight lateral markers were placed 5 cm from the midpoint between each pair of spinous process markers, and four markers were placed on the right and left anterior superior-iliac spines and posterior superior iliac spines (**Figure 6.1**). Marker positions were collected at 250Hz using eight Eagle cameras (EGL500RT, Cortex, Motion Analysis Corp, CA, USA). After marker placement, trials of normal standing posture, frontal plane ROM in standing, transverse plane ROM in sitting, and walking gait were completed. For each task, a demonstration was provided along with standardised instructions and verbal cues (**Appendix E**). Verbal instructions were consistent with those used in previous studies.[148] [152] [192] Each task was completed at a self-selected pace in the same order. Multiple practice

attempts were provided, and two successful captures of each task were completed. Nine participants returned for a second testing session for reliability assessment purposes.



**Figure 6.1. Multi-segment spine marker set.**

Data processing was conducted in Visual 3-D (6.01.09, C-Motion, Inc. MD, USA). Marker data were filtered at 6Hz with a low-pass Butterworth filter to eliminate motion artefact. The trunk was divided into a series of five segments, including the pelvis, lower lumbar, upper lumbar, lower thoracic and upper thoracic spine segments. For each task, lower lumbar angles (LL) were defined as the angles between the lower lumbar and pelvis segments, the upper lumbar angles (UL) as the angles between the upper lumbar and lower lumbar segments, the lower thoracic angles (LT) as the angles between the lower thoracic and upper lumbar segments and the upper thoracic angles (UT) as the angles between the upper thoracic and lower thoracic segments.[148] To calculate ROM in the movement tasks, the start position was subtracted from the end position for both right and left sides, and the

higher value of the two trials to the right was added to the higher value of the two trials to the left. For gait, the first and second right heel strikes were defined as the start and end of the gait cycle respectively. Using a customised Matlab script (R2016b, MathWorks, Inc, MA, USA), joint angles captured with the standing reference posture were subtracted from the time series data, with the gait cycle time normalised to 100 points for each trial (using the Matlab spline function). Minimum and maximum peaks for each segment were extracted and used to calculate ROM.[148]

The Shapiro-Wilk test was used to determine whether data were normally distributed. Variables identified as non-parametric were log-transformed prior to any further analysis.[211] Independent T-tests were used to examine differences between groups and effect size (ES) was calculated using Cohen's d.[167] Effect Size results were interpreted as <0.1: trivial, 0.1–0.6: small, 0.6–1.2: moderate, and >1.2: large.[212] Intraclass correlation coefficients (ICC) (2-way mixed effects) and typical error of measurement expressed as a coefficient of variation (CV) were used to assess the test-retest reliability of kinematic variables collected on the day of testing as well as for measures collected on two separate days.[213] All statistical analyses were performed using SPSS software for Windows (version 22.0, SPSS Inc., IL, USA). Statistical significance was set at $P < 0.05$ for all tests. The sample size allowed a 0.99 power to detect a large (ES = 1.2) difference between groups for the entire sample and for females only, as well as a 0.72 power for the entire sample and 0.64 power for females only to detect a moderate (ES = 0.6) difference between groups, using an alpha of 0.05. As the male sample allowed for a power of only 0.51 to detect a large effect size and 0.21 to detect a moderate effect size, males were not analysed separately.

### 6.2.4. Results

There were no differences between the LBP and No LBP groups for age, height, body mass, BMI, or sagittal standing posture. Dancers with LBP had significantly higher emotional distress and more painful body regions than dancers without LBP (**Table 6.1**). Of the dancers with LBP, 16 (46%) reported current LBP, 29 (83%) reported chronic LBP, 13 (37%) experienced leg pain referral, 25 (71%) consulted a medical professional, and 23 (66%) consumed medication for their LBP. Only one dancer with LBP was classified as having moderate kinesiophobia (score = 33-42). The remaining dancers were classified as having sub-clinical (13-22) or mild (23-32) kinesiophobia.[197]

Good to excellent same day test-retest reliability for all ROM measures was demonstrated with ICC scores of 0.75 – 0.98 and CV scores between 4% – 24%.[213] Test-retest reliability on two different days was moderate to good with ICC's ranging from 0.63 to 0.88 and CV scores between 8 – 25%.

When males and females were analysed together, no differences in frontal plane ROM in standing or transverse plane ROM in sitting were observed. When males were removed from the analysis, dancers with LBP displayed reduced UL in seated rotation (ES=-0.61, 95% Confidence Interval (CI): -1.2, 0.02 p=0.04) (**Table 6.2**). During walking gait, no differences in either frontal or transverse planes were observed between groups. For females only, significantly reduced LLa (ES=-0.65, 95% CI: -1.24, -0.06, p=0.03) and increased LT (ES=0.62, 95% CI: 0.04, 1.21, p=0.05) were observed (**Figure 6.2**, **Table 6.3**).

**Table 6.1. Participant descriptive data.** Results are reported as mean (standard deviation) for continuous variables and frequencies (percentage) for categorical variables.

| Population descriptor | All | LBP | No LBP | P |
|---|---|---|---|---|
| Male | 12 (20) | 9 (26) | 3 (13) | 0.22 |
| Female | 47 (80) | 26 (74) | 21 (88) | |
| Age (Yrs) | 24.9 (6.1) | 25.0 (6.0) | 24.7 (6.4) | 0.85 |
| Height (CM) | 167.2 (9.0) | 166.7 (9.3) | 168.0 (8.6) | 0.59 |
| Body Mass (KG) | 62.1 (9.7) | 62.3 (10.8) | 61.7 (8.2) | 0.81 |
| BMI | 22.1 (2.4) | 22.4 (2.6) | 21.8 (2.0) | 0.39 |
| Curvature 3-7º (Y/N) | 10 (17) | 7 (20) | 3 (13) | 0.45 |
| *Dance level* | | | | |
| Full time Professional | 10 (17) | 7 (20) | 3 (13) | 0.70 |
| Independent/ Part time Professional | 27 (46) | 17 (49) | 10 (42) | |
| Pre-Professional Student | 22 (37) | 11 (31) | 11 (46) | |
| *Primary dance style* | | | | |
| Ballet | 5 (9) | 3 (9) | 2 (9) | 0.75 |
| Modern/ Contemporary | 44 (75) | 25 (71) | 19 (79) | |
| Musical Theatre/ Other | 10 (17) | 7 (20) | 3 (13) | |
| *Psychosocial measures* | | | | |
| Tension/ Anxiety (/10) | 5.4 (2.1) | 5.9 (2.0) | 4.7 (2.1) | **0.03** |
| Depression (/10) | 3.3 (2.4) | 3.7 (2.5) | 2.6 (2.0) | 0.06 |
| Emotional Distress Total (/20) | 8.7 (3.9) | 9.7 (3.9) | 7.3 (3.5) | **0.02** |
| Harkness Discomfort Scale (not incl. LB region) (/80) | 12.9 (8.0) | 14.8 (7.8) | 10.1 (7.6) | **0.03** |

BMI, body mass index; Bold indicates p <0.05.

**Table 6.2. Differences between groups: Maximum ROM assessment**

| Plane of motion | | All Participants | | | | Females Only | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | No LBP | LBP | ES (95% CI) | p | No LBP | LBP | ES (95% CI) | P |
| Frontal Plane | UT | 30.37 (7.31) | 30.31 (4.55) | -0.01 (-0.53, 0.51) | 0.97 | 30.54 (7.76) | 29.93 (3.74) | -0.11 (-0.68, 0.47) | 0.72 |
| (degrees) | LT | 41.31 (8.71) | 41.47 (8.09) | 0.02 (-0.05, 0.54) | 0.94 | 42.29 (8.71) | 41.67 (8.86) | -0.07 (-0.65, 0.51) | 0.81 |
| | UL | 26.94 (6.92) | 23.21 (7.81) | -0.50 (-1.02, 0.03) | 0.07 | 27.71 (8.07) | 23.89 (8.71) | -0.50 (-1.09, 0.08) | 0.10 |
| | LL | 16.54 (6.35) | 15.69 (6.03) | -0.14 (-0.66, 0.38) | 0.61 | 16.52 (6.75) | 15.63 (5.90) | -0.14 (-0.72, 0.44) | 0.63 |
| Transverse Plane | UT | 34.68 (10.81) | 33.42 (9.86) | -0.12 (-0.64, 0.38) | 0.65 | 34.07 (10.65) | 31.29 (8.36) | -0.30 (-0.87, 0.28) | 0.32 |
| (degrees) | LT | 40.74 (12.02) | 41.48 (8.96) | 0.07 (-0.45, 0.59) | 0.80 | 42.74 (11.16) | 42.53 (9.15) | -0.02 (-0.60, 0.56) | 0.96 |
| | UL | 17.36 (3.94) | 15.18 (4.27) | -0.53 (-1.04, 0.00) | 0.05 | 17.80 (3.45) | 15.35 (4.42) | -0.61(-1.20, 0.02) | **0.04** |
| | LL | 6.72 (2.99) | 6.6 (3.42) | -0.03 (-0.55, 0.49) | 0.90 | 6.79 (3.09) | 6.30 (2.93) | -0.16 (-0.74, 0.41) | 0.58 |

Bold indicates p <0.05.

**Table 6.3. Differences between groups: ROM in walking gait.**

| Plane of motion | | All Participants | | | | Females Only | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | No LBP | LBP | ES (95% CI) | p | No LBP | LBP | ES (95% CI) | P |
| Frontal Plane | UT | 5.94 (2.19) | 6.11 (1.90) | 0.09 (-0.43, 0.61) | 0.75 | 6.13 (2.27) | 5.91 (1.85) | -0.11 (-0.68, 0.47) | 0.72 |
| (degrees) | LT† | 5.05 (1.49) | 5.75 (1.57) | 0.3 (-0.22, 0.83) | 0.26 | 5.01 (1.53) | 5.75 (1.60) | 0.3 (-0.28, 0.88) | 0.30 |
| | UL† | 3.82 (1.51) | 3.91 (1.47) | 0.06 (-0.46, 0.58) | 0.12 | 3.92 (1.51) | 4.18 (1.45) | 0.17 (-0.41, 0.74) | 0.57 |
| | LL | 5.45 (1.24) | 5.26 (1.77) | -0.12 (-0.64, 0.40) | 0.63 | 5.44 (1.25) | 5.13 (1.71) | -0.2 (-0.78, 0.37) | 0.49 |
| Transverse Plane | UT† | 4.29 (1.47) | 4.62 (1.55) | 0.18 (-0.40, 0.76) | 0.50 | 4.16 (1.49) | 4.27 (1.51) | 0.06 (-0.05, 0.64) | 0.83 |
| (degrees) | LT† | 6.97 (1.45) | 8.43 (1.47) | 0.5 (-0.08, 1.09) | 0.06 | 6.86 (1.46) | 8.61 (1.42) | 0.62 (0.04, 1.21) | **0.04** |
| | UL† | 4.78 (1.66) | 4.30 (1.44) | -0.25 (-0.82, 0.33) | 0.38 | 4.93 (1.68) | 4.48 (1.48) | -0.21 (-0.79, 0.36) | 0.47 |
| | LL | 5.61 (1.15) | 5.09 (1.71) | -0.35 (-0.93, 0.23) | 0.16 | 5.82 (1.05) | 4.90 (1.66) | -0.65 (-1.24, -0.06) | **0.03** |

† Effect size calculated based on log transformed data. Mean and SD has been back transformed; Bold indicates p <0.05.
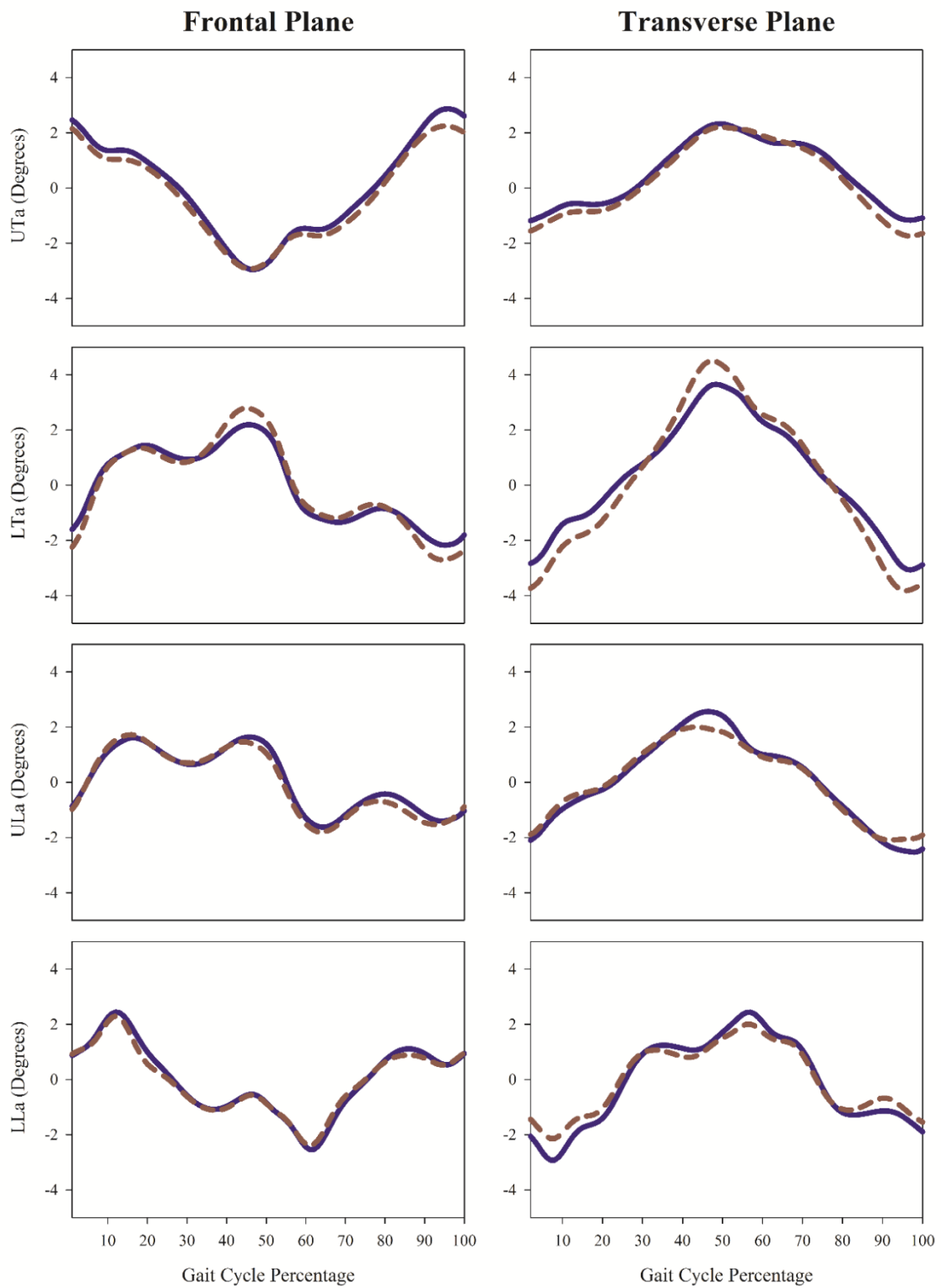
**Figure 6.2. Mean time normalised spine mobility during gait for females only.** The No LBP group is represented by the blue (complete) line, the LBP group by the red (dash) line.

### 6.2.5. Discussion

This study examined differences in spine mobility in dancers with and without LBP. Assessment of maximum ROM and walking gait was performed as these tasks have previously been used to identify kinematic impairment associated with LBP.[65 66 88 148] Furthermore, as sex contributes to variability in spine kinematics,[156 204 205] analysis was performed on males and females together as well as females separately. No significant differences between groups were observed in spine segment ROM when the males and females were analysed together. When females were analysed separately, those with recent LBP did display reduced upper lumbar angles during the transverse plane ROM assessment and walked with altered spine kinematics in the transverse plane compared to their asymptomatic counterparts (e.g., reduced LL segments but increased LT segments), but no differences in the frontal plane were observed. Overall, while a small number of significant differences amongst the female sample prevent a simple interpretation, the results do not support a strong relationship between reduced spine ROM and LBP in dancers.

An absence of clear differences between groups was unexpected and contrasts with prior research conducted in non-dancers. Previously, a meta-analysis of 26 studies identified significantly reduced lumbar spine mobility all three planes of motion for people with LBP compared to those without,[66] as did a study that used a multi-segment spine model in athletes.[88] Although we did observe reduced upper lumbar angles in the transverse plane in female dancers with LBP, the key finding is that these measures had limited ability to discriminate between dancers with and without recent LBP, who were significantly different in other measures, such as emotional distress. This finding does suggest dancers are unlike other studied populations, which is not an unprecedented observation. Two recent studies conducted within a professional ballet company found that, unlike non-

athletic and other athletic populations, trunk stiffness was not significantly higher in dancers with a history of LBP compared to dancers without,[80] and that dancers with LBP did not have a reduced ability to reduce the abdominal cross-sectional area during a 'draw-in' manoeuvre.[5] Possible explanations for this may include that dance practice, which places large emphasis on how movements are performed, protects against kinematic changes associated with LBP, that spine mobility is required for progression within dance and that some natural selection has occurred, or that there is such variability within the population that differences may be hidden.

In the current study, female dancers with recent LBP displayed reduced lower lumbar and increased lower thoracic angles in the transverse plane during walking gait. Previous studies have found altered spine kinematics during gait in people with LBP, although the specific differences vary between studies. For example, a series of studies on walking gait in persons with LBP identified a more rigid and less variable coordination pattern for people with LBP in the transverse plane, but not the frontal plane.[64 65] However, unlike the current study, these studies did not detect differences in ROM during gait. Importantly, as the trunk was modelled as a single segment between the pelvis and shoulders, comparison with the current study is difficult. Using the same model as the current study, Christe, et al. [148] identified reduced lower lumbar angles in the frontal plane in chronic LBP participants, confirming the presence of altered kinematics in the LBP patients, but unlike in the current study did not observe differences in absolute range of motion for any segment in the transverse plane. The population studied may provide explanation for some of these differences. On average, dancers have flatter standing postures than non-dancers,[61] unique abdominal muscle morphology,[5] and bone morphology that may allow greater ROM at the hip.[214]

We speculate that the differences in spine segment ROM observed in walking gait in the current study may indicate an altered movement strategy, whereby female dancers with recent LBP compensate for reduced mobility in painful regions by increasing mobility in less painful regions. If so, these changes may offer short term protective benefit. However, caution should be exercised when considering the utility of adaptation. If the differences represent a suboptimal response, or persist for longer than required, they may result in abnormal tissue loading and contribute to the recurrence of symptoms.[63] That these differences were only visible once males where removed from the analysis may reflect the influence of sex on spine kinematics.[156 204 205] Alternatively, it may reflect variability in how individuals respond to pain.[63 155] Regardless, the findings cannot be generalised to all dancers.

The findings of the current study present several implications. First, for clinical practice, collectively, the simple movement assessments did not provide clear, generalisable information about the experience of LBP. Future research should consider whether more challenging or dance specific movement assessments are better able to identify movement impairment in dancers with LBP. Second, the current study does not support that movement changes related to pain are more pronounced in a population with high mechanical demands such as dancers. Whether dance practice protects against these changes, or dancers possess pain thresholds that allow them to resist movement change warrants further attention. Third, although pain can change movement, that dancers with recent and impactful LBP did not present with clear movement differences reminds that LBP is not exclusively a movement condition.

There are several methodological issues that require consideration when interpreting the findings of this study. First, participants were eligible for the no pain group if they had not

experienced any form of LBP in the past 12 months. While the authors believe that dancing at a high level without experiencing LBP for 12 months is enough to consider an individual back healthy, it is possible that some participants in the No LBP group had a history that may have influenced the kinematic measurements. Second, although individuals with a scoliosis were not eligible for participation, 10 participants presented with a curvature between 3-7°. As these participants did not meet the threshold for exclusion, and their total spine mobility was within the normal range of variance observed in the other participants, we did not exclude them from the analysis. Nonetheless, it is still possible that these spine characteristics influence spine mobility or LBP in ways not understood. Third, the use of skin markers may influence kinematic data. However, the values obtained for segmental range of motion in clinical tasks agreed with data from x-ray analysis of normal spine movement,[159] and the reliability of the methods was good, including testing on two separate days requiring reapplication of markers, indicating the measures used were appropriate.

### 6.2.6. Conclusion

Despite suggestion of an altered movement strategy in female dancers with recent LBP, collectively, the ability of segmental spine ROM measures to discriminate between dancers with and without LBP was limited. The findings do not support that altered kinematic associated with LBP are more pronounced in a movement orientated population such as dancers.

## 6.3. Summary of Chapter Six

Chapter Six examined differences in spine kinematics in dancers with and without recent LBP. When females were analysed separately, dancers with recent LBP did display altered spine kinematics when walking. This altered kinematic strategy may reflect that the experience of pain or its anticipation influence movement execution and behaviour. However, collectively, the ability to differentiate between dancers with and without recent LBP using measures of spine kinematics was low. No differences were observed when males and females were analysed together and only a small total number of moderate sized differences were observed in females. When considering the characteristics (e.g. chronicity and referred pain) and the impact (e.g. care-seeking and medication use) of LBP, as well as the higher emotional distress evident in the pain group, it becomes clear that pain can have significant impact without causing movement incapacity.

# Chapter Seven: Discussion and conclusion

## 7.1. Overview of Chapter Seven

The overarching aim of this thesis was to investigate the prevalence, impact, and associated factors for LBP in dance. To do so, this program of research included a systematic review, a prospective cohort study, and two three-dimensional motion analysis studies. This chapter provides a summary of the key findings and presents the strengths and limitations of this overall programme of research. Implications and recommendations relating to clinical practice and future research are considered.

## 7.2. Strengths and limitations of this research

The research conducted within this thesis had several key strengths. First, the cohort study was the first to prospectively investigate the prevalence and impact of LBP in dance. The prospective approach provided new information on the duration, intensity, and variation of LBP symptoms experienced in a dance population. The study methods (e.g. a prospective design that used an established LBP definition and one-month recall period) and reporting of outcomes (e.g. duration and intensity of LBP episodes) were consistent with recommendations from dance science and public health literature.[22 29 55] Furthermore, the multivariable statistical analysis used to examine potential LBP risk factors allowed for adjustment of potential confounding variables that has been recommended in LBP and dance injury literature.[22 82] The biomechanical studies employed three-dimensional motion analysis and a multi-segment spine marker set to examine a series of movements that have previously been able to discriminate between non-dancers with and without LBP.[66 148] These methods provided a more sensitive and precise characterisation of spine movement

than those which model the lumbar spine as a single segment,[149 196] or assessments that rely on clinical interpretation of movement outcomes. These key strengths resulted in a comprehensive program of research.

Several limitations should be considered when interpreting the findings of this research. First, for all studies, a highly trained, specialist population was recruited. Although this is a strength, it did limit the potential number of participants, and along with the high prevalence of LBP observed, limited the power of several statistical analyses. In study three this was compounded by participant attrition. In studies four and five, the small participant numbers prevented sub-grouping based on sex or common classification approaches based on movement and posture for biomechanical analyses (e.g. the O'Sullivan classification system or the movement system impairment approach).[215 216] Differentiating people with LBP into more homogeneous sub-groups may have enhanced the ability to detect alterations in spine movement associated with LBP. Second, participants included pre-professional and professional dancers from both contemporary dance and classical ballet disciplines. While this wide range of participants improves the generalisability of the findings, differences in workloads and repertoires across dance levels, disciplines and styles limits the specificity of outcomes. Third, the biomechanical studies were cross-sectional in design and only able to analyse spine movement in participants with LBP in relation to their asymptomatic counterparts. They were not able to examine causation or the extent to which movement may fluctuate with LBP symptoms over time.

## 7.3. Key Findings

1. The heterogeneous nature of available research into LBP in dance limits
   understanding

***Summary:*** Study one systematically reviewed the available research into LBP and injury in dance. There was considerable methodological heterogeneity amongst the research design, population sampled, definitions used, data collection methods, and reporting of outcomes in the included studies.

***Implication:*** Large heterogeneity in study methods and findings creates limitations and prevents clear summary and interpretation of results from different studies. In addition, absence of studies that have performed multivariable analyses limits the insight of LBP risk factors. Hence, although it is often implied that dancers are vulnerable to LBP and injury, a clear understanding of the problem is not available. Consequently, the ability to plan, monitor, and evaluate low back specific intervention strategies in dance is currently limited.

***Recommendation:*** Investigation of LBP requires definitions and study designs that are sensitive to the complex nature of pain. As pain is subjective, these definitions should combine self-report with standardised language as well as a description of the low back. In addition, items relating to duration, intensity, and impact of the pain should be included. This may improve future comparisons of LBP prevalence figures in dance, provide opportunities for statistical summaries as well as intervention evaluation. Furthermore, future studies examining the association between potential risk factors and LBP in dance should control for all known confounding factors, including age, sex, physical and psychosocial factors, as well as factors related to dance practice (e.g. training hours, repertoire, attitudes towards pain).

2. The prevalence of LBP in dance is high

*Summary:* Studies one, two, and three identified a point, monthly, yearly, and lifetime prevalence that was at least equal to, if not higher than, prevalence rates reported in the global adolescent and adult populations, as well as sub-elite and elite populations participating in Olympic sports. In the prospective study, more than half of responders indicated they limited their dance participation to some extent because of LBP in a nine-month period. Moreover, close to a quarter of these dancers experienced chronic LBP in during this time. Importantly, the findings from studies two and three, which were not included in the systematic review in chapter two, did not change the conclusions of chapter two. Rather they reinforced that the prevalence of LBP in dance is high.

*Implication:* Pre-professional and professional dancers are vulnerable to LBP. Strategies are needed to reduce the occurrence and minimise the impact of LBP in dance.

*Recommendation:* Given dancers are vulnerable to LBP, education regarding the experience of LBP and its implications seems appropriate. Education presenting simple, evidence-based information about LBP may be preventative while also reducing in clinically important ways both LBP-related fear-avoidance beliefs and disability.[38 217]

3. There is considerable variability in how individual dancers experience LBP

*Summary:* While study three identified a high prevalence of LBP, for some dancers, the experience of LBP did not result in any modification to practice and was limited to a single episode. For others, activity limitation was severe, pain was ongoing, and was associated with consumption of healthcare services and analgesic medication.

*Implication:* These findings present several implications. First, the experience of LBP does not determine the degree of disability; however, nor does it guarantee automatic recovery. Hence, traditional definitions of injury that require a time loss or medical attention threshold for registration will not provide an accurate description of LBP prevalence. Second, even with the use of appropriate definitions, a simple description of prevalence will only provide a partial overview of the problem and is unable to fully capture the burden of LBP disability.

*Recommendations:* Future LBP epidemiological studies should not just consider the prevalence of LBP, but also the symptoms, impact, and behaviour it provokes. In addition, future research is needed to investigate the factors that moderate the progression of a single episode of LBP to more disabling, chronic pain.

4. A history of LBP predicts future episodes of LBP

*Summary:* In study three, dancers with a history of LBP were significantly more likely to experience an episode of activity limiting LBP. History has been a dominant risk factor for LBP in several previous investigations of non-dancers,[51] and, in dance, there is some evidence that supports that previous injury may predict future injury.[22 59]

*Implication:* The association between history and future occurrence may reflect the cyclic nature of the condition. As such, it is unlikely that the experience of LBP is limited to a single episode.

*Recommendation:* History of LBP should continue to be included in pre-screening to identify dancers who may have increased vulnerability. Understanding the cyclic nature

of LBP may improve management and allow for the development of interventions that focus on limiting the impact of recurrent episodes.

5. <u>There was no association between personal or demographic factors and LBP</u>

*Summary:* In studies two and three, no personal or demographic factors were associated with the experience of LBP. The systematic review also supported this, as no one factor was consistently associated with LBP across reviewed studies. This is consistent with prior LBP research in general and sporting populations and acknowledges there is no simple explanation for LBP.

*Implication:* LBP is not a simple condition that can be easily attributed to a narrow selection of biological or dance practice factors. All individuals that participate in dance may be vulnerable.

*Recommendation:* As available evidence has not identified association between individual or demographic factors and LBP in dance, strategies or initiatives directed towards LBP in dance should be inclusive of all dancers.

6. <u>Subtle differences in movement may exist in some dancers with LBP</u>

*Summary:* In study five, female dancers with LBP displayed reduced transverse plane ROM of the lower lumbar spine segment and increased ROM of the lower thoracic spine segment during walking gait. It is possible that this change in movement represents an altered movement strategy and that lower lumbar movement is restricted in response to or anticipation of pain, and, to compensate, movement in the lower thoracic segment is increased.

*Implication:* Although these differences may reflect a protective movement strategy, caution is needed when considering the utility of adaptation. If the movement difference represents a suboptimal response, or persists for longer than required, it may result in abnormal tissue loading and contribute to symptom recurrence. Although an association between LBP and altered spine kinematics was identified, the clinical significance of (including arguments for and against) this finding requires further investigation.

*Recommendation:* Prospective research is needed to understand how movement changes in response to pain, whether changes precede or are a consequence of pain, and the extent to which movement changes fluctuate with pain symptoms.

7. <u>Overall, no clear and generalisable relationship between LBP and spine kinematics was identified</u>

*Summary:* In study four, there was no interaction between dance and LBP for spine posture, ROM, or movement asymmetry. In study five, although female dancers with recent LBP did display an altered movement strategy during walking gait, the differences between groups were subtle, and the total number of differences in all assessments was small. These investigations were limited to the frontal and transverse planes.

*Implication:* Clinical assessment of posture and ROM does not provide generalizable information about dancers with LBP. Moreover, dancers who experienced recent, impactful, and often chronic LBP presented with increased emotional distress but not clear differences in movement. This is a reminder that LBP should not simply be

considered solely a mechanical condition. Pain can have significant impact without causing disability.

***Recommendation:*** Subgrouping dancers with LBP based on posture, pain provoking movement patterns,[215 216] sagittal plane assessment, or the use of more probing clinical assessment may be required to provide information about potential movement deficits related to LBP in dance, although this has not yet been confirmed in this population. Whether dance protects against changes typically associated with LBP, or dancers possess pain thresholds that allow them to resist movement change warrants further attention.

## 7.4. Concluding statement

Prior to this research, the lower back was considered a common site of injury in dance, which was often attributed to the repetitive movement and lifting demands required by dancers. However, given the limitations in pre-existing research, clarity on this relationship was lacking. This thesis confirms LBP is a common problem within dance. Moreover, it provides new information concerning how LBP is experienced by dancers and the associated factors. Impact ranged from personal discomfort that did not manifest into externally recordable outcomes, through to more severe, disabling, and chronic symptoms. Consistent with previous research, there was some evidence for changes in movement in female dancers with LBP. However, the effect sizes of these biomechanical differences were modest, the number of differences between groups was small, and the differences were not generalisable to all participants or consistent across studies. This complexity should not be viewed as a negative. Rather, it is hoped that a more complete understanding of LBP within dance will allow for a more sensitive, tailored approach to LBP management.

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# Appendices

## Appendix A: Research portfolio appendix

*Manuscripts related to this thesis*

<u>Study One</u>

Swain, C. T. V., Bradshaw, E. J. Ekegren, C. L., Whyte, D. G. Epidemiology of low back pain and injury in dance: a systematic review.

Status (27.01.2019): Accepted for publication. Journal of Orthopaedic & Sports Physical Therapy. ID: 07-18-8609-LR.

| Author | Contribution (%. Nature of contribution) |
|---|---|
| Christopher T.V. Swain | 75%. Concept and design, data extraction, data synthesis, interpretation of results and writing of manuscript |
| Elizabeth Bradshaw | 10%. Concept and design, data extraction, writing of manuscript |
| Christina L. Ekegren | 5%. Concept and design, writing of manuscript |
| Douglas G. Whyte | 10%. Concept and design, data extraction, writing of manuscript |

Statement from the student:

*I acknowledge that my contribution to the above paper is 75% percent.*

Christopher Swain. 14/8/18

Statement of contribution of others:

I acknowledge that my contribution to the above paper is accurate.

Elizabeth Bradshaw 14/8/18          Christina Ekegren 17/8/18          Doug Whyte. 17/8/18.

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Study Two:

Swain, C. T. V., Bradshaw, E. J., Whyte, D. G., & Ekegren, C. L. Life history and point prevalence of low back pain in pre-professional and professional dancers. *Phys Ther Sport*. 2017; 25:34-8.

*Status: Published*

| Author | Contribution (%. Nature of contribution) |
|---|---|
| Christopher T.V. Swain | 80%. Concept and design, recruitment, data collection, analysis, writing of the manuscript. |
| Elizabeth J. Bradshaw | 5%. Concept and design, writing of manuscript. |
| Douglas G. Whyte | 5%. Concept and design, writing of manuscript. |
| Christina L. Ekegren | 10%. Concept and design, data analysis, writing of the manuscript. |

Statement from the student:

*I acknowledge that my contribution to the above paper is 80% percent.*

Christopher Swain. 14/8/18

Statement of contribution of others:

I acknowledge that my contribution to the above paper is accurate.

Elizabeth Bradshaw 14/8/18          Doug Whyte 17/8/18          Christina      Ekegren
17/8/18

Study Three:

Swain, C. T. V., Bradshaw, E. J., Whyte, D. G., & Ekegren, C. L. The prevalence and impact of low back pain in pre-professional and professional dancers: a longitudinal study. *Phys Ther Sport*. 2018; 30:8-13.

*Status: Published*

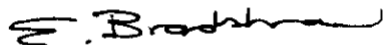| Author | Contribution (%. Nature of contribution) |
|---|---|
| Christopher T.V. Swain | 80%. Concept and design, recruitment, data collection, analysis, writing of the manuscript. |
| Elizabeth J. Bradshaw | 5%. Concept and design, writing of manuscript. |
| Douglas G. Whyte | 5%. Concept and design, writing of manuscript. |
| Christina L. Ekegren | 10%. Concept and design, data analysis, writing of the manuscript. |

Statement from the student:

I acknowledge that my contribution to the above paper is 80% percent.

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17/8/18

Study Four:

Swain, C. T. V., Whyte, D. W., Ekegren, C. L. et al. Multi-segment spine kinematics:

Relationship with dance training and low back pain.

Status (27.01.2019): Accepted for publication. Gait & Posture. ID: GAIPOS_2018_578.

| Author | Contribution (%. Nature of contribution) |
|---|---|
| Christopher T.V. Swain | 65%. Concept and design, recruitment, data collection, data processing, data analysis, writing of the manuscript. |
| Douglas G. Whyte | 5% Concept and design, writing of the manuscript. |
| Christina L. Ekegren | 5% Concept and design, writing of the manuscript. |
| Paul Taylor | 5% Concept and design, writing of the manuscript. |
| Kate McMaster | 5% Recruitment, data collection, approval of the final manuscript. |
| Connor Lee Dow | 5% Recruitment, data collection, approval of the final manuscript. |
| Elizabeth J. Bradshaw | 10% Concept and design, writing of the manuscript. |

Statement from the student:

I acknowledge that my contribution to the above paper is 65% percent.

Christopher Swain. 27.7.2018

Statement of contribution of others:

I acknowledge that my contribution to the above paper is accurate.

Doug Whyte 17.8.18          Christina Ekegren 17.8.18          Paul Taylor 10.8.18

Kate McMaster 10/8/18          Connor Lee Dow 10/8/18          Elizabeth Bradshaw 14/8/18

| Author | Contribution (%. Nature of contribution) |
|---|---|
| Christopher T.V. Swain | 60%. Concept and design, recruitment, data collection, data processing, data analysis, writing of the manuscript. |
| Elizabeth J. Bradshaw | 5% Concept, writing of the manuscript. |
| Christina L. Ekegren | 5% Concept, writing of the manuscript. |
| Karl F. Orishimo | 5% Concept, data processing and interpretation, writing of the manuscript. |
| Ian J. Kremenic | 5% Concept, data interpretation, writing of the manuscript. |
| Marijeanne Liederbach | 5% Concept and design, recruitment, data interpretation, writing of the manuscript. |
| Marshall Hagins | 15% Concept and design, recruitment, data collection, data interpretation, writing of the manuscript. |

Statement from the student:

I acknowledge that my contribution to the above paper is 60% percent.

Christopher Swain. 27.7.2018

Statement of contribution of others:

I acknowledge that my contribution to the above paper is accurate.

Elizabeth Bradshaw 30/7/18          Christina Ekegren. 27/7/18

Karl F. Orishimo 28/7/18

Ian J. Kremenic 13/8/18

Marijeanne Liederbach 13/8/18

Marshall Hagins 27/7/18

*Conference presentations related to this thesis*

Swain, C., Bradshaw, E., Ekegren, C., et al. Multi-segment spine range of motion in dancers with and without recent low back pain. 17th World Congress on Pain; September 2018, Boston, USA.

Swain, C., Bradshaw, E., Whyte, D., et al. The experience of low back pain in pre-professional and professional dancers: a longitudinal study. Med Sci Sports Exerc. 49(5S):423-424, May 2017.

Swain, C., Ekegren, C., Whyte, D., et al. Lifetime history and point prevalence of low back pain in pre-professional and professional dancers. 2017. J Sci Med Sport. 20: e55.

Swain, C; Whyte, D; Bradshaw, E. Physical exposure and low back pain in dance. Proceedings from the 26th Annual Conference of the International Association of Dance Medicine and Science 2016; Hong Kong.


*Letter to the editor published during the completion of this thesis*

Swain C.T.V., Ekegren C.L. Upholding standards of reporting in the synthesis of dance epidemiology literature: Letter to the editor re: Prevalence and profile of musculoskeletal injuries in ballet dancers. *Phys Ther Sport* 2016; 22:129-30.

*Endeavour Research Fellowship*

Completion certificate on next page.

**Australia Awards**

# ENDEAVOUR
## Scholarships and Fellowships

This is to certify that

## *Mr Christopher Swain*

has completed an

## Endeavour Research Fellowship

**Senator the Hon Simon Birmingham**
Minister for Education and Training

January 2018

**Appendix B: Risk of Bias in Prevalence Studies Tool**

Adapted from:

Hoy D, Brooks P, Woolf A, Blyth F, March L, Bain C et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. J Clin Epidemiol. 2012;65(9):934-9.

| Risk of bias item | Risk of bias level/ examples |
|---|---|
| 1. Was the study's target population a close representation of the national population? | Low risk: the study's target population was a close representation of the national population.<br>e.g. The study sampled multiple cohorts in multiple locations |
| | High risk: the study's target population was clearly not representative of the national population.<br>e.g. The study sampled a single cohort only or multiple cohorts limited from a single city. |
| 2. Was the sampling frame a true or close representation of the target population? | Low risk: the sampling frame was a true or close representation of the target population.<br>e.g. The target population was professional ballet dancers and the sampling frame was a professional ballet company. |
| | High risk: the sampling frame was not a true or close representation of the target population.<br>e.g. The sampling frame was limited to only injured dancers. |
| 3. Was some form of random selection used to select the sample or was a census undertaken? | Low risk: a census was undertaken, or, some form of random selection was used to select the sample.<br>e.g. An entire cohort was invited to participate. |
| | High risk: a census was not undertaken; random selection was not used.<br>e.g. Only dancers treated by one health professional were sampled. |
| 4. Was the likelihood of non-response bias minimal? | Low risk: the response rate for the study was ≥ 75% or there were no significant differences in relevant demographic characteristics between responders and non-responders. |
| | High risk: the response rate was < 75%, and there were significant demographic differences between responders and |

| | non-responders or differences between responders and non-responders were not reported. |
|---|---|
| 5. Were data collected directly from the subjects (as opposed to a proxy)? | Low risk: all data were collected directly from the subjects. |
| | High risk: data were collected from a proxy. e.g. Physiotherapist records were used to determine prevalence or incidence. |
| 6. Was an acceptable case definition used in the study? | Low risk: an acceptable definition of pain or injury was used, and the low back region was clearly defined. e.g. LBP was defined as pain experienced between the lower 12<sup>th</sup> rib and upper gluteal fold and was accompanied by a diagram. |
| | High risk: an acceptable definition of pain or injury was not used, and/or no description of the low back was provided. e.g. No threshold for injury reporting is provided and no description of the low back region was provided. |
| 7. Was the study instrument that measured the parameter of interest shown to have reliability and validity? | Low risk: the instrument used had been shown to have reliability and validity. |
| | High risk: reliability or validity had not been established. |
| 8. Was the same mode of data collection used for all subjects? | Low risk: the same mode of data collection was used for all subjects. |
| | High risk: the same mode of data collection was not used for all subjects. |
| 9. Was the length of the shortest prevalence period for the parameter of interest appropriate? | Low risk: the shortest prevalence period for the parameter of interest was appropriate e.g. the study reports point prevalence, one-month prevalence, or injury was registered upon occurrence. |
| | High risk: The shortest prevalence period for the parameter of interest was not appropriate e.g. the study reports prevalence greater than one-month recall. |
| 10. Were the numerators and denominators accurate and appropriate? | Low risk: there were no errors in the reporting of the numerator and denominator for the parameters of interest. |
| | High risk: there were clear errors in the numerator and the denominator reported. |

LBP = Low Back Pain

## Appendix C: Initial low back pain questionnaire (Study Two)

Q1 Enter your mothers' initials and the final 3 numbers of your phone number (e.g. AM452)*
*This will be used as your identification number for this study*

_____

Q2 Gender*

○ Male (1)

○ Female (2)

Q3 What is your date of birth (DD/MM/YYYY)?*

_____

Q4 Height (cm)

_____

Q5 Weight (kg)

_____

Q6 What year/ form of school are you in?*

_____

Q7 How old were you when you began formal dance training?*

_____

Q8 *The following questions relate to menstrual function.*

*These questions are standard in sport medicine and are important as there is often an association between menstrual function and bone health.*

*Please note that all responses are confidential, and the researchers will not see your individual identity.*

Q9 Have you had a menstrual period?

⭕ Yes  (1)

⭕ No  (2)

⭕ I don't want to answer this  (3)

Q10 How old where you when you first had your menstrual period? Please answer to the nearest half year (e.g. 12.5)

_____

Q11 How many periods have you had in the past 12 months?

_____

Q12 Are you taking any female hormones (e.g. birth control pills, estrogen, progesterone)?
*Please note that all responses are confidential, and the researchers will not see your individual identity*

◯ Yes (1)

◯ No (2)

Q13 Please list the brand of any birth control pills
*Please note that all responses are confidential, and the researchers will not see your individual identity*

_____

**End of Block: Initial Block**

Q14 *The following questions are designed to give an indication of your maturation stage.*

*These questions are standard in sports medicine and healthcare research.*

*Please note that all responses are confidential, and the researchers will not see your individual identity.*

---

Q15 *You do not have to answer these questions if you do not want to.*

○ I am happy to answer these  (1)

○ I do not want to answer these  (2)

---

Q16



Stage 2          Stage 3          Stage 4          Stage 5

---

Q17 Which of the following best describes your current stage of pubic hair development?

○ Stage 1  (1)

○ Stage 2  (2)

○ Stage 3  (3)

○ Stage 4  (4)

○ Stage 5  (5)

○ I don't want to answer this  (6)

---

Q18



Stage 1. Prepubertal

Stage 2. Elevation of breasts and papilla

Stage 3. Further elevation and areola but no separation of contours

Stage 4. Areola and papilla form a secondary mound above level of the breast

Stage 5. Areola recesses to the general contour of the breast

---

Q19 Which of the following best describes your current stage of breast development?

○ Stage 1  (1)

○ Stage 2  (2)

○ Stage 3  (3)

○ Stage 4  (4)

○ Stage 5  (5)

○ I don't want to answer this  (6)

---

Q20

**Genital and Pubic Hair Development Stages**



Stage 2          Stage 3          Stage 4          Stage 5

---

Q21 Which of the following best describes your current stage of pubic hair development?

○ Stage 1 (no hair)  (1)

○ Stage 2  (2)

○ Stage 3  (3)

○ Stage 4  (4)

○ Stage 5  (5)

○ I don't want to answer this  (6)

----

Q22 Which of the following best describes your current stage of genital development?

○ Stage 1  (1)

○ Stage 2  (2)

○ Stage 3  (3)

○ Stage 4  (4)

○ Stage 5  (5)

○ I don't want to answer this  (6)

End of Block: Growth and Maturation

Start of Block: LBP History

Q23



Low Back

Please do not report pain from feverish illness or menstruation

---
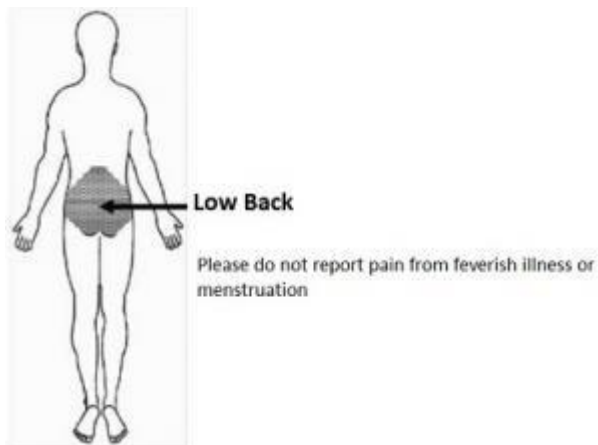
Q24 Have you ever experienced low back pain at any time in your life?
(In the area shown on the diagram above)

○ Yes  (1)

○ No  (2)

---

Q25 When did you last experience low back pain?

○ I currently have low back pain  (1)

○ Within the last 3 months  (2)

○ Within the last year  (3)

○ More than 1 year ago  (4)

End of Block: LBP History

**Appendix D: Monthly low back pain questionnaire (Study Three)**

Q1 Enter your identification number
*This was your mothers initials and the final 3 numbers of your phone number (e.g. AM452)*

_____

Q2
**Low Back Pain**
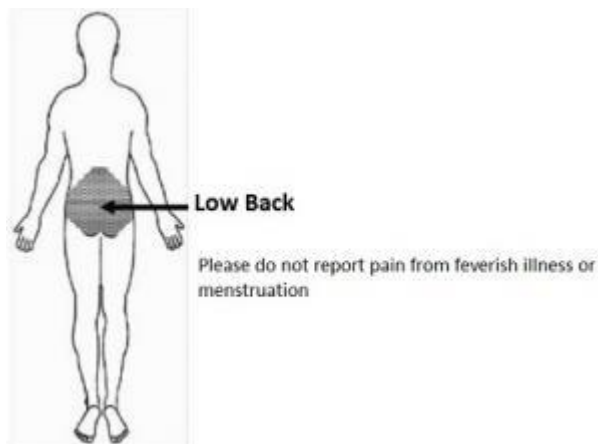


Q3 During November did you have pain in your lower back?

○ Yes  (1)

○ No  (2)

Q4 Is this back pain new (i.e. was not present during the previous questionnaire)?

○ Yes  (1)

○ No  (2)

---

Q5 How intense is the pain on a scale of 0-10? Where 0 means 'no pain' and 10 means 'the worst pain'

▼ 0 (12) ... 10 (32)

---

Q24 Are you currently experiencing low back pain?

○ Yes  (1)

○ No  (2)

---

Q6 What percentage of dance activities (i.e. class, rehearsal, performance) have you **missed** due to your low back pain?

○ 0% (1)

○ 1-25% (4)

○ 26-50% (2)

○ 51-75% (3)

○ 76-100% (5)

---

Q7 What percentage of dance activities (i.e. class, rehearsal, performance) have you **modified** due to your low back pain?

○ 0% (1)

○ 1-25% (2)

○ 26-50% (3)

○ 51-75% (4)

○ 76-100% (5)

---

Q8 In November, how many days of dance activities in total have you missed or modified due to your low back pain?
(e.g. 2 days missed, 3 days modified)

_____

Q9 Did you see any medical, health or rehabilitation professional for treatment of your low back pain?
(e.g. a doctor, physiotherapist, Pilates teacher, physiologist etc.)

○ Yes (please list)  (1) _____

○ No  (3)

Q10 Did you take any medication or pain killers for your back pain?

○ Yes (please list)  (1) _____

○ No  (2)

**End of Block: LBP**

**Start of Block: Dance Activity**

Q11 Over the month, which of the following activities have you completed?

☐      Classical/ Ballet Class  (1)

☐      Contemporary Class  (2)

☐      Other Dance Class Types (e.g. Jazz, Spanish, Hip Hop)  (3)

☐      Rehearsal and performance development (inc. choreographic practice etc.)  (4)

☐      Performance  (5)

☐      Other training (e.g. Pilates, yoga, gym work etc.)  (6)

☐      Nothing.  (8)

---

Q12 How many ballet classes did you complete in November?

|  | Classes Attended |
| --- | --- |
| Week 1 (31/10-6/11) (1) | ▼ 0 (1 … 12 (13) |
| Week 2 (7-13/11) (2) | ▼ 0 (1 … 12 (13) |
| Week 3 (14-20/11) (3) | ▼ 0 (1 … 12 (13) |
| Week 4 (21-27/11) (4) | ▼ 0 (1 … 12 (13) |

---

Q13 What is the average length of each ballet class (e.g. 1.5hrs)?

_____

Q14 How many Contemporary classes did you complete in November?

| | Classes Attended |
|---|---|
| Week 1 (31/10-6/11) (1) | ▼ 0 (1 … 12 (13) |
| Week 2 (7-13/11) (2) | ▼ 0 (1 … 12 (13) |
| Week 3 (14-20/11) (3) | ▼ 0 (1 … 12 (13) |
| Week 4 (21-27/11) (4) | ▼ 0 (1 … 12 (13) |

Q15 What is the average length of each Contemporary class (e.g. 1.5hrs)?

_____

Q16 How many other dance classes (e.g. world dance, hip hop etc.) did you complete?

| | Classes Attended |
|---|---|
| Week 1 (31/10-6/11) (1) | ▼ 0 (1 … 12 (13) |
| Week 2 (7-13/11) (2) | ▼ 0 (1 … 12 (13) |
| Week 3 (14-20/11) (3) | ▼ 0 (1 … 12 (13) |
| Week 4 (21-27/11) (4) | ▼ 0 (1 … 12 (13) |

Q17 What is the average length of these classes (e.g. 1.5hrs)?

_____

Q18 How many rehearsal days and rehearsal hours did you complete?

|  | Rehearsal Days | Rehearsal Hours |
|---|---|---|
| Week 1 (31/10-6/11) (1) | ▼ 0 (1 ... 7 (8) | ▼ 0 (1 ... 50hrs (51) |
| Week 2 (7-13/11) (2) | ▼ 0 (1 ... 7 (8) | ▼ 0 (1 ... 50hrs (51) |
| Week 3 (14-20/11) (3) | ▼ 0 (1 ... 7 (8) | ▼ 0 (1 ... 50hrs (51) |
| Week 4 (21-27/11) (4) | ▼ 0 (1 ... 7 (8) | ▼ 0 (1 ... 50hrs (51) |

Q19 How many performances have you been involved in during November?

|  | Performance Number | Performance Hours |
|---|---|---|
| Week 1 (31/10-6/11) (1) | ▼ 0 (1 ... 10 (11) | ▼ 0 (1 ... 15hrs (16) |
| Week 2 (7-13/11) (2) | ▼ 0 (1 ... 10 (11) | ▼ 0 (1 ... 15hrs (16) |
| Week 3 (14-20/11) (3) | ▼ 0 (1 ... 10 (11) | ▼ 0 (1 ... 15hrs (16) |
| Week 4 (21-27/11) (4) | ▼ 0 (1 ... 10 (11) | ▼ 0 (1 ... 15hrs (16) |

Q20 What kind of supplemental training have you performed in November?

○ Pilates/ Yoga/ Somatics  (1)

○ Gym Work/ Weight Training  (2)

○ Aerobic exercise (e.g. running, swimming)  (3)

○ Other  (4)

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

Q21 :) Thanks!!!!

**End of Block: Dance Activity**

**Appendix E: Study Four participant form**

**Initial page for dance participants**

<u>Multi-segment spine kinematics and trunk muscle activity in non-dancers as well as dancers with and without low back pain</u>

Participant ID number:

Sex: M / F

Current age:

| Height (CM) | Body Mass (kg) | BMI |
| --- | --- | --- |
| | | |

---

*Background*

Which of the following best describes you?

◯ I am not a dancer

◯ I am a dancer

*Dance background*

◯ Professional with a contemporary dance company

◯ Professional with a classical ballet company

◯ Freelance/ Independent professional

◯ Full time tertiary (university) student

◯ Full time ballet school student

◯ Other dancer (Please list)

How old were you when you first started dancing?

How many years of formal dance training have you completed:

     Secondary/ ballet school years:

     University level years:

How many years have you been dancing professionally?

Approximately how many hours a week do you dance?

---

**Initial page for non-dance participants**

<u>Multi-segment spine kinematics and trunk muscle activity in non-dancers as well as dancers with and without low back pain</u>

Participant ID Number:

Sex: M / F

Current age:

| Height (CM) | Body Mass (kg) | BMI |
|---|---|---|

*Vocation*

What is your current vocation (e.g. nursing student?)

*Dance Background*

Have you ever completed dance training?    **Y**        **N**

*If Yes, which best describes your dance background?*

◯  Recreational dancer/ attend public classes

◯  Formal part time dance training

◯  Full time ballet school student

◯  Full time university dance student

◯  Professional dancers

◯  Other dancer (Please list)

How many years have you been dancing at the above levels?

Do you currently dance?   **Y**        **N**

*Physical Activity*

Describe your current physical activity/exercise levels:

|  | Light | Moderate | Vigorous |
|---|---|---|---|
| Activity Type (e.g. walking, tennis etc) | _____ ___ | _____ | _____ |
| Frequency (times/ week) | _____ ___ | _____ | _____ |
| Duration (mins/wk) | _____ ___ | _____ | _____ |

*The following questions are to discern your ability to participate in this study safely. Please note that all responses will remain confidential.*

Do you currently have, or have recently experienced, an injury that may limit your ability to complete physical activity?                                                                          **Y        N        Don't know**

Are you pregnant?                                                    **Y        N        Don't know**

Do you have any known spinal deformities (e.g. scoliosis)?           **Y        N        Don't know**

Are there any additional precautions that need to be considered when you engage in physical activity?
                                                                     **Y        N**

Are you currently able to participate in a full dance class without limitation?     **Y        N        Don't know**

---

*Low Back Pain*



Low Back

Please do not report pain from feverish illness or menstruation

Have you experienced low back pain in the last 12 months (In the area shown on the diagram above)?

**Y        N**

If yes, how many episodes/ times have you experienced low back pain in the past 12 months

○ Once Only

○ Twice

○ More than twice

Did the pain ever last more than 7 consecutive days?                         **Y        N**

Do you feel that LBP was aggravated by dance practice or other physical activity?       **Y        N**

Did this LBP result in:

○ Modification to your basic daily activities

○ Modified dance practice

○ Missed dance practice (e.g. class/ rehearsal or performance)

**1 – What is your pain RIGHT NOW?**

No pain ———————————————— Worst possible pain
0 1 2 3 4 5 6 7 8 9 10

**2 – What is your TYPICAL or AVERAGE pain?**

No pain ———————————————— Worst possible pain
0 1 2 3 4 5 6 7 8 9 10

**3 – What is your pain level AT ITS BEST (How close to "0" does your pain get at its best)?**

No pain ———————————————— Worst possible pain
0 1 2 3 4 5 6 7 8 9 10

**4 – What is your pain level AT ITS WORST (How close to "10" does your pain get at its worst)?**

No pain ———————————————— Worst possible pain
0 1 2 3 4 5 6 7 8 9 10

Did you ever consult with a rehabilitation or health professional (e.g. doctor, physio, exercise physiologist, pilates rehabilitation, psychologist) about your pain?

**Y        N**

Please list the types of professional you have seen? _____

If yes, approximately how many times have you seen a health professional in the last:

3 Months: _____

12 Months: _____

Did you ever use of medication or pain killers for your low back pain? (e.g. paracetamol, ibuprofen, voltaren etc.)

**Y        N**

If yes, did this medication use ever extend beyond 14 consecutive days?        **Y        N**

*Perceived Aggravating Factors*

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Please place a tick in any of the boxes if you feel low back pain when doing any of the following activities:

○ Standing

○ Sitting postures

○ Flexion of the Spine

○ Extension

○ Side bending

○ Twisting/ Rotating

○ Multidirectional Movements

○ Lifting

○ Long dance hours/ high workloads

○ Single straight leg lifting to the front

○ Single straight leg lifting to the back

○ Not dancing

○ Other (Please list)


*Other aggravating factors*
Do you feel that other factors, such as low mood, poor sleep, general stress etc. contribute to your back pain?



*Pain strategies*
Please describe any pain management/ avoidance strategies you employ (either voluntarily or involuntarily).



*Perceived Relieving Factors*
Please describe any activities or postures that relieve pain

# Tampa Scale for Kinesiophobia

1 = strongly disagree
2 = disagree
3 = agree
4 = strongly agree

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. I'm afraid that I might injury myself if I exercise | 1 | 2 | 3 | 4 |
| 2. If I were to try to overcome it, my pain would increase | 1 | 2 | 3 | 4 |
| 3. My body is telling me I have something dangerously wrong | 1 | 2 | 3 | 4 |
| 4. My pain would probably be relieved if I were to exercise | 1 | 2 | 3 | 4 |
| 5. People aren't taking my medical condition seriously enough | 1 | 2 | 3 | 4 |
| 6. My accident has put my body at risk for the rest of my life | 1 | 2 | 3 | 4 |
| 7. Pain always means I have injured my body | 1 | 2 | 3 | 4 |
| 8. Just because something aggravates my pain does not mean it is dangerous | 1 | 2 | 3 | 4 |
| 9. I am afraid that I might injure myself accidentally | 1 | 2 | 3 | 4 |
| 10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening | 1 | 2 | 3 | 4 |
| 11. I wouldn't have this much pain if there weren't something potentially dangerous going on in my body | 1 | 2 | 3 | 4 |
| 12. Although my condition is painful, I would be better off if I were physically active | 1 | 2 | 3 | 4 |
| 13. Pain lets me know when to stop exercising so that I don't injure myself | 1 | 2 | 3 | 4 |
| 14. It's really not safe for a person with a condition like mine to be physically active | 1 | 2 | 3 | 4 |
| 15. I can't do all the things normal people do because it's too easy for me to get injured | 1 | 2 | 3 | 4 |
| 16. Even though something is causing me a lot of pain, I don't think it's actually dangerous | 1 | 2 | 3 | 4 |
| 17. No one should have to exercise when he/she is in pain | 1 | 2 | 3 | 4 |

# Pain Catastrophizing Scale

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.

Instructions:
*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<br>Not at all | 1<br>To a slight degree | 2<br>To a moderate degree | 3<br>To a great degree | 4<br>All the time |
|---|---|---|---|---|---|
| I worry all the time about whether the pain will end. |  |  |  |  |  |
| I feel I can't go on. |  |  |  |  |  |
| It's terrible and I think it's never going to get any better |  |  |  |  |  |
| It's awful and I feel that it overwhelms me. |  |  |  |  |  |
| I feel I can't stand it anymore |  |  |  |  |  |
| I become afraid that the pain will get worse. |  |  |  |  |  |
| I keep thinking of other painful events |  |  |  |  |  |
| I anxiously want the pain to go away |  |  |  |  |  |
| I can't seem to keep it out of my mind |  |  |  |  |  |
| I keep thinking about how much it hurts |  |  |  |  |  |
| I keep thinking about how badly I want the pain to stop |  |  |  |  |  |
| There's nothing I can do to reduce the intensity of the pain |  |  |  |  |  |
| I wonder whether something serious may happen. |  |  |  |  |  |

## Appendix F: Study Five participant form

<div style="border:1px solid">

**Demographics**

Sex:  M  /  F                         Current Age:

Please leave this line blank, to be collected by a researcher

Height (CM):              Body Mass (kg):              BMI:              Scoliometer Measure:

**Dance Background**

*Please choose the most accurate responses based on your current activities.*

What is your professional level?

o        Full-time professional dancer
o        Part-time professional dancer
o        Freelance/Independent professional dancer
o        Full-time tertiary (university) student majoring in dance

What is your primary style of dance as a professional / dance major? (choose one)
o        ballet
o        modern
o        contemporary
o        musical theater / Broadway
o        jazz
o        tap
o        ballroom / Latin / social dance
o        African
o        Other, please describe:


What other styles of dance do you perform and study regularly?

o        ballet
o        modern
o        contemporary
o        musical theater / Broadway
o        jazz
o        tap
o        ballroom / Latin / social dance
o        African
o        Other, please describe:


How many years old were you when you first started dancing in a classroom setting?

How many years of formal dance training have you completed?

        Secondary/ ballet school years:

University level years:

How many years have you been dancing professionally?

Approximately how many hours a week do you dance?

</div>

**Low Back Pain Occurrence**



Please do not report pain from feverish illness or menstruation

Have you experienced low back pain in the last 12 months (In the area shown on the diagram above)?

If you answered NO, please skip to page 6, "Low Back Pain Impact."

If yes, how many episodes/ times have you experienced low back pain in the past 12 months

o        Once Only
o        Twice
o        More than twice

When was your most recent episode of low back pain?

o        I currently have low back pain
o        Within the last 2 months
o        Within the last 3-12 months
o        More than 12 months ago

Has your back pain ever lasted for more than 3 months off and on (it hurt at least once a week but not every day)?

Has your back pain ever lasted for more than 3 months continuously (it hurt more or less every day)?

Did you experience pain that goes down the leg?

If yes, did this pain go below the knee?

**Low Back Pain Treatment**

If you have had low back pain (LBP):

Did you ever consult with a rehabilitation or health professional about your LBP?

If yes, please list the types of professional you have seen for your LBP:

If yes, approximately how many times have you seen a health professional in the last 12 months for your LBP?

Did you ever use medication or pain killers for your LBP?

If yes, did this medication use ever extend beyond 14 consecutive days?

**Low Back Pain Impact**

Please answer these questions whether you have experienced low back pain or not

Question 1:

Have you had any difficulties in participating in normal training and performance due to low back pain problems during the past two months?

o        Full participation without low back pain
o        Full participation but with low back pain
o        Reduced participation due to low back pain
o        Cannot participate due to low back pain


Question 2:

To what extent have you reduced how much you train due to low back pain during the past two months?

o        No reduction
o        To a minor extent
o        To a moderate extent
o        To a major extent
o        Cannot participate at all


Question 3:

To what extent has low back pain affected your performance during the past two months?

o        No effect
o        To a minor extent
o        To a moderate extent
o        To a major extent
o        Cannot participate at all


Question 4:

To what extent have you experienced low back pain related to your dancing during the past two months?

o        No pain
o        Mild pain
o        Moderate pain
o        Severe Pain

**Perceived Aggravating Factors of Low Back Pain**

Please mark any of the circles if you feel low back pain when doing any of the following activities:

o        Standing
o        Sitting postures
o        Bending forwards of the spine (flexion)
o        Arching the spine backwards (extension)
o        Side bending
o        Twisting / Rotating
o        Multidirectional Movements
o        Lifting
o        Long dance hours/ high workloads
o        Single straight leg lifting to the front
o        Single straight leg lifting to the back
o        None, I do not feel back pain
o        Other (Please list)


Movement Preferences


When you are standing around relaxed, like waiting in a line, on which leg do you tend to stand?
                                                                                    Right          Left                    No preference


Which hand would you typically use to throw a ball?     Right                Left                    No preference


Which leg would you typically use to kick a ball?    Right          Left              No preference


When you carry a bag on ONE shoulder (not across your chest), on which shoulder do you typically carry it?                                                     Right          Left
        No preference


When you carry a bag on one shoulder WITH the strap across your chest so the bag hangs on the opposite side, on which shoulder to you prefer to carry it?
                                                                                    Right              Left                    No preference/Not sure

**How are you Feeling?**

**From the Orebro Pain Questionnaire (Linton 2003)**

*Please circle your most accurate answer.*

**How tense or anxious have you felt in the past week?**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|----|

Absolutely calm and relaxed                    As tense and anxious as I've ever felt

**How much have you been bothered by feeling depressed in the past week?**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|----|

Not at all                                                        Extremely

**Wellness Questionnaire**

**(McLean 2010; Hooper and Mackinnon 1995)**

**Please circle your current status for each of the following categories:**

**Fatigue**

| Very Fresh | Fresh | Normal | More Tired Than Normal | Always Tired |
|---|---|---|---|---|

**Sleep Quality**

| Very Restful | Good | Difficulty Falling Asleep | Restless Sleep | Insomnia |
|---|---|---|---|---|

**General Muscle Soreness**

| Feeling Great | Feeling Good | Normal | A Bit Sore | Very Sore |
|---|---|---|---|---|

**Stress Level**

| Very Relaxed | Relaxed | Normal | Feeling Stressed | Highly Stressed |
|---|---|---|---|---|

**Mood**

| Very Positive | A generally Good Mood | Less Interested in Others &/or Activities Than Usual | Snappiness at Family, Friends and Co-Workers | Highly annoyed/ Irritable/ Down |
|---|---|---|---|---|

## HARKNESS DANCE DISCOMFORT RATING SCALE

You may experience a variety of discomforts within your body on any given day. We are interested in identifying those discomforts which are related to your "Dance Activities."
*Please circle the most appropriate answer, one for each row.*

| | | | | | |
|---|---|---|---|---|---|
| Please note the **frequency** of your foot-ankle discomfort. | Never | Rare | Occasional | Frequent | Continuous |
| Please note the **severity** of your foot-ankle discomfort. | None | Minimal | Moderate | Significant | Intolerable |
| Please note the **frequency** of your knee discomfort. | Never | Rare | Occasional | Frequent | Continuous |
| Please note the **severity** of your knee discomfort. | None | Minimal | Moderate | Significant | Intolerable |
| Please note the **frequency** of your hip discomfort. | Never | Rare | Occasional | Frequent | Continuous |
| Please note the **severity** of your hip discomfort. | None | Minimal | Moderate | Significant | Intolerable |
| Please note the **frequency** of your low back discomfort. | Never | Rare | Occasional | Frequent | Continuous |
| Please note the **severity** of your low back discomfort. | None | Minimal | Moderate | Significant | Intolerable |
| Please note the **frequency** of your upper back-neck discomfort. | Never | Rare | Occasional | Frequent | Continuous |
| Please note the **severity** of your upper back-neck discomfort. | None | Minimal | Moderate | Significant | Intolerable |
| Please note the **frequency** of your shoulder-arm discomfort. | Never | Rare | Occasional | Frequent | Continuous |
| Please note the **severity** of your shoulder-arm discomfort. | None | Minimal | Moderate | Significant | Intolerable |

# Tampa Scale for Kinesiophobia

| | 1 = strongly disagree | 2 = disagree | 3 = agree | 4 = strongly agree |
|---|---|---|---|---|
| 1. I'm afraid that I might injury myself if I exercise | 1 | 2 | 3 | 4 |
| 2. If I were to try to overcome it, my pain would increase | 1 | 2 | 3 | 4 |
| 3. My body is telling me I have something dangerously wrong | 1 | 2 | 3 | 4 |
| 4. My pain would probably be relieved if I were to exercise | 1 | 2 | 3 | 4 |
| 5. People aren't taking my medical condition seriously enough | 1 | 2 | 3 | 4 |
| 6. My accident has put my body at risk for the rest of my life | 1 | 2 | 3 | 4 |
| 7. Pain always means I have injured my body | 1 | 2 | 3 | 4 |
| 8. Just because something aggravates my pain does not mean it is dangerous | 1 | 2 | 3 | 4 |
| 9. I am afraid that I might injure myself accidentally | 1 | 2 | 3 | 4 |
| 10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening | 1 | 2 | 3 | 4 |
| 11. I wouldn't have this much pain if there weren't something potentially dangerous going on in my body | 1 | 2 | 3 | 4 |
| 12. Although my condition is painful, I would be better off if I were physically active | 1 | 2 | 3 | 4 |
| 13. Pain lets me know when to stop exercising so that I don't injure myself | 1 | 2 | 3 | 4 |
| 14. It's really not safe for a person with a condition like mine to be physically active | 1 | 2 | 3 | 4 |
| 15. I can't do all the things normal people do because it's too easy for me to get injured | 1 | 2 | 3 | 4 |
| 16. Even though something is causing me a lot of pain, I don't think it's actually dangerous | 1 | 2 | 3 | 4 |
| 17. No one should have to exercise when he/she is in pain | 1 | 2 | 3 | 4 |

**Appendix G: Verbal instructions for movement tasks (Study Five)**

Normal Standing (Image 1):

Stand in a relaxed position like how you would normally stand on two feet. Feet pelvis-width apart, knees straight and arms hanging freely, look forward.

*[Threshold for verbal correction: > / < two fists feet width apart]*

Coronal Plane ROM in Standing (Image 2):

With your feet positioned pelvis width apart, easily bend to your (direction) side as far as you can, sliding your arm along your leg, then return to the starting position. Imagine you are between two plates of glass that do not allow you to twist or bend forward or backward as you bend to the side. Return to the resting position.

Transverse Plane ROM Sitting (Image 3):

With your arms crossed your over your chest (hands on shoulders) and keeping both sit bones on the stool, rotate your chest to [direction] as far as you can while looking over your shoulder. Return to the resting position.

*[Setup: The feet are supported at 90' of dorsiflexion, the hips and knees are at 90' of flexion and neutral hip abduction and adduction, the participants arms and hands are across his/her chest].*

<u>Gait (Image 4):</u>

Walk at your natural pace in a relaxed manner. Contact the first force plate with your right foot and the second force plate with your left foot.

*[Participant given multiple attempts prior to recording to find correct foot placement pattern and walking rhythm].*

IMAGES:



1.　　　　　2.　　　　　3.　　　　　4.
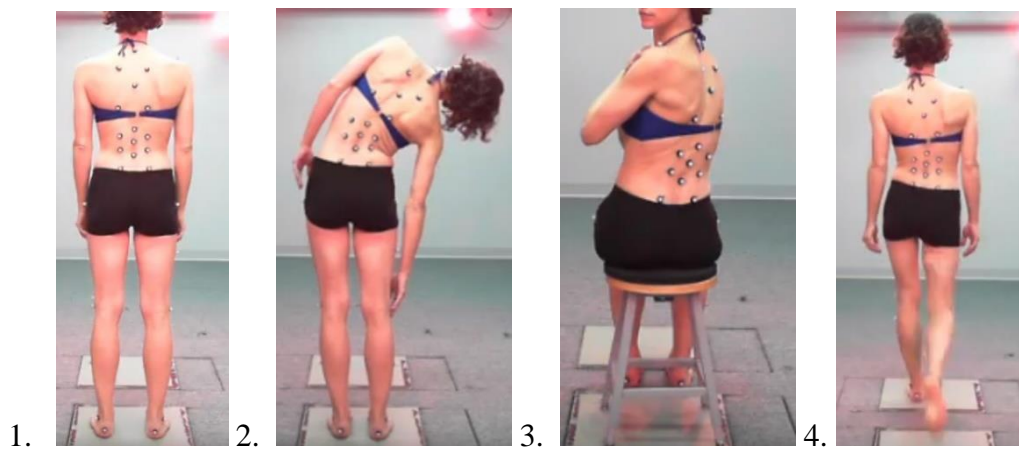
**Appendix F: Ethics approval, information letters and consent forms**

# ✠ACU
## AUSTRALIAN CATHOLIC UNIVERSITY

Human Research Ethics Committee
**Committee Approval Form**

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**Principal Investigator/Supervisor:** Dr Elizabeth Bradshaw

**Co-Investigators:**

**Student Researcher: :** Christopher Swain

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**Ethics approval has been granted for the following project:**
The prevalence, incidence, and impact of low back pain in dance

**for the period:** 30/09/2016

**Human Research Ethics Committee (HREC) Register Number:** 2015-187H

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<u>Special Condition/s of Approval</u>
*Prior to commencement of your research,* the following permissions are required to be submitted to the ACU HREC:
N/A

The data collection of your project has received ethical clearance but the decision and authority to commence may be dependent on factors beyond the remit of the ethics review process and approval is subject to ratification at the next available Committee meeting. The Chief Investigator is responsible for ensuring that outstanding permission letters are obtained, interview/survey questions, if relevant, and a copy forwarded to ACU HREC before any data collection can occur. Failure to provide outstanding documents to the ACU HREC before data collection commences is in breach of the National Statement on Ethical Conduct in Human Research and the Australian Code for the Responsible Conduct of Research. Further, this approval is only valid as long as approved procedures are followed.

Clinical Trials: You are required to register it in a publicly accessible trials registry prior to enrolment of the first participant (e.g. Australian New Zealand Clinical Trials Registry http://www.anzctr.org.au/) as a condition of ethics approval.
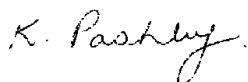
It is the Principal Investigators / Supervisors responsibility to ensure that:
1.      All serious and unexpected adverse events should be reported to the HREC with 72 hours.
2.      Any changes to the protocol must be reviewed by the HREC by submitting a Modification/Change to Protocol Form prior to the research commencing or continuing. http://research.acu.edu.au/researcher-support/integrity-and-ethics/
3.      Progress reports are to be submitted on an annual basis. http://research.acu.edu.au/researcher-support/integrity-and-ethics/
4.      All research participants are to be provided with a Participant Information Letter and consent form, unless otherwise agreed by the Committee.
5.      Protocols can be extended for a maximum of five (5) years after which a new application must be submitted. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

Researchers must immediately report to HREC any matter that might affect the ethical acceptability of the protocol eg: changes to protocols or unforeseen circumstances or adverse effects on participants.

Signed: ......      *K. Pashley.*      ......      Date: .... 07/10/2015.....
(Research Services Officer, Australian Catholic University, Tel: 02 9739 2646)

# PARTICIPANT INFORMATION LETTER

**PROJECT TITLE: The prevalence, incidence and impact of low back pain in dance students and professionals**
**INVESTIGATOR 1: Dr Elizabeth Bradshaw**
**INVESTIGATOR 2: Dr Christina Ekegren**
**STUDENT RESEARCHER: Christopher Swain**
**STUDENT'S DEGREE: Doctor of Philosophy**

Dear Participant,
You are invited to participate in this research project that investigates the prevalence, incidence and impact of low back pain in full time dance students and professionals. Please see the information below on the research project and what participation involves.

*What is the project about?*
The research project investigates the prevalence and incidence of low back pain (LBP) in dance, and the relationship between LBP and dance training. It is hoped that the research will provide increased insight into the experience of LBP in dance, which will then contribute to more effective LBP prevention and management strategies.

*Who is undertaking the project?*
This project is being conducted by Mr Chris Swain as a part of his doctoral research studies at Australian Catholic University under the supervision of Dr Elizabeth Bradshaw and Dr Christina Ekegren. Mr Chris Swain has previously completed both an MSc (Dance Science) and BSc (Exercise Physiology) and has also worked in clinical rehabilitation. Dr Elizabeth Bradshaw is a Sport Biomechanist who works closely with gymnasts and dancers. The research team is based in the School of Exercise Science on the Melbourne campus. Dr Christina Ekegren is an NHRMC early career fellow within the Department of Epidemiology and Preventative Medicine at Monash University, and has previously worked on injury surveillance projects with a number of dance organisations.

*Are there any risks associated with participating in this project?*
If you agree to participate, you will be asked to disclose information regarding your experience of LBP and dance practice. All information collected will be stored anonymously and remain confidential.  It is possible that recounting episodes of back pain may cause emotional distress. In this instance we recommend you consult a health professional.
*What will I be asked to do?*

- If you agree to participate in this study, you will be asked to sign a consent form prior to participation. For participants under the age of 18, you will be asked to provide informed

parental consent form and sign an individual assent form prior to any assessments being performed.
- You will be asked to complete a single initial online questionnaire.
- The questionnaires will be distributed by email.
- The questionnaire contains questions regarding your physical profile, injury history and dance background. It is expected to take around 5 to 10 minutes.
- For female participants only, the initial questionnaire will contain question about menstrual patterns. These questions are standard in sports medicine and we are asking these because physically active girls and women with low energy availability and menstrual dysfunction may be more prone to bone stress injuries and other types of musculoskeletal injury. These questions are optional and the researchers will not know the identity of responders.
- The study will not interfere with your training or practice in any way.

### *What are the benefits of the research project?*
The research project will evaluate the rate of LBP in dance as well as a number of the risk factors that may contribute to the development of LBP. The findings may contribute to the development of improved prevention and management strategies for both dance schools and companies.

In return for participation, schools and companies will receive a final written report with key findings and strategic implications. Individual participants will receive a summary of the findings as well as the key points. Individuals may gain further insight into their dance workload and practice, as well as the interaction between practice and injury. No personal information will be included in these reports.

### *Can I withdraw from the study?*
Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. If you choose to withdraw, previously completed questionnaires may still be used in the research as questionnaires are anonymous.

### *Will anyone else know the results of the project?*

All Participant information collected during this study will be de-identified and confidential. The only persons with access to the data are the researchers and they will not know the identity of individual responses. At the conclusion of the study, the findings may be aggregated and used in scientific presentations or publications; however, no individually identifiable data will be apparent. The data collected from this study will only be used for research relating to Mr Swain's PhD and will not be used for any further research without additional participant consent.

### *Will I be able to find out the results of the project?*
At the conclusion of the study, the researchers will provide participants and participating organisations a summary of the aggregated data, results and potential implications. No personal information will be included.

### *Who do I contact if I have questions about the project?*
If you have any questions concerning the project please do not hesitate to contact Chris Swain.
E-mail: chris.swain@acu.edu.au
Phone: +61 (0) 435 059 452

### *What if I have a complaint or any concerns?*

The study has been reviewed by the Human Research Ethics Committee at Australian Catholic University (review number 2015-187H). If you have any complaints or concerns about the conduct of the project, you may write to the Manager of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Manager, Ethics
c/o Office of the Deputy Vice Chancellor (Research)
Australian Catholic University
North Sydney Campus
PO Box 968
NORTH SYDNEY, NSW 2059
Ph.: 02 9739 2519
Fax: 02 9739 2870
Email: resethics.manager@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

***I want to participate! How do I sign up?***
If you are interested participants can contact Chris Swain at chris.swain@acu.edu.au. We will ask you to complete a consent form, or parental/ guardian consent and participant assent if they are under 18 years of age. Your participation is greatly appreciated.

Yours sincerely,

**Dr Elizabeth Bradshaw**
**Principal Investigator**

**Dr Christina Ekegren**
**Investigator 2**

**Mr Christopher Swain**
**Student Researcher**

CONSENT FORM

TITLE OF PROJECT: The prevalence, incidence, and impact of low back pain in dance

INVESTIGATOR 1: Dr Elizabeth Bradshaw

INVESTIGATOR 2: Dr Christina Ekegren

STUDENT RESEARCHER: Christopher Swain

I .................................................... have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this research that will involve completing one

questionnaire per month for 12 months, realising that I can withdraw my consent at any time without any adverse consequences. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

Participant                                                                                    Email
…………………………………………………………………………………………………

Participant                                    Phone                                        Number
…………………………………………………………………………………...

NAME OF PARTICIPANT:   ...................................................................................

SIGNATURE ....................................................................          DATE

..............................

SIGNATURE OF STUDENT RESEARCHER: ...................................................................

DATE:.......................………

PARENT/GUARDIAN CONSENT FORM

TITLE OF PROJECT: The prevalence, incidence, and impact of low back pain in dance

PRINCIPAL INVESTIGATOR: Dr Elizabeth Bradshaw

INVESTIGATOR 2: Dr Christina Ekegren

STUDENT RESEARCHER: Christopher Swain

I ................................................ have read and understood the information provided in the Letter to the Participants. Any questions I have asked have been answered to my satisfaction. I agree that my child, nominated below, may participate in this research that will involve completing one questionnaire per month for 12 months, realising that I can withdraw my consent at any time without any adverse consequences. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify my child in any way.

Participant Email

…………………………………………………………………………………………………

Participant Phone Number

…………………………………………………………………………………….........................

NAME OF PARENT/GUARDIAN: ...................................................................................

SIGNATURE ...............................................……………………… DATE:

NAME OF CHILD ........................................................................................................

**ASSENT OF PARTICIPANTS AGED UNDER 18 YEARS**

I …………………… understand what this research project is designed to explore. What I will be asked to do has been explained to me. I agree to participate in this research that will involve completing one questionnaire per month for 12 months, realising that I can withdraw at any time without having to give a reason for my decision.

NAME OF PARTICIPANT AGED UNDER 18: ................................................................

SIGNATURE: ....................................................................................... DATE:

SIGNATURE OF STUDENT RESEARCHER: ...............................................................

DATE:

# ✛ACU
## AUSTRALIAN CATHOLIC UNIVERSITY

Human Research Ethics Committee
**Committee Approval Form**

---

**Principal Investigator/Supervisor:** Dr Elizabeth Bradshaw

**Co-Investigators:** Dr Doug Whyte, Dr Christina Ekegren

**Student Researcher: :** Christopher Swain (HDR Student)

---

**Ethics approval has been granted for the following project:**
MULTI-SEGMENT SPINE KINEMATICS AND TRUNK MUSCLE ACTIVITY: EFFECTS OF DANCE TRAINING AND LOW
BACK PAIN

**for the period:** 31/12/2017

**Human Research Ethics Committee (HREC) Register Number:** 2016-213E

---

**Special Condition/s of Approval**
*Prior to commencement of your research,* the following permissions are required to be submitted to the ACU
HREC:

The data collection of your project has received ethical clearance but the decision and authority to commence
may be dependent on factors beyond the remit of the ethics review process and approval is subject to
ratification at the next available Committee meeting. The Chief Investigator is responsible for ensuring that
outstanding permission letters are obtained, interview/survey questions, if relevant, and a copy forwarded to
ACU HREC before any data collection can occur. Failure to provide outstanding documents to the ACU HREC
before data collection commences is in breach of the National Statement on Ethical Conduct in Human Research
and the Australian Code for the Responsible Conduct of Research. Further, this approval is only valid as long as
approved procedures are followed.

Clinical Trials: You are required to register it in a publicly accessible trials registry prior to enrolment of the first
participant (e.g. Australian New Zealand Clinical Trials Registry http://www.anzctr.org.au/) as a condition of
ethics approval.

It is the Principal Investigators / Supervisors responsibility to ensure that:
1.      All serious and unexpected adverse events should be reported to the HREC with 72 hours.
2.      Any changes to the protocol must be reviewed by the HREC by submitting a Modification/Change to
        Protocol Form prior to the research commencing or continuing. http://research.acu.edu.au/researcher-
        support/integrity-and-ethics/
3.      Progress reports are to be submitted on an annual basis. http://research.acu.edu.au/researcher-
        support/integrity-and-ethics/
4.      All research participants are to be provided with a Participant Information Letter and consent form,
        unless otherwise agreed by the Committee.
5.      Protocols can be extended for a maximum of five (5) years after which a new application must be
        submitted. (The five year limit on renewal of approvals allows the Committee to fully re-review
        research in an environment where legislation, guidelines and requirements are continually changing, for
        example, new child protection and privacy laws).

Researchers must immediately report to HREC any matter that might affect the ethical acceptability of the
protocol eg: changes to protocols or unforeseen circumstances or adverse effects on participants.

Signed: ...... *K. Pashley.* ...... Date: .... 14/11/2016.....
(Research Services Officer,  Australian Catholic University, Tel: 02 9739 2646)

# PARTICIPANT INFORMATION LETTER

**PROJECT TITLE:** The effects of low back pain on spine movement

**INVESTIGATOR 1:  Dr Doug Whyte**
**INVESTIGATOR 2:  Dr Elizabeth Bradshaw**
**INVESTIGATOR 3: Dr Christina Ekegren (Monash University)**
**STUDENT RESEARCHER: Christopher Swain**
**STUDENT'S DEGREE: Doctor of Philosophy**

Dear Participant,

You are invited to participate in this research project. Please see below information on the research project and what participation in the research project involves.

### *What is the project about?*
The research project investigates spine movement in trained dancers and non-dancers with and without low back pain (LBP). The primary purpose of this study is to obtain knowledge that will contribute to improved management and treatment for dancers with LBP or injuries, and to contribute to general knowledge on the influence of physical training on spine movement patterns.

### *Who is undertaking the project?*
This project is being conducted by Mr Chris Swain as a part of his doctoral research studies at Australian Catholic University under the supervision of Dr Elizabeth Bradshaw, Dr Doug Whyte and Dr Christina Ekegren. Mr Chris Swain has previously completed both an MSc (Dance Science) and BSc (Exercise Physiology) and has also worked in a range of clinical rehabilitation settings as an accredited exercise physiologist. Dr Elizabeth Bradshaw is a Sport Biomechanist who works closely with gymnasts, Dr Doug Whyte performs exercise physiology research and Dr Christina Ekegren is a physiotherapist whose research is based on injury epidemiology in both the dance and broader community.

### *Are there any risks associated with participating in this project?*
You will be asked to perform a series of spine movement tasks that replicate basic daily activities (see page 3). As these are physical tasks there is risk of sustaining a musculoskeletal injury. However, the movements are all low intensity, and will pose no more risk than other daily tasks. If you are a dancer, you will also be asked to perform a few common dance movements (see page 3), posing no greater risk than a typical dance class. In the event that you do experience pain, the researchers will provide you with exercises to both relieve and rehabilitate pain. All persons involved in testing participants aged below 18 years of age will have a current working with children check and there will be a minimum of two testers present for these sessions.

### *What will I be asked to do?*
- You will be asked to come to ACU's biomechanics research lab in Fitzroy on one single occasion for testing. The single sessions will be approximately one hour.
- Your age, height, body mass and low back pain history will be collected.
- Both dancers and non-dancers will be asked to perform a series of basic postural and range of motion exercises. There are nine total movements that you will perform three times each.

- If you are a dancer you will also be asked to perform a series of posture tasks, spine range of motion tests, and spine movements that are common in dance settings (including flexion/ extension, port de bras and roll down movements). You will be asked to perform a total of 16 movements three times each.
- To assess spine movements, all participants will be fitted with 19 small reflective (ball) markers, which will be attached onto the skin on your trunk using double-sided tape. This will require that you wear a sports bra or crop top (females) or be shirtless (males) to allow markers to be placed on the skin.
- Please note that the Vicon motion analysis system does not capture your physical image, just the position of the markers in space as you move. In addition, this process will be conducted with the upmost professionalism and a screened off area is provided for changing. During laboratory sessions, access to the laboratory is limited and a sign is placed on the door advising other staff not to enter whilst the trial is in progress.
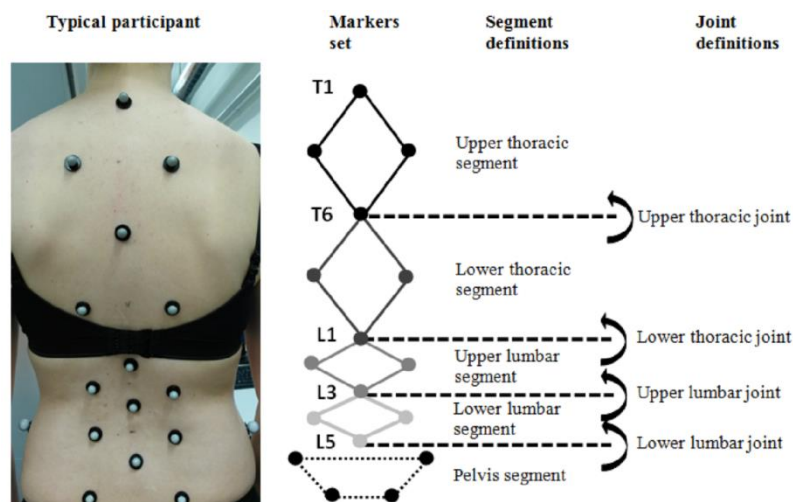


*Christe, et al. [149]*

- Dancers and non-dancers with a history of LBP will also complete a number of psychosocial questionnaires that are used to examine for factors that may influence movement behaviours in people with LBP or other musculoskeletal injury.
- Please bring with you training shorts, leggings or tracksuit pants and a crop top for the tests

| Non-Dance Trials | | Dance Trials | Low Tempo | Medium Tempo |
|---|---|---|---|---|
| Standing Posture | 3 | Forward Port de Bras | 3 | 3 |
| Normal Sitting | 3 | Backwards Port de Bras | 3 | 3 |
| Slumped Sitting | 3 | Side Port de Bras | 3 | 3 |
| Sitting with a flexed Spine | 3 | Full Port de Bras | 3 | 3 |
| Flexion ROM | 3 | C-Curve | 3 | 3 |
| Extension ROM | 3 | Arabesque | 3 | |
| Lateral Bending ROM | 3 | Attitude Front | 3 | |
| Rotation ROM | 3 | Leg Swing Series | 3 | |
| Roll down | 3 | | | |
| Total Spine Movements | 27 | | 24 | 15 |

Table 1: Movements performed

*What are the benefits of the research project?*
The purpose of the research is to learn about spine movement relative to the experience of LBP in dance. The research has been designed to inform clinical practice and improve rehabilitation interventions for dancers. Individuals who participate will receive detailed biomechanics feedback about spine movement that can have implications for health or dance practice. Feedback will include immediate visual feedback as well as an individual report at the end of the study. Individuals with back pain will also be shown evidence based rehabilitation exercises to improve the management of LBP. Participants will also be offered a parking or travel reimbursement of a maximum of $10 per participant.

*Can I withdraw from the study?*
Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. If you choose to withdraw, you can request for collected data to be discarded.

*Will anyone else know the individual results of the testing?*
No. Participant information collected during this study will be de-identified and confidential. Although the motion capture system records participants, it only captures the reflective markers, and not your physical image. The only persons with access to the data are the researchers. At the conclusion of the study, the findings may be aggregated and used in scientific presentations and publications; however, no individually identifiable data will be apparent. The data collected from this study will only be used for research relating to Mr Swain's PhD and will not be used for any further research without additional participant consent.

*Will I be able to find out the results of the project?*
At the conclusion of the study, the researchers will provide all participants with a summary of the aggregated data, results and potential implications. No identifiable personal information will be included. Individuals will receive feedback regarding the findings of the study as well as their own results.

*Who do I contact if I have questions about the project?*
If you have any questions concerning the project please do not hesitate to contact Chris Swain.
E-mail: chris.swain@acu.edu.au
Phone: +61 (0) 435 059 452

*What if I have a complaint or any concerns?*
The study has been reviewed by the Human Research Ethics Committee at Australian Catholic University (review number 2016-213E). If you have any complaints or concerns about the conduct of the project, you may write to the Manager of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Manager, Ethics
c/o Office of the Deputy Vice Chancellor (Research)
Australian Catholic University
North Sydney Campus
PO Box 968
NORTH SYDNEY, NSW 2059
Ph.: 02 9739 2519
Fax: 02 9739 2870
Email: resethics.manager@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

***I want to participate! How do I sign up?***

Interested participants can contact Chris Swain via email at chris.swain@acu.edu.au or by phone (0435 059 452) Participants will be required to complete an informed consent form prior to participation.

Yours sincerely,

**Dr      Doug Whyte**
**Investigator 1**

**Mr Chris Swain**
**Student Researcher**

**Dr      Elizabeth Bradshaw**
**Investigator 3**

**Dr Christina Ekegren**
**Investigator 4**

CONSENT FORM

TITLE OF PROJECT: Analysis of spine movement in non-dancers as well as dancers with and without low back pain

PRINCIPAL INVESTIGATOR: Dr Elizabeth Bradshaw

STUDENT RESEARCHER: Christopher Swain

CO-INVESTIGATOR 1: Dr Doug Whyte

CO-INVESTIGATOR 2: Dr Christina Ekegren (Monash University)

I .................................................. have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this research that will involve:

- A single session at ACU's biomechanics lab, which will last between 30-60 minutes
- Performing a series of posture and spine movements in a motion analysis setting
- Placement of reflective markers onto the trunk for motion analysis
- Completing a series of questionnaires relating to pain

I realise that I can withdraw my consent at any time without any adverse consequences. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

V.20140203

NAME OF PARTICIPANT:    ......................................................................................................

SIGNATURE ....................................................................

DATE................................

SIGNATURE OF STUDENT RESEARCHER: ............................................................................................

DATE:................................

PARENT/GUARDIAN CONSENT FORM

TITLE OF PROJECT: Analysis of spine movement in non-dancers as well as dancers with and without low back pain

PRINCIPAL INVESTIGATOR: Dr Elizabeth Bradshaw

STUDENT RESEARCHER: Christopher Swain

CO-INVESTIGATOR 1: Dr Doug Whyte

CO-INVESTIGATOR 2: Dr Christina Ekegren (Monash University)

I ................................................... have read and understood the information provided in the Parent or Guardian Information Letter. Any questions I have asked have been answered to my satisfaction. I agree that my child, nominated below, may participate in this research that will involve:

- A single session at ACU's biomechanics lab, which will last between 30-60 minutes
- Performing a series of posture and spine movements in a motion analysis setting
- Placement of reflective markers onto the trunk for motion analysis
- Completing a series of questionnaires relating to pain

I realise that I can withdraw my consent at any time without any adverse consequences. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify my child in in any way.

NAME OF PARENT/GUARDIAN: ..................................................................................................

SIGNATURE ................................................................………………………                    DATE:


NAME OF CHILD

SIGNATURE OF STUDENT RESEARCHER ................................................………………………

                                                                                                        DATE:

**ASSENT OF PARTICIPANTS AGED UNDER 18 YEARS**


I ……………………… understand what this research project is designed to explore. What I will be asked to do has been explained to me. I agree to take part in this research that involves:

- A single session at ACU's biomechanics lab, which will last between 30-60 minutes
- Performing a series of posture and spine movements in a motion analysis setting
- Placement of reflective markers onto the trunk for motion analysis
- Completing a series of questionnaires relating to pain


I realise that I can withdraw from the study at any time without having to give a reason for my decision.


NAME OF PARTICIPANT AGED UNDER 18:   ......................................................................................

SIGNATURE:   DATE:.................................................................................

SIGNATURE OF STUDENT RESEARCHER: ...............................................................................

DATE:

# Approval of Submission

May 3, 2018

On 5/3/2018 the IRB reviewed and approved the following submission:

| | |
|---|---|
| principal investigator | Donald Rose |
| study number | i17-00490_CR1 |
| study title | SPINAL ASYMMETRY AND LOW BACK PAIN IN DANCE: A CLINICAL AND BIOMECHANICAL INVESTIGATION |
| performance period | 5/3/2018 - 5/2/2019 |
| location(s) | Hospital for Joint Diseases (NYUMC Locations) |
| sponsor(s) | Name: Dance Harkness Injury Pgm |
| review type | Continuing Review    [Expedited Categories #s 4, 7] |
| board name | Reported to all boards |
| materials approved for use | • 17-00490_Asymmetry_Protocol_080817_Clean.pdf, Category: IRB Protocol;<br><br>***  This study is closed to new enrollment  *** |

The current IRB Status of your study is: Approved. This study was reviewed by the NYU School of Medicine's Institutional Review Board (IRB). During the review of your study, the IRB specifically considered:

1. the risks and anticipated benefits (if any) to your subjects
2. the selection of subjects
3. the procedures for securing and documenting informed consent
4. the safety of your subjects
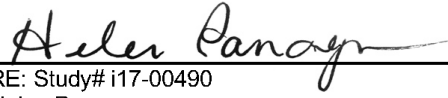5. the privacy of your subjects and confidentiality of the data

Your study cannot commence until all ancillary review decisions are complete.  To determine the state of all ancillary reviews, go the MyStudies page of this study in Research Navigator. Ancillary review statuses are located on the top/right area of your study's main screen.

Note: Ensure that approval has been issued in MyAgreements/CRMS and the Clinical Research Support Unit ("CRSU"; formerly OCT) before you proceed with any aspect of this study, including the enrollment of human subjects.

## Review Notes
For NIH Grant funded research: the IRB has found the IRB approved protocol referenced above to be consistent with the NIH grant application.

Sincerely,

V.20140203

_Helen Panageas_     5/3/2018

RE: Study# i17-00490
Helen Panageas
Director, NYU SoM Institutional Review Board
Federalwide Assurance: FWA00004952

_NYU School of Medicine's IRB operates in accordance with Good Clinical Practices (GCP) and applicable laws and regulations. Federal rules allow IRBs to document their determination/authorization process in their policy manual. Determination letters generated by NYU SoM's IRB administration system are not physically signed as per policy. All approved study materials are clearly identified and locked in each study submission record within the IRB's administration system._

## NYU School Of Medicine IRB Policy

- _All current IRB policy documents can be found on our website: http://irb.med.nyu.edu_
- _You must submit all modifications to this study (e.g., protocol updates, modified recruitment materials, consent forms, etc.) using Research Navigator to communicate with the IRB ("eSubmission") for review and approval prior to initiation of those change(s), except where necessary to eliminate apparent immediate hazards to the subject(s). Changes made to eliminate apparent immediate hazards to subjects must be reported to the IRB within 24 hours._
- _All adverse and/or unanticipated event(s) that occur while conducting this study must immediately be reported to the IRB via eSubmission._
- _You may only use IRB-approved copies of your consent form(s), questionnaire(s), letter(s), advertisement(s), etc. in your study. Never use expired consent forms._
- _If modifications are made to the study or adverse events occur while conducting study, the PI must inform all research staff listed on this study._
- _IRB's approval is valid until the end date of the performance period indicated above. A reminder to submit a continuation should be e-mailed to the PI, PI Proxy and Primary Contact 90, 60 and 30 days prior to this study's expiration date. However, the PI is solely responsible for submitting all continuation materials at least eight weeks prior to expiration, regardless of whether you receive a reminder notice._
- _Prior to initiating an IRB-approved study, you must receive written approval from an authorized representative for each site where your study will take place. Key contacts are:_
  - _Bellevue Hospital: when Bellevue Hospital is listed as a site where your study takes place, note that you may have to complete additional work in BHC's Reason system. Bellevue will be contacting you with any additional needed information. For questions on Bellevue Hospital research, please contact BellevueResearch@bellevue.nychhc.org_
  - _CTSI - Clinical and Translational Science Institute, NYU School of Medicine [formerly General Clinical Research Center (GCRC)]: email ctsi@nyumc.org_
  - _NYU Langone Health Centers (Tisch Hospital/Rusk Institute/Co-op Care/HJD/Perlmutter Cancer Center) site approval is handled for you automatically (as needed) by the CRSU_
- _The IRB may terminate studies that are not in compliance with NYU Langone Health/School of Medicine Policies & Procedures and the requirements of the Institution's Federal Wide Assurance with the federal government._
- _Direct IRB questions and comments to 212-263-4110 or IRB-INFO@nyumc.org_

## IRB Experience Survey
_Providing exceptional customer service is a top priority of the IRB and your responses will help us understand how we can continue to improve our service to the research community._

_Let us know what you think about your experience with the IRB by completing this 5-minute survey. Your feedback is valuable and we thank you for your time._

**Enter Survey Here**

207

V.20140203

**Research Subject**
**Informed Consent Form**

| | |
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| **Title of Study:** | Spinal asymmetry and low back pain in dance: a clinical and biomechanical investigation s17-00490 |
| **Principal Investigator:** | Donald J Rose, MD
Harkness Center for Dance Injuries
NYU Langone Medical Center
614 2nd Avenue, Suite G
New York, NY  10016
212-598-6054 |
| **Emergency Contact:** | Marshall Hagins, DPT 212-598-6022 |

## 1. About volunteering for this research study

You are being invited to take part in a research study. Your participation is voluntary which means you can choose whether or not you want to take part in this study.

People who agree to take part in research studies are called "subjects" or "research subjects". These words are used throughout this consent form.  Before you can make your decision, you will need to know what the study is about, the possible risks and benefits of being in this study, and what you will have to do in this study. You may also decide to discuss this study and this form with your family, friends, or doctor.  If you have any questions about the study or about this form, please ask us. If you decide to take part in this study, you must sign this form. We will give you a copy of this form signed by you for you to keep.

## 2. What is the purpose of this study?

The purpose of this study is to see how spine postures influence spine movement and the relationship between these and low back pain. The research will also compare differences in spine movement between dancers with and without low back pain. We will do this through a questionnaire, clinical assessments, and biomechanical motion analysis.  We are asking you to take part in this research study because you are a dancer with or without low back pain.

## 3. How long will I be in the study? How many other people will be in the study?

Your participation in this study involves one visit to the Harkness Center's biomechanics lab. The visit will last about 2 hours. We expect to enroll 60 subjects in this study. The entire study will last about 6 months.

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## 4. What will I be asked to do in the study?

In this study, individuals with and without low back pain will be asked to sign this consent and do the following:

1.  Complete a questionnaire

    The questionnaire will ask you about demographic information (age and sex), your dance background and medical history, and any past experience of pain, symptoms, and impact. It also will ask you about your attitudes towards pain and perceived aggravating factors. All responses to the questionnaire are de-identified and remain confidential.

2.  Have your spine assessed by health professionals who are members of the research team

    The assessment includes passive testing of spine range of motion, which involves some hands-on assessments, and active assessments. During the assessments, you will perform standing and sitting tasks, as well as small bending and twisting movements of the spine. These will be assessed manually and visually by either one or two health professionals. All tests are performed at a pace and within a range you are comfortable with. Each test will be performed twice per side (left and right), for a total of four times if you are assessed by one health professional, or eight times if you are assessed by both health professionals.

3.  Perform a series of movements that will be captured by the Harkness Center's motion analysis system.

    To assess spine movements, you will have 35 small reflective markers (balls) attached onto the skin on your trunk, legs, feet, and head using double-sided tape. This will require that you wear shorts and a sports bra or crop top (women) or be shirtless (men) to allow markers to be placed on the skin. If your trunk is hairy, a researcher may need to shave small patches on your back to allow the markers to adhere. Once the markers are in place, you will then be asked to perform a series of standing, sitting, and spine bending tasks, as well as everyday movements including walking and stepping, as well as dance movements including a passé in turnout, an arabesque, and a series of sautés (small jumps) in first position while the motion analysis system captures your movement. Each of these biomechanics tasks will be performed twice per side (left and right). Please note that the motion analysis system does not capture your physical image, just the position of the markers in space as you move.

4.  Complete an online questionnaire that will be emailed to you six months after your visit. This questionnaire will follow up your single visit and will contain questions about low back pain. It is anticipated to take less than five minutes. You may choose to opt out of this portion of the study if you wish.

    ☐ I agree to be contacted via email in six months to complete the online questionnaire.

    ☐ I do not want to be contacted in six months.

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Signature of subject or legal representative                                     Date

## 5.  **What are the possible risks or discomforts?**

When completing the questionnaires, it is possible that recounting episodes of low back pain may result in frustration, feeling uncomfortable, or a degree of distress. The spine movement assessments and functional tasks involve movement, which does present risk of physical injury. However, you will not be asked to perform movements outside of your comfort zone and these movements will not pose risk that is greater than a typical dance class.

It is possible that the double-sided tape used to adhere the markers could cause irritation or redness.

Although there is a risk for loss of confidentiality when participating in research studies, we will not label the data we collect with information that can identify you. Instead, your data will be labelled with a code and the information will be secured. Only the research team will have access to your data. Your name or any identifying information will not be included in presentations or publications.

Unforeseeable Risks: the research may involve risks that are currently unforeseeable.

## 6.      **What if new information becomes available?**

During the course of this study we may find more information that could be important to you. This includes information that might cause you to change your mind about being in the study. We will notify you as soon as possible if such information becomes available.

## 7.      **What are the possible benefits of the study?**

You are not expected to get any direct benefit from participating in this research study. The study will improve our understanding of what factors contribute to the development of low back pain, and will also help us develop clinical assessments for health professionals to use with individuals who have low back pain. These benefits may translate to society.

## 8.      **What other choices do I have if I do not participate?**

This is not a study related to diagnosis or treatment of a disease or condition in eligible subjects. You are free to choose not to participate in the study. There are no alternatives to participation.

## 9.      **Will I be paid for being in this study?**

You will be paid $40 in the form of a MasterCard gift card for completing the visit.
In order for you to receive payment, you will need to give the study staff your Social Security Number or Alien Registration number, and date of birth.  If you do not have or wish to give these numbers, you may be in the study but will not receive any payment.

## 10.    **Will I have to pay for anything?**

There will not be any fees charged to you for your participation in this research study.

## 11.    **What happens if I am injured from being in the study?**

There is minimal risk for injury while participating in this study. In addition, there may be risks associated with this study that we do not know about. In spite of all precautions, you might develop medical complications from being in this study.

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For medical emergencies contact 911. If you think you have been injured as a result of taking part in this research study, tell the principal investigator as soon as possible. The principal investigator's name and phone number are listed at the top of page 1 of this consent form.

If such complications arise, we will assist you in obtaining appropriate medical treatment but this study does not provide financial assistance for medical or other injury-related costs. There are no plans for the NYU School of Medicine or Medical Center to pay you or give you other compensation for the injury.  You do not give up your legal rights by signing this form.

## 12.  When is the study over? Can I leave the study before it ends?

This study is expected to end after all subjects have completed all visits, and all information has been collected. If you decide to participate, you are free to leave the study at any time. Leaving the study will not interfere with your ability to access the Harkness Center for Dance Injuries for any reason.

## 13.  How will my information be protected?

NYU Langone Medical Center, which includes NYU Hospitals Center and NYU School of Medicine, is committed to protecting the privacy and confidentiality of your health information.  We are asking for your permission to use and to disclose your health information in connection with this study. You have the right not to give us this permission, in which case you will not be able to participate in this study.  If you do not give this permission, your treatment outside of this study, payment for your health care, and your health care benefits will not be affected.

**What information about me may be used or shared with others?**
The following information may be used or shared in connection with this research:

- Information in your research record, for example: questionnaires, results from your spine assessments, and results of the clinical assessments and movement analysis.

You have a right to access information in your medical record.  In some cases when necessary to protect the integrity of the research, you will not be allowed to see or copy certain information relating to the study while the study is in progress, but you will have the right to see and copy the information once the study is over in accordance with NYU Langone Medical Center policies and applicable law.

**Why is my information being used?**
Your health information will be used by the research team and others involved in the study to conduct and oversee the study.

**Who may use and share information about me?**
The following individuals may use, share or receive your information for this research study:
- The Principal Investigator, study coordinators, other members of the research team, and personnel responsible for the support or oversight of the study.

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- Governmental agencies responsible for research oversight (e.g., the Food and Drug Administration or FDA).

Your information may be re-disclosed or used for other purposes if the person who receives your information is not required by law to protect the privacy of the information.

**How long may my information be used or shared?**
Your permission to use or share your personal health information for this study will never expire unless you withdraw it.

**Can I change my mind and withdraw permission to use or share my information?**
Yes, you may withdraw or take back your permission to use and share your health information at any time.  If you withdraw your permission, we will not be able to take back information that has already been used or shared with others.  To withdraw your permission, send a written notice to the principal investigator for the study noted at the top of page 1 of this form.  If you withdraw your permission, you will not be able to stay in this study.

## 14.  The Institutional Review Board (IRB) and how it protects you

The IRB reviews all human research studies – including this study. The IRB follows Federal Government rules and guidelines designed to protect the rights and welfare of the people taking part in the research studies. The IRB also reviews research to make sure the risks for all studies are as small as possible.
The NYU IRB Office number is (212) 263-4110.  The NYU School of Medicine's IRB is made up of:
 ☐ Doctors, nurses, non-scientists, and people from the Community

## 15.  Who can I call with questions, or if I'm concerned about my rights as a research subject?

If you have questions, concerns or complaints regarding your participation in this research study or if you have any questions about your rights as a research subject, you should speak with the Principal Investigator listed on top of the page 1 of this consent form.  If a member of the research team cannot be reached or you want to talk to someone other than those working on the study, you may contact the Institutional Review Board (IRB) at (212) 263-4110.

Name of subject                          Signature                 Date

Name of person obtaining consent          Signature                 Date

**When you sign this form**, you are agreeing to take part in this research study as described to you. This means that you have read the consent form, your questions have been answered, and you have decided to volunteer.

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