Use of the Oslo Sports Trauma and Research Centre overuse questionnaire (OSTRC-O2) to measure the prevalence, incidence and severity of musculoskeletal complaints in pre-professional dance students

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Abstract

Background: Dance is a demanding and athletic artform with training at the pre-professional level featuring intensive workloads. As such, dance training is associated with high risk of injury, however the extent of dance injuries is unclear. Growing evidence suggests that dancers frequently underreport injury, modify their dancing and are likely to 'dance through' pain.

Objectives: The Oslo Sports Trauma and Research Centre Overuse Injury questionnaire (OSTRC-O2) was used to assess the extent and severity of musculoskeletal complaints among dancers in pre-professional training, assessing their impact on performance, dance modifications, and pain levels. Associations between hours spent in dance training and the incidence of musculoskeletal injuries, injured anatomical locations, and additional physical activity were also observed.

Methods: In this cohort study, 21 students of a full-time dance-training school in New Zealand (age 17.6 years ± 1.3 years) were surveyed weekly using the online OSTRC-O2 questionnaire. Additional questions quantified the hours spent in class, rehearsals, performance and extra physical activity, and whether participants sought medical attention. The 5-week observation period included the academic term and end of year performances.

Results: Total prevalence rate of musculoskeletal complaints across the five weeks was 2.0 per participant, with nearly all (95%) reporting a complaint and 30% having a substantial problem as defined in the OSTRC context. The incidence of musculoskeletal complaints was 9.5 injuries/1000 dance hours. 88% experienced some level of pain while dancing, but most (98%) continued to participate. Lower legs (38%) and feet and toes (26%) were the most reported locations of injury while less than half (45%) of participants sought medical support. There was some evidence of a positive association between the incidence of musculoskeletal complaints and dance hours with dance style, body weight and dance experience suggestive of higher odds of injury in contrast to age and height which were potentially protective. However, no variables were statistically significant.

Conclusion: Among élite level pre-professional dancers, the risk of musculoskeletal complaints is high. The OSTRC-O2 questionnaire severity score can be used to monitor ongoing musculoskeletal complaints and the recovery from such complaints. Changes in the OSTRC severity score can inform dancers, teachers and medical clinicians and can be used as an outcome measure. Dancers appear to manage their musculoskeletal complaints independently and are likely to participate while in pain.

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Contents

Tables

Figures

Abbreviations

Abbreviation	Term
BMI	Body Mass Index
IADMS	International Association for Dance Medicine and Science
OSTRC-O2	Oslo Sports Trauma and Research Centre Overuse questionnaire (version 2)
OSTRC-H2	Oslo Sports Trauma and Research Centre Health Problems questionnaire (version 2)
DEs	Dance exposures

Chapter 1: Purpose

1.1 Introduction

Dancing is a demanding art form known for its high rate of overuse injuries, prompting an increased interest in purposeful injury reporting to aid in risk mitigation (Liederbach et al., 2012). Dancers are required to have muscular strength and endurance, anaerobic and aerobic energy capacity, speed, agility, flexibility, coordination, motor control, and psychological readiness (Lee et al., Kenny et al., 2015; Shah et al., 2012; Smith et al., 2015). Pre-professional dancers will typically train from a relatively young age, at high volumes and intensities, and in movement ranges that might be considered beyond normal (Kenny et al, 2015). While already possessing a high level of physical accomplishment, they are still developing their technical skills and building the strength and athleticism required for a professional career (Luke et al., 2002). However, all dancers, regardless of skill level, face the risk of musculoskeletal injuries (Hincapie et al., 2008, Leanderson et al., 2011) with classical ballet dancers in particular encountering unique challenges due to the art form's complex technical requirements and exacting aesthetic ideals (Hamilton, 1989; Vassallo et al., 2019). Dance is as strenuous and demanding as most sporting activities, with the high standard of proficiency demanded of all first-class athletes (Clarkson, 1985; Hamilton, 1989). Ballet dancers' perfectionist ideals of technique and artistry contribute to a unique injury risk, one that is proposed to influence the distribution and experience of injury (Vassallo et al., 2019).

Injury not only affects individual dancers but also imposes significant burdens on dance organisations (Liederbach et al., 2012). Professional dancers may be at risk of losing contracts or roles if they become injured, while pre-professional students may find their career aspirations cut short if the rigours and unrelenting requirements of dance technique and training leave them with on-going injuries (Bowerman, 2013). This large economic and personal burden of musculoskeletal injuries in dancers underscores the importance of ongoing injury tracking to inform prevention and management strategies (Kenny et al., 2018; Karreman et al., 2019).

The literature pool for dance medicine is extremely small when compared with sports medicine research and other athletic genres/modes (Gottschlich & Young, 2011; Bronner et al., 2006). Unlike traditional injury surveillance systems of athletics, which are based on time-loss or medical attention (Clarsen et al., 2014), dance injuries often manifest as overuse injuries or non-time-loss injuries. Using time-loss as the definition of injury definition may not recognise that dancers often continue to dance through injuries or musculoskeletal complaints without seeking medical attention (Allan et al., 2012; Hincapie et al., 2008; Gottschlich & Young., 2011; Shah et al., 2012).

There are challenges in comparing studies on dancer injuries due to methodological variations and inconsistencies in injury definitions (Anand Prakash & Akilesh, 2023; Bronner et al., 2006). This makes it difficult to quantify and report a single overall injury rate for dancers, and often there is no accounting for workload exposure, or uniform method for data collection or reporting of injuries (Anand Prakash & Akilesh, 2023; Bronner et al., 2006; Gottschlich & Young, 2011; Gamboa et al., 2021). Various source populations, such as ballet and contemporary dancers, are included in studies, leading to diverse samples. This diversity, coupled with different inclusion and exclusion criteria, can reduce the homogeneity of the sample population (Gottschlich & Young, 2011). Discrepancies between self-reported and medically reported injury rates further complicate injury research, emphasizing the need for accurate injury reporting and data collection methods (Kenny et al., 2021; Thomas & Tarr, 2009; Caine et al., 2016). Thus, the challenge of dance injury research is the collection of accurate injury reporting and incidence data (Vassallo, 2019: Bronner, 2006), as a first step towards injury prevention (Karreman et al, 2019).

Reporting of injuries is also highly dependent on the availability of and access to dance-specific healthcare services. Differences have been noted between the wrap-around services available to ballet dancers holding fulltime positions in professional companies compared with contemporary dancers in less well-resourced contemporary dance companies (Shah et al., 2012). It has been suggested that the lack of an impartial third party is a practical barrier to dancers reporting injury, and that the disclosure of injury or seeking advice may be easier from an independent health-care

professional (Vasallo, 2019). Other reasons for not reporting dance-related injuries have been cited as beliefs that their dancing was not affected, and that they didn't want to stop dancing (Luke, 2002), demonstrating a desire to constantly "work hard" (Vassallo et al., 2019).

Regardless, previous research has reported that various intrinsic and extrinsic factors are significantly associated with an increased risk of dance-related injury, including previous injury (Kenny et al., 2019) entering full-time training (Caine et al., 2016; Fuller et al., 2019; Vassallo et al., 2018), training hours (Ekegren at al., 2011; Gamboa et al., 2008; Steinberg et al., 2014), dancer fitness (Dang et al., 2023; Kenny et al., 2016; Koutedakis & Jumurtas, 2004) and being an adolescent dancer (Gamboa et al., 2008, Leanderson et al., 2011) ,as well as the physical nature of dance that requires repetitive movements often exceeding anatomical limitations (Luke et al., 2002; Steinberg et al., 2012).

To address such challenges in the dance literature base, the Standard Measures Consensus Initiative in 2012 by the International Association for Dance Medicine and Science (IADMS) defined the term "injury" as an anatomic, tissue-level impairment resulting from dance practice, as diagnosed by a licensed health care practitioner, resulting in full-time loss of activity for one or more days beyond the day of onset. At the same time, they introduced the concept of "musculoskeletal complaint" for events falling short of this definition (Liederbach et al., 2012). An overuse injury, or non-traumatic injury, is defined as "self-reported musculoskeletal complaint/modified participation, but no time off" (Liederbach et al., 2012). With this definition, it becomes possible to identify injuries that do not result in full-time loss for the dancer. Time loss and medical attention injury definitions both underestimate the burden of injury in preprofessional ballet dancers (Kenny et al., 2016) as non-time-loss injuries may be more common than time-loss injuries in dancers. These injuries may not be readily identified, monitored, or analysed by teaching or management staff, especially concerning pain levels, severity, and ongoing impact on participation.

The most reported injured body areas vary across studies, and injuries also differ between male and female dancers due to the defined gender roles found in ballet (Dang et al., 2023; Mendes-Cunha et

al., 2023). Most of the current literature agrees that lower extremity injuries are the most common area affected for dancers, followed by the back (Gottschlich & Young, 2011, Caine et al, 2016, Smith et al., 2014; Smith and Micheli, 2006; Prakash & Akilesh, 2023). However, the Australia Safe Dance 4 study found that the ankle, knee, and hip were the most frequently reported injury sites (Vasallo, 2017). A large study of over 200 dancers in the UK found that the lower back and knee were the most commonly reported sites of pain and injury (Thomas & Tarr, 2009). Female dancers, especially ballet dancers, are more likely to suffer from lower leg and foot problems due to the requirements of pointe work, while male dancers experience injuries to shoulders, knees, and Achilles (Caine et al., 2016; Dang et al., 2023; Mendes-Cunha et al., 2023). Male dancers land with 6,000 newtons of force in large jumps (approximately 8 times their body weight), often landing on one leg, which puts a huge strain through their knees and lower leg structures, such as the Achilles tendon, while lifting and partner work can contribute to shoulder injuries (Nilsson et al., 2001). As such, male professional dancers have been shown to have a higher proportion of traumatic injuries, accounting for half of their injuries (Preston et al., 2015).

Injuries are multi-factorial in nature, yet intrinsic factors considered to predispose a dancer to injury include biomechanical variables, scoliosis or excessive or insufficient joint range-of-motion (Gamboa et al., 2008). Other associated risk factors for dance-related injury among pre-professional ballet and university contemporary dancers include injury history, insufficient strength and flexibility, improper technique or alignment, and poor psychological coping skills (Kenny et al., 2015). The literature also lists previous dance experience (Caine et al., 2016), faults in technique, (Negus et al., 2005), and imbalances between strength and flexibility along with poor postural alignment, (Gamboa et al., 2008) and exceeding anatomical limitations (Luke et al., 2002; Steinberg et al, 2012). It has been found that a lack of functional ‘turn-out’ (external rotation in the acetabular joint) can contribute to the number and severity of overuse injuries (Negus et al., 2005). It is concluded that these assumptions are largely intuitive, as there are very few studies looking at the relationships between measurement of intrinsic characteristics and dance injuries (Gambo et al., 2008).

Extrinsic factors may include training volume, stress, shoes, and calcium intake (Caine et al., 2016) while fatigue has been indicated as a significant factor associated with injury (Vassallo, 2017; Liederbach et al., 2001). Kenny at al. (2015) found in a systematic review of the risk factors for musculoskeletal injury in pre-professional dancers that the most modifiable risk factors were anthropometrics (i.e. body mass index, adiposity), joint range of motion, (i.e. lower extremity), dance exposure (i.e. years training, exposure hours) and age. Psychosocial factors are also a component of injury, with one study showing that freedom from worry and confidence were significant predictors for frequency of injury in dancers (Noh et al., 2011).

Dancers are usually in full-time training from a relatively young age (often as young as 14) compared with other elite athletes (Caine et al., 2015). This intensity of early training may put this population at risk and Negus et al (2005) note that of the 50% of pre-professional dancers in Australia with a persistent or recurrent injury, 35% of these occurred before the age of 18. A systematic review of the incidence and prevalence of musculoskeletal injuries in ballet, found that the average age of amateur/pre-professional dancers was just 16.2 years (Preston et al., 2015). This study also found that the amateur dancers had a higher proportion of overuse injuries than the professional dancers, suggesting that the intensity of training in terms of hours per week and number of months across the year, should be considered to potentially decrease injuries among younger dancers.

New Zealand has a vibrant dance scene, long-established professional ballet company, and a number of pre-professional schools which produce dancers who go on to achieve highly on the world stage, yet there is a dearth of research focusing on the prevalence, incidence, and severity of overuse injuries among élite, pre-professional dance students. Given the intensive training regimen and early age at which dancers begin training, understanding and addressing injury risks are crucial for the long-term well-being of New Zealand's aspiring dancers.

Improved monitoring of dance injuries and an attempt to understand the root causes, may aid full-time training institutions to minimise the physical vulnerabilities and injury risk of young dancers.

Using validated injury monitoring tools such as the OSTRC-O2 overuse injury questionnaire can enhance understanding of musculoskeletal complaints among dancers, provide information on participation, modification, performance effect and pain that a dancer experiences, aiding in injury prevention efforts and helping researchers to understand the extent and severity of musculoskeletal complaints.

1.2 Aims

The aim of this research is to use an online surveillance questionnaire to assess musculoskeletal complaints among dancers in pre-professional training, assessing their impact on performance, dance modifications, and pain levels.

1.2.1 Objectives

1. To observe musculoskeletal complaints among pre-professional dancers, using the Oslo Sports Trauma and Research Centre's Overuse Injury questionnaire (OSTRC-O2), modified for dance specificity.
2. To determine the prevalence, incidence and severity of these musculoskeletal complaints including anatomical location and reported pain levels and management of their musculoskeletal complaints.
3. To investigate the association between dance training hours and the incidence of new injuries.
4. To observe additional physical activity completed by pre-professional dancers.

1.2.2 Hypotheses

1. Most adolescent dance students in full-time, pre-professional dance training will experience and self-report a musculoskeletal complaint during the data collection.
2. There will be an association between long dance training hours and the incidence of musculoskeletal complaints.
3. Dancers will participate in various physical activities outside of school.

4. That dancers will modify or reduce their dancing rather than stop altogether while injured or recovering, so the traditional definition of "time loss" used in sport does not apply to the dance community.
5. Dancers will report managing their musculoskeletal complaints and training load on their own while continuing to participate and modify their dancing in class, rehearsals, and performances, as necessary.

1.3 Structure of thesis

This thesis is composed of four chapters. It begins by introducing overuse injuries in dance and highlights areas of further research needed on dancers in New Zealand. The second chapter is an extended review that explores the literature surrounding overuse injuries and discusses related themes relevant to the identified risk factors for dance-related injuries. The third chapter presents the methodology, results and discussion of the study's findings. The final chapter of the thesis presents a summary of the research, the limitations and future directions for research on overuse injuries in dancers.

1.4 Researchers contributions

Table 1.1. Summary of Researchers' Contributions to Study

Author	Contribution to Thesis
Ellena Conland **MHs Student sport and exercise**	Primary author of thesis. Recruited participants, collected data. Conducted statistical analysis, interpreted results.
Dr Claire Badenhorst Primary Supervisor Lecturer School of Sport, Exercise and Nutrition.	Assisted with use of Qualtrix software for the online research questionnaire. Assisted with statistical analysis and interpretation of results. Revised and approved the thesis.
Dr Toby Mündel **Original Supervisor** **Lecturer School of Sport, Exercise and Nutrition.**	Assisted with research design and ethics application.

Chapter 2: Literature Review

2.1 Introduction

Dance is a physically demanding art form and much of the current literature suggests that injuries are an important health issue for dancers at both the professional level and pre-professional (Hincapié et al., 2008; Leanderson et al., 2011). An increased injury risk is commonly attributed to the demands of a vast and ever-changing dance environment (Anand Prakash & Akilesh, 2023) that requires increasing volume and intensity of training (Critchley et al., 2023) and higher levels of physical accomplishment at a younger age (Keay et al, 2020; Kenny et al., 2021) However, it has been noted that compared with sporting genres, the evidence base literature on dance medicine is extremely small (Gottschlich & Young, 2011; Bronner et al, 2006). Numerous studies have been conducted to understand the prevalence, types, risk factors, and preventive measures associated with dance injuries. Currently there is no clear agreement on the prevalence of or the risk factors for injury, a result that is likely due to the heterogeneity of the previous studies in terms of dance context, appropriate injury definitions and utilized surveillance systems (Anand Prakash & Akilesh, 2023; Smith et al, 2015). To provide context for this thesis, the purpose of this literature review is to provide a comprehensive overview of recent research on the prevalence and incidence of dance injuries among pre-professional dancers, while highlighting common themes, results, research gaps and suggested causes.

2.2 Methodology

A systematic search of electronic databases, including PubMed, MEDLINE, Scopus, and Google Scholar, was conducted using keywords such as dance *injury* OR survey OR prevalence OR risk factors. Studies published in peer-reviewed journals between 1985 and 2023 were included in this literature review. The inclusion criteria included research that had investigated dance-related injuries among dancers of pre-professional and professional levels and included both ballet and contemporary dance studies.

2.3 Prevalence and incidence of injuries and the OSTRC questionnaire

The prevalence and incidence of acute injury patterns in sport have been researched extensively over the years using a variety of monitoring systems (Clarsen et al., 2012). Epidemiological patterns differ depending on the sport, player position, gender, and amount of participation, allowing for the development of injury prevention strategies. The majority of recent studies surveilling injuries, risk factors and prevention strategies use registration methods that are based on consensus statements for the study of injuries in football, published in 2006 and later adapted for other sports (Fuller et al., 2006). Time loss remains a fundamental component of "standard" registration methods as it forms the basis for the measurement of injury severity, and consequently, there are very few studies that specifically aim to collect data on overuse injuries (Clarsen et al., 2012).

One such tool developed for the monitoring of injuries in sports, which looks beyond acute injury and time-loss as a method of registration, is the online Oslo Sports Trauma Research Centre overuse injury questionnaire. The OSTRC overuse injury questionnaire (OSTRC-O) was initially developed and to capture and monitor the consequences of long-term, overuse injuries among Norwegian Olympic and Paralympic athletes (Clarsen et al., 2012). It is a validated, 4-item questionnaire developed to assess four domains to evaluate the consequences of overuse injuries on athletes: (1) sports participation, (2) training volume, (3) sports performance and (4) pain (Clarsen 2012). However, while being suitable for capturing overuse injuries longitudinally in athletic populations, athletes may continue to participate while suffering illness or acute injuries, which led to the development of the OSTRC Questionnaire on ‘health problems’ (OSTRC-H), covering anything from an acute injury to mental health issues or colds and flus (Clarsen et. al, 2014). Both the OSTRC overuse injury and health problems questionnaires have been widely used and cited in sports injury research since the initial publication in 2013 and 2014 (Clarsen et al, 2020). Across numerous sporting codes and athletic populations, it has been translated, modified, and validated into numerous languages, including French, Spanish, Danish, Japanese, Thai, and Chinese. It has been applied to academic studies in hip hop, ballet, and contemporary dance, among other dance forms.

Prevalence is the proportion of injuries in a population at any one time and some researchers consider it a more appropriate measure of the magnitude of injuries than incidence (Bahr, 2009). Within the field of dance, studies have reported varying prevalence rates of dance injuries across different dance genres and populations (Anand Prakash & Akilesh, 2023; Smith at al., 2015). While insights from previous work suggest that dancers may be subject to acute injuries, overuse injuries are by far the most common with 40%-50% of injuries being reported as overuse in both ballet and contemporary populations (Allan, 2012; Gamboa et al., 2008; Leanderson et al., 2011; Poggini et al., 1999; Steinberg et al., 2008). However, a recent review reported between 26% to 84% in any artistic dancer and 42% to 343% in ballet dancers experience dance-related musculoskeletal pain (Anand Prakask & Akilesh; 2023). In addition, a study by Smith et al. (2010) found that 80% of professional ballet dancers reported at least one injury within a 12-month period. Conversely, studies that have focused on specific dance styles, such as modern dance or hip-hop, have reported lower overuse injury prevalence rates ranging from 25% to 50% (Liederbach et al., 2008; Smith & Micheli, 2006). Discrepancies in studies between dance forms and context, injury definitions, registration methods, and surveillance systems have been cited previously in the dance literature as a barrier to gathering accurate epidemiological data on injury prevalence (Bronner et al., 2006; Kenny et al., 2018; Liederbach et al., 2012; Anand Prakash & Akilesh, 2023). More recently, a standardization in research, particularly with active and prospective injury surveillance, injury classification, injury evaluation, and injury reporting has been recommended to help improve evidence of overall injury rates in dancers and mitigate previous research discrepancies and variability (Liederbach et al., 2012; Anand Prakash & Akilesh, 2023). For instance, it has been recommended that as well as reporting on overall dance-injury rates, it is important to determine injury rates by gender, technique level, and activity setting (Caine et al., 2016) as has been done by recent researchers (Drysdale at al., 2023).

Incidence rate is the traditional measure of injury rates, defined as the number of new injuries per 1,000 hours of sports or activity participation (Orchard & Hopkins, 2007). The overall incidence rate of dance injury has been reported to range from 0.8 to 4.7 injuries per 1,000 hours of dance exposures

(DEs) (Caine et al, 2016). Similarly, a study conducted by Luke et al (2002) estimated an injury incidence rate of 4.7 per 1000 dance hours in pre-professional dancers, similar to that reported in a recent meta review which found the incidence of dance injuries to be less than 5 injuries per 1000 dance hours, with lower extremities and back being the commonly reported sites of injury (Anand Prakash & Akilesh, 2023). Interestingly, within dance literature research some report injuries per 1,000 hours of dance (i.e. work exposure) and others report injuries per 1,000 hours of dance participation, often referred to as exposure hours (i.e. one class, rehearsal or performance). Exposure hours are problematic as a measure of actual work, due to the intermittent nature of dance, in which dancers may spend periods at rest, sitting and watching or waiting for their turn. As a result, the physical intensity or expenditure is likely to be highly variable across exposure events (Gamboa et al., 2008). Therefore, it is acknowledged that analysing incidence rates in dance is challenging (Smith et al, 2015) and indeed, many studies do not report on injury incidence per 1,000 hours or per 1,000 exposures, at all (Bronner et al 2006; Bowerman, 2013). Additionally, it has been suggested that reporting incidence fails to account for injuries that are present at the start of a study, which may preclude the registration of a large proportion of overuse injury problems and therefore may not provide the complete overview of such injuries (Clarsen et al., 2013). Of note, Kenny et al. (2018) reported in their cohort study that 81% of dancers had at least one physical complaint during the academic year, yet only 41% of dancers reported at least 1 time-loss injury. Dance injuries may be underreported, with previous research suggesting that dancers may ignore the pain and discomfort of minor musculoskeletal complaints (Honrado et al., 2021) and modify rather than dis-continue their training, therefore making true incidence rates hard to evaluate.

Compared to athletes in other sports, dancers have a lower incidence of acute and contact injuries, including a lower risk of ACL injury. Women's gymnastics has the highest incidence rate of ACL injuries, (0.33 per 1000 athlete-exposures [AEs]), followed closely by women's soccer (0.28 per 1000 AEs) and women's basketball (0.23 per 1000 AEs), (Hansberger et al, 2018). Dancers may experience fewer ACL injuries due to their rigorous jump and balance training, which results in a reduced

occurrence of the biomechanics related to ACL injury, especially during single leg jump landings (Hansberger et al., 2018). It has also been shown that dancers have higher hip muscle activation compared to non-dancers during landing, which helps them to land with more neutral knee kinematics (less valgus) than non-dancers (Turner et al, 2019). Interestingly, rates of ACL injuries are similar among dancing cohorts regardless of sex, in contrast to athletic populations where females experience an increased rate of ACL injuries. This is because female dancers use landing patterns similar to those of male athletes, i.e., less knee valgus (Hansberger et al., 2018). Dancers have also been observed to have no difference in strength between the different sides of the body, presumably due to well-established technical training that requires even use and execution of movement for dance choreography from a young age (Koutedakis & Jamurtas, 2004) This is in comparison with professional athletes such as tennis players, who can have up to 30% difference in bone mass and 18% greater lean mass of their dominant racket arm compared to the non-dominant arm (Sanchis-Moysi et al., 2010). This research suggests that dancers are well balanced physically from the technical side of their training, which may aid the mitigation of risk factors that could contribute to injury that have been observed in other athletic populations.

2.3.1 Definitions of injuries

There are different operational definitions of injury presented across athletic and dance populations and epidemiological studies (Fuller et al., 2006, Liederbach et al., 2012), which complicates comparisons between injury studies on dancers (Bowerman, 2013). The International Association of Dance Medicine and Sciences (IDAMS) worked to standardise dance epidemiology and injury surveillance practices, along with agreed upon operational definitions. The 2012 IDAMS position statement recommended the use of Standard Measures Consensus Initiative (SMCI) definition of an injury as both a “medical diagnosis” and “an anatomic tissue-level impairment as diagnosed by a licensed health care practitioner that results in full time loss of activity for one or more days beyond the day of onset”. Liederbach & Richardson (2007) noted that a ‘purposeful’ injury surveillance system should be used to capture information accurately to document how many injuries happened

over a certain time period, to whom they occurred, when, where and with what outcome, as well as providing information about the mechanism of injury (such as landing from a jump) identify the tissue injured or damaged, and reason as it why it happened (i.e. human factors, environmental factors etc.). Much of the previous studies do not define injury at all, especially in terms of tissue damage, thus our current understanding of injury prevalence and incidence is likely to be limited and under reported (Bowerman, 2013).

While the categorisation of time loss or medical attention are well suited to a sport epidemiological research setting and captures acute injuries, this does not necessarily capture recurrent and overuse injuries (Bahr, 2009; Clarsen et al, 2013). Within sporting disciplines, the need for medical attention has long been used as a definition of injury (Fuller et al., 2006). This has similarly been used in dance research, with some earlier studies only classifying and recording injuries for which medical attention had been sought (Ekegren et al., 2011; Gamboa et al., 2008; Leanderson et al., 2011). In addition, in 2012 IDAMS defined an event that falls short of the strict definition of injury, as a "musculoskeletal complaint" which incorporated overuse injuries (Liederbach et al., 2012). This paper noted the need to capture 'real time data', as non-time-loss injuries may be more common than time-loss injuries in dancers. As such, a definition of "function lost" may be a more useful definition for reporting injury rates and impacts within dancers, as dancers are unlikely to be off completely, due to an injury (Critchley et al. 2023). Accordingly, recent studies have re-defined time loss as "restricted/modifying" rather than "off and undergoing rehab" in order to describe the phenomenon of musculoskeletal complaints more accurately in the dance population (Critchley et al, 2023).

There are strengths and limitations to each definition of injury, and the appropriate definition for the injury outcome of interest should be chosen for injury surveillance research (Clarsen, 2014). For instance, the effect of time loss injuries is more problematic for a professional dance company who may have to juggle roles, hire temporary dancers and alter repertoire at short notice due to injured dancers and have an impact on organisational costs (Bronner at al., 2017). In these instances, self-reported musculoskeletal complaints and the inclusion of "all complaints" such as illness, may give a

more accurate overview than the traditional “time loss” or “medical attention” definitions (Clarsen et al, 2014, Kenny et al., 2017). The Oslo Sports Trauma and Research Centre Health questionnaire (OSTRC-H2) may be used to capture and encompass “all complaints”, including any physical or psychological complaints resulting from relevant sports participation, regardless of its consequences. While it has been used in many studies on athletes, the OSTRC survey is still relatively new for the monitoring of musculoskeletal complaints and/or health problems in dancers, although has been used in several dance injury studies such as those by Kenny at al., (2018) Critchley at al., (2022, 2023) and Van Winden et al., (2019). This OSTRC questionnaire is potentially highly suitable to describe the phenomenon of musculoskeletal complaints in dance, where dancers manage their injuries with reduced participation and modification (i.e. loss of function) rather than having time off completely.

2.4 Dancers as athletes

Dance is physically demanding, with aesthetic, technical and repertoire demands meaning dancers can be described as ‘performing athletes’, shown to exert themselves in both training and performances (Kaey et al, 2020; Koutedakis & Jamurtas, 2004). Dancers conduct multiple physical activities within a day, which requires high levels of stamina, unlike sports exposures where athletes either have a game or a practice but not both (Bronner et at., 2017). Dancer fitness depends on the individual’s ability to combine high intensity intermittent spurts requiring both anaerobic and aerobic fitness, and the ability to develop high levels of muscle tension (Malkogeorgos et al., 2013; Rafferty, 2010). There is consensus that inadequate physical fitness is a factor in dance-related injury (Dang et al., 2022), and previous research has suggested that dancers may not necessarily be prepared for the physical demands of dance (Koutedakis et al., 2005; Rafferty, 2010). Dancers need to be strong, yet their potentially reduced level of physical fitness may be associated with relatively high levels of overuse injury, which in turn affects their ability to perform to their maximum potential (Rafferty, 2010). The “Achilles heel” of the dance world is that individuals are selected based on dance ability alone. As such, the dancer's capacity as an athlete may be limited by their muscular strength and

balance, bone and join integrity and their aerobic capacity, even while at the height of their professional career (Koutedakis & Jamurtas, 2004).

The demands of sport and dance training and performance have direct parallels, yet a divide remains with governing bodies of sport and dance (Kaey et al, 2020). Insights from previous research have suggested that dance training programmes lack what has benefited other elite athletes (Rafferty, 2010) and that dance training by itself does not always provide a sufficient conditioning for the prevention of injuries or skeletal imbalances often associated with rehearsals or performances (Malkogeorgos et al., 2013). Conversely, Shah et al, (2012) found in their study of contemporary dancers who were both freelance and company dancers, that additional outside exercise such as weightlifting, or Pilates did not lower the odds of injury. A major barrier cited to the addition of strength training into a dancer's training is that the increase in muscular strength and size would diminish the dancer's aesthetic appeal (Koutedakis and Jamurtas, 2004). Yet, in a recent review, 80% of the included studies reported that there was a significant reduction in injury rate, the time between injuries, pain intensity and severity and missed dance activity due to injury after fitness training was introduced for dancers (Dang et al, 2023). In addition, the effects of supplementary strength training on dancers and resulting increases in muscular strength have been suggested to have benefits for enhancing jump and overall performance (Koutedakis at al., 2005; Vetter & Dorgo, 2009). As such, recent research points to complementary physical fitness training as having a beneficial effect not only on injury incidence but in aiding dance performance.

2.5 Exposure hours and training load

Training as a dancer consists of many hours in different technique classes, long rehearsals and performances usually scheduled in the evenings, therefore training load or stimulus is applicable to this population in the same way as the athletic population. While the association between training load and injury, and the value of monitoring workload, wellness and fatigue is well established in sport, it is relatively novel in ballet (Volkova et al., 2023). Training load describes the total cumulative volume, intensity, and type of physical activity that an athlete undertakes during training and

competition, whether from single or multiple sessions (Soligard et al, 2016). Additionally, the stress that is imposed by a training stimulus is considered to include not only the physiological and mechanical loads placed on an individual, but also the psychological strains (Soligard et al, 2016). Interestingly, there is conflicting evidence for a relationship between session frequency and injury risk, however the relationship between training load and injury is strongest for subjective internal training load using rating of perceived exertions and relative training load assessed using the acute: chronic workload ratio (Gabbett, 2018). Training load is an important variable in understanding overuse injuries and in developing prevention strategies. It has been noted that a lack of standard methodology for expressing workload exposure in dance injury studies is another factor that makes it difficult to compare epidemiological data (Gamboa et al., 2008).

While dance may be considered different to sport, dancers, like athletes, will experience variations in training load across a season. Kenny et al (2018) found that the injury prevalence amongst university level dancers significantly increased when training and rehearsal loads are high, and when performances are approaching. Likewise, it has been found in pre-professional dancers that weekly injury prevalence fluctuates throughout a training season (Critchley et al., 2022). Various methods have been used to determine the training load that dancers may experience during class, rehearsal, or performance. A recent study that examined training load monitoring in dance settings across the genres of classical ballet and modern dance, found that dance hours were the most common tool used to assess training load (Volkova et al, 2023). Objective measures used in studies include heart rate monitoring (Volkova et al., 2023) and the use of wearable accelerometers, which has similarly been used in the athletic setting (Shaw et al., 2023). Additional research has used rating of perceived exertion (RPE) and accelerometers to ascertain the daily workload in in terms of work intensity and rest data in female professional ballet dancers (Twitchet et al., 2010). Results in this last study indicated significant differences between dancer rankings (corps de ballet, first artist, soloist, and principal) for mean exercise intensity and the percentage of time spent at sedentary intensity (< 3 METS), moderate intensity (3-6 METS) ($p < 0.005$), and vigorous intensity (6-9 METS). These authors

noted the dancers' ranking in their companies should be considered in devising work-rest schedules to help them to avoid fatigue and resultant injuries (Twitchet et al, 2010). Similar to these results, a longitudinal study within professional ballet company dancers across five seasons found that overuse injury time-loss was greater in soloist performers, compared with the corps de ballet, potentially due to the greater difficulty of technical requirements of those roles (Shaw et al., 2023). This research shows that dancers have differing levels of work intensity based on their roles which may need to be considered in injury monitoring.

Research that has examined the relationship between combined training and game load and injury risk in elite Australian footballers, concluded that as incremental weekly load increases, so too does the risk of injury (Rogalski et al, 2012). This previous research qualified training and game loads as self-described session rate of perceived exertion (RPE) multiplied by duration in minutes, to record exertion load which gave a rolling weekly sum against which recorded injuries were compared. These sums were described as arbitrary units (AU) and were reported against a reference group of the lowest training load range (Rogalski et al, 2012). Using the same AU, the average weekly training loads in dance have been said to be comparatively higher than those observed in-season for Australian footballers e.g., 1,651 arbitrary units [AU] (Rogalski et al, 2012) vs. 4,175 AU in adolescent ballet students (Fuller et al, 2019). This suggests that the training load exposure hours of dance students is excessively high in comparison with other athletes or sports and as such has been identified as a risk factor in dance-related injuries and injury risk. Whether the risk of dance-related injury is affected by training load is yet to be established, and currently more research is needed in this area (Boeding et al, 2019). However, recent research has concluded that professional ballet companies should consider implementing training principles such as periodization and progression, particularly in the case of senior-ranking dancers, older dancers and dancers with higher rates of previous injury (Shaw et al., 2021).

2.6 Pre-professional students

Dancers start dance classes on average at 5.8 years old (Kaey et al., 2020) and female dancers begin training up to four years earlier than males (Hamilton et al., 2006). Pre-professional ballet training may start as early as the ages of 8 to 10 years, with a professional career commencing approximately 10 years later (Caine et al., 2016). Young bodies have growth plates that are still maturing, and the growth process itself can leave a younger dancer vulnerable to injury (Caine et al., 2016) as they may complete training beyond their physical capabilities (Mendez-Cunha et al., 2022). There is evidence that injuries tend to occur as dancers are transitioning to full-time ballet or contemporary dance training or into professional careers (Fuller et al, 2019), a result that may be due to an increase in training hours (Kenny et al., 2021). When beginning their pre-professional full-time training, an adolescent dancer may increase their volume of training to 20 to 30 hours per week (Fuller et al, 2019) although only 1.7% of their time will be in performance, the remainder of their dance load is typically spent in classes and rehearsals (Ekegren, et al, 2014). This performance volume is significantly lower than that of professional dancers, who may be expected to complete 15 performance seasons per year, equating to approximately 145 performances for each dancer (Fuller et al., 2019). Steinberg at al. (2014) in their study of more than 806 pre-professional dancers reported a higher incidence of injuries per 1,000 hours of dance practice in the 11–12-year-old group, compared with the 13-18 age group indicating that younger adolescent dancers are more vulnerable than older teenage dancers, perhaps due to differences in strength levels. These authors subsequently suggest that the intensity of training, including the number of months and number of hours of training per week, is an important factor that should be considered to decrease future injuries among young dancers. While training load surveillance has been identified as helping to optimise performance within sporting populations, there is little within the dance literature exploring the relationship between overtraining, fatigue, injury and burnout (Liederbach et al, 2013; Kellman, 2010). This highlights the need to consider close monitoring and surveillance systems of young

dancers' load and training hours, a cohort identified to have increased injury risk, therefore requiring optimal rest and recovery periods built into their training to help mitigate injury risk.

2.7 Pathology of overuse injuries

2.7.1 Biomechanics and Loading of Tissue

Research conducted by tissue biomechanists, and biomedical engineers has provided information about the mechanical limits of human and animal tissue, highlighting a complex interaction between overuse, limits of human tissue and injury (Murgia, 2013). Basic concepts of tissue mechanics describe force applied to a tissue (such as collagen that makes up tendons or ligaments), creating stress on that tissue and in response to stress, the tissue will change shape, which is measured by strain. Stress and strain forces may be described as tension (pulling – tensile loads), compression (pushing) and shear (perpendicular to the long axis of the tissue). There is a continuum of normal bone strain leading to appropriate remodelling, but if strain becomes excessive or adequate rest is not allowed, stress reaction and eventually stress fracture may result (Harrast, 2019). A dancer's body is exposed to all three of these forces repeatedly as a result of participation in dance training and performance. Therefore, repetitive movements, exceeding natural anatomical limitations and systemic overloading involving the lower extremities are contributing factors to dance injuries (Honrado et at., 2021; Luke et al., 2012; Mendez-Cunha et al., 2022; Vasallo, 2019).

2.7.2 Motor control and repetition

Reaching a state where a sport skill involves automatic processing of movement is one of the primary goals of athletic training (Gray, 2015). Skill that is executed unconsciously is thought to involve "muscle memory" or motor control, and once initiated, this automatic processing mode runs without the use of attentional or working-memory resources (Grey, 2015). To develop fine control of movement in both static and dynamic conditions, dancers rely on repetition of movements to gain motor control and perfect dance technique (Hansberger et al, 2018). Dancers only advance to a professional level after many years of carefully graded technical exercises, which appears to confer a protective effect in adequately preparing the body for increasingly difficult movement demands. The

repeated practice of dance movements results in muscle-memory patterns that become familiar to a dancer allowing refined movement anticipation (Hansberger et al, 2018). For example, dancers perform jumps that involve landing from mid-air rotations, an intricate combination of characteristics that athletes in other jump-landing sports do not necessarily practice repeatedly (Hansberger et al., 2018). Thus, a dancer's motor control evolves in response to dance specific training, and enables more accurate, efficient and repeatable movement patterns (Gildea et al., 2014). Ironically, this repeated practice of specific movements may cause overuse injuries (Bahr, 2009) and yet it is necessary for a dancer to achieve the exacting technical skills required (Murgia, 2013). This same phenomenon has been observed in sport literature, where overuse injuries occur in large amounts of sports with highly technical requirements, such as tennis, where a movement is repeated continuously (Bahr, 2009).

2.7.3 Structural adaptations and anthropometric variabilities

It has been suggested that dancers push structural tissue to the limit and have joint ranges worked to the outer limit of a "natural" range of motion (Murgia, 2013). Ballet technique requires maximal external rotation through the hip joint, hyper-extension through the knee joints and plantar flexion of the ankle joint to create the desired dance aesthetic and in females, for 'pointe work'. The use of "turn out" and dancing "en pointe" are both movements that frequently go beyond anatomical limitations (Luke et al., 2002). Bone is known to adapt to repetitive mechanical stresses, and bone adaptations may be seen throughout the skeleton (Biehler-Gomez & Cattaneo, 2021). The skeletal structure and shape of a dancer's body is a good example pf Wolf's Law, which describes the adaptation of the inert structures of the body to external stressors. This is partly because dance technique is started at a young age, allowing these adaptations to occur with growth. Structural adaptations seen in the bodies of dancers include an excessively straight thoracic spine and tibial and femoral torsion/bowing developed from standing with the legs externally rotated from the hip joint in 'turn-out' (Hamilton et al., 2006).

The question of whether forced or compensated turn-out in ballet dancers leads to an increase in musculoskeletal injuries in ballet dancers was investigated in a recent systematic review (Kaufmann et al., 2021). This review drew no definite conclusions between the effects of compensating or forcing turnout and musculoskeletal injuries for dancers of all levels, ages and genders, which the authors postulated may be due to turnout being dependent a number of complex factors beyond hip joint dominance. In contrast to this, another study looked to investigate whether dancers are more at risk of injury when they excessively rely on non-hip components of turnout (such as knee and ankle) to compensate for deficits in external rotation from the hip joint (Baker Jenkins et al, 2013). These researchers found that the variables of 'compensated turnout' and 'muscular turnout' corresponded to an increase in the odds that the dancer would sustain two or more injuries during the study period (Baker Jenkins et al, 2013). These last findings would suggest inherent, anthropometric variations within dancers' bodies may make them more vulnerable to injury and speaks to the value of pre-screening dancers at a younger age for suitability (Kenny et al., 2021; Lee et al., 2017).

2.8 Overuse injuries

An overuse injury, or non-traumatic injury, is defined as "self-reported musculoskeletal complaint/no time off" or "self-reported musculoskeletal complaint/modified participation, but no time off" (IADMS, 2012). Overuse injuries are a result of "repeated bouts of physical load without adequate recovery periods" (Timpka et al., 2014) and researchers agree that they are the most commonly reported injury in dance (Allan et al., 2012; Hincapie et al., 2008, Bronner et al., 2003: Gamboa et al., 2008; Leanderson et al., 2011; Luke et al., 2002). Overuse injuries and pain problems are often variable over the longer term, with periods of remission and exacerbation, which makes them difficult to record in an epidemiological study when standard methods of injury registration such as needing medical attention or time loss are used (Bahr,2009). Long-term injuries are caused by repeated micro-trauma with small tears or incongruence in the connective tissue, often without a single, identifiable event responsible for the injury (Fuller et al., 2006; Murgia, 2013). Injuries such as these are often the

result of a pathological process that may have been developing for a long period of time and occur as a result of the tolerance of the tissue being exceeded with repetitive, low-grade forces.

Damage to a dancer's body is particularly worrisome, especially if the dancer is young, due to the long-term consequences of an injury (Phillips, 1999). Researchers have questioned whether the extreme motion and stress placed on a dancer's body have long-term effects such as degenerative conditions like osteoarthritis (Smith et al, 2012). Evidence suggests that while an overuse injury is less serious than a traumatic injury and may not result in the cessation of dance activity, it may progress on to more severe injuries (Caine et al, 2016). This suggests it is important for dancers and those involved in their care and training to understand overuse injuries and the possible causative events surrounding them, to help prevent and effectively treat such injuries before developing into more serious problems.

2.8.1 Common overuse injuries

Studies have identified a wide range of injuries affecting dancers, including sprains, strains, fractures, tendinitis, and overuse injuries (Hincapié et al., 2008). Overuse injuries can occur anywhere in the body, and to any type of tissue, where the overloading of stress and the positive response to strain is insufficient to overcome the damage incurred because of the stress. These types of injuries can lead to pain and dysfunction, and might include swelling, instability, reduced strength, limited range of motion, and decreased agility or other functional limitations (Bohr, 2009). Most of the current literature is in agreement that lower extremity injuries are the most common area affected for dancers, followed by the back (Gottschlich & Young, 2011; Caine et al., 2016; Smith et al., 2014; Smith & Micheli, 2006; Anand Prakash & Akilesh, 2023). A large study of 71 pre-professional dancers found the three most common injury locations were the hip (17.54%), knee and ankle (14.91%), followed by the tibia and foot (Caine et al, 2016). This same study found the three most common types of injury to tissue were tendonitis (22.81%), sprain (16.67%), and strain (14.91%). Upper extremity injuries among ballet dancers are more common in males, due to repetitive arm movements and lifts (Nilsson et al., 2001; Preston et al, 2015) as are lower back injuries for the same reason.

In addition, research suggests there are demographic and injury trends in ballet (Caine et al, 2016). Female dancers tended to report higher injury rates of overuse injuries compared to their male counterparts, who were found to sustain more acute traumatic injuries (Mendes-Cunha et al., 2023), Preston et al, 2015) which is supported by Dang et al (2023) who found that female dancers are at higher risk of injury and report more severe injury than males. Conversely, reviews of injuries in male and female amateur dancers have reported a similar rate of injury (Smith et al. 2015). It has been suggested that the ability to jump, turn and lift is considered more important for male dancers than refined technique, which may account for the sex differences regarding injuries between males and females (Hamilton et al., 1989). These authors theorised that male dancers are not expected to have the turn-out, ankle flexibility and pointed feet that a female dancer must have, although this is debated in the current dance environment (Kaey et al., 2019). Hamilton et al. (1989) also noted that female dancers appeared to have injured themselves attempting to obtain a better technique than their bodies "would allow". It would appear from the literature that further focus, and research is needed to identify anatomical areas most prone to injury with associative causative reasons, which could be sex and role based.

2.8.2 Dancers and jumping

The frequency of performing jump-landing activities in dance puts a dancer at risk of lower extremity injuries, with jumping and landing movements being the most common mechanism of time-loss injury (Mattiussi et al., 2021). Indeed, dancers have been measured to have a jump rate of 4.99 ± 4.93 jumps.min^{-1} during a professional ballet performance (Wyon et al., 2011). Lower extremity strength is essential for the performance of the explosive leaps and jumps that are required in dance, (Malkogeorgos et al., 2013) and the foot/ankle complex plays an essential role in attenuating such landing forces (Arzevedo et al., 2020). The addition of technology to monitor dancers jumping is demonstrated by a recent study that aimed to determine an algorithm for measuring jump height and frequency in ballet, using a wearable accelerometer (Shaw et al., 2023). This study proposed that the

algorithm may be used to implement periodisation strategies, or plan return-to-jump pathways for rehabilitating athletes.

A study comparing the multi-segmented foot kinematics during forward and lateral single-leg jump-landings between professional dancers and non-dancers found that dancers had higher hindfoot-tibia, and forefoot-hindfoot plantarflexion at initial contact than non-dancers (Azevedo et al., 2020). The authors observe that this pattern was commonly linked to a better shock absorption mechanism in jump landings, which challenges the findings that dancers have a high rate of lower extremity injuries as a result of jump-landing activities (Arzevedo et al., 2020). In contrast to this, another study compared the differences in lower limb landing kinematics between adolescent dancers and non-dancers (Hendry et al., 2019). They observed that while the dancers landed with greater sagittal plane range of motion, this appeared to provide, surprisingly, no mechanical advantage and no reduction in ground reaction force. Given the age of the dancers, 11.9±1.1 years and non-dancers aged 10.9 ± 0.9, it could be concluded that the dancers were not yet at an age where they may be able to fully apply their learning dancing and landing techniques or have gained adequate strength levels. However, such a proposition remains to be investigated in future research.

2.9 Dancers' perceptions of injury

Dancers have a relatively short career, which can be cut short by injury. Vassallo (2019) found that 63% of respondents reported a fear of sustaining a dance-related injury, and the same number of dancers also expressed a belief that there is stigma regarding sustaining an injury, and that dancers may hesitate to report an injury. In turn this meant that ~50% of the dancers delayed reporting or seeking care for their injury, and instead choose to "dance through" (Vassallo et al., 2019).

Studies have found that injuries reported and registered with third parties (such as physiotherapists) are much lower than self-reported injury rates (Kenny et al., 2021; Thomas & Tarr, 2009, Caine et al, 2016) suggesting a hesitancy to seek professional help. Less than 50% of dancers seek help from a physician for an injury (Gottschlich & Young, 2011) and it has been reported that dancers perceive

that physicians would not be helpful or understand their personal dance and training requirements (Shah et al., 2012). This is supported by data obtained by Air et al., (2014) who investigated perceptual influences on the choice of healthcare-seeking decisions that dancers made. Notably in this study, dancers perceived dance teachers to be first-line treatment providers (47.5%), followed by physiotherapists (30%) and lastly doctors (12.5%) who were rated only slightly higher than fellow dance students (10%) (Air et al, 2014). It has also been observed that dancers may perceive the recommended time off from dance as being excessive and therefore not comply with advice from a physician (Shah et al., 2012). The Safe Dance 4 survey identified a desire among dancers to be more actively involved in their rehabilitation (Vassallo, 2017). It was also noted in this study that most dancers would prefer to take their own preventative and management steps with a suspected injury. Respondents to the previous Safe Dance I and III studies reported that they were not given as much information as they would have liked from their treating clinician/s about their injury and recovery (Vassallo, 2017). Cumulatively, this research indicates that dancers want to understand their own injuries and take responsibility for managing them.

Dancers have a need to maintain flexibility, strength and technique, rather than have time off or a total rest from dance (Kenny et al., 2018). Dancers are more likely to want to work around their injuries and appear to have an expectation that injury 'goes with the territory' and that suffering is part of dance (Soundry & Lim, 2023). A study of professional contemporary dancers found that while 82% of those surveyed had experienced between one and seven injuries in the previous 12 months, most of the dancers missed no performances due to injury, (Shah et al, 2012), which demonstrates the intense desire to participate in their art. Additionally, 14% of the professional dancers surveyed in one study did not expect their injury to completely resolve (Vassallo et al., 2018) and dancers have reported modifying their dance participation in order to continue professional dance (Vasallo, 2018, Shah et al, 2012). Interestingly, research on functional return to dance following injury found that of the dancers surveyed who had experienced a 'common' injury (excluding back), only 63% returned to the full capacity of their pre-injury level (Junck et al., 2017) which indicate the serious consequences

of such injuries. The researchers also noted that while there were significantly correlated variables, there were better outcomes if the dancer was younger, their injuries were not chronic, and their recovery was not limited by fear. A dancer's desire or need to continue dancing, and psychological factors that may be present in the management and recovery of injuries are areas that warrant further research.

2.9.1 Dancers' perceptions of pain

Understanding the experience of pain for professional and pre-professional dancers is complex (Soundry & Lim, 2023). Pain has been defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage." (Raja et al. 2020) and yet for a dancer, pain is not necessarily unexpected or worrisome. This is because no matter how large the danger signals are, whether mechanical, chemical, heat or cold stimulus, the signals will not be interpreted or felt as pain until the brain processes the incoming information (Claus & MacDonald, 2017). This altered perception can be seen with professional dancers who perceive pain as a positive experience, due to feelings of having worked hard for their art (Soundry & Lim, 2023). Studies suggest the concept of 'dancing through' pain or an injury is indicative of the high self-efficacy and resilience that dancers possess (Claus & MacDonald, 2017; Thomas & Tarr, 2009).

Furthermore, a study of over 260 professional ballet and contemporary dancers found that the dancers did not report their injuries for the belief that pain with dance is inherent, and that they could cope with the pain (Luke et al., 2002). This is supported from the results of a large study on contemporary dancers in the UK, in which 43% of those who reported recent dance-related pain did not consider that the pain constituted an injury, rather, these dancers defined injury as something that stopped them from dancing or moving normally (Thomas & Tarr, 2009). The "no pain, no gain" approach has long been embedded in the culture of dance training. While an early study on dancers' fitness and welfare discussed the need to move on from this mentality (Koutedakis, 1997), future research may need to consider a more thorough investigation of this mentality in younger or semi-professional dancing cohorts.

Common perceptions around injuries and pain can have both an anecdotal basis or a clinical basis (Molnar & Karin, 2017). When dancers were free to describe pain and injury in their own terms they frequently differentiated between the idea of “good” pain and “bad” pain, or what was also described as “tolerable” and “intolerable” pain (Tarr & Thomas, 2021). Good pain centered around muscular aches and fatigue, from heavy rehearsal periods or workouts while “bad” pain was described as a distraction from performance or causing a dancer to be unable to do what they would normally do and was described as “pain which seems to be causing further damage” (Tarr & Thomas, 2021). The researchers did note that some of the descriptors of both types of pain did overlap, such as numbness, burning and aches. Regardless, the subjectivity of the distinction between the two types of pain casts doubts on its validity (Molnar & Karin, 2017). Both interestingly and worryingly, was the fact that some dancers only defined injury in terms of an acute event, seemingly unaware that on-going, aching pains might also be a sign of injury.

Pain is complicated, and the perception of pain or how an individual experiences pain is very variable and may not be reflective of the actual injury or degree of tissue damage sustained (Butler & Mosley, 2013; Claus & MacDonald, 2017). When trying to determine whether to train through pain, ignoring pain may have minimal effect in certain circumstances or disastrous consequences in others (Claus & MacDonald, 2017). One issue that has been identified is that an individual’s sensory perception of pain and what is going on within their body and the brain’s interpretation of this may not accurately reflect the input or causative factors (Clause & McDonald, 2017). This is potentially problematic for young dancers who are still developing sensorimotor control and awareness and may not have the experience yet to understand or differentiate between pain signals. Clause & McDonald (2017) recommend that specific exercise training to develop control of posture and movement can improve motor skills and tissue integrity, which in turn can help normalise the perception of sensory stimuli from the peripheral nervous system to the brain. For this reason, asking a dancer to regularly reflect on their dancing and note their pain levels could be valuable in helping them to develop this knowledge, as pain is a useful and important warning of danger or tissue injury.

2.10 Conclusion

The highly athletic nature of dance means injury is a prevalent issue, with overuse injuries accounting for half of all injuries sustained. This review has discussed the currently available research on the epidemiology of dance injuries and probable risk factors. Associated risk factors for musculoskeletal complaints are difficult to link to one specific causative reason but are due to complex interactions between multiple intrinsic and extrinsic circumstances. -Importantly, dancers will modify or reduce their dancing rather than stop altogether while injured or recovering, so the traditional definitions of "time loss" used in sport do not apply to the dance community. Pain is both normalised and ignored by dancers and does not appear to prevent performance. Additionally, dancers want to understand their injuries and take responsibility for managing them.

As has been discussed, dance training at the pre-professional level features intensive, increased workloads which is associated with increased risk of injury. Therefore, accurate workload and injury monitoring is critical to avoid the long-term consequences of overuse injuries for young dancers and resulting disruption to their training. While different training schools have different approaches, dance training follows a very similar pattern worldwide. Few studies have been done on New Zealand dancers. Investigating self-reported musculoskeletal complaints in elite, pre-professional dancers could enable a more accurate picture of the occurrence and severity of injuries, for on-going epidemiological purposes and building injury prevention strategies.

Chapter 3: Materials and Methods

3.1 Methodology

This was a cohort study conducted in New Zealand at a national full-time dance training school over five weeks of an academic term from October 2022-December 2022. The OSTRC-O2 overuse injury questionnaire (Clarson et al., 2020), which is a self-reported overuse injury questionnaire, was sent electronically to all dancers in the study once a week over a 5-week period. The complete questionnaire can be seen in Appendix C.

3.1.1 Participants and recruitment

Twenty-one dancers from a pre-professional dance school in New Zealand (mean ± SD; age 17.6 years ± 1.3 years; age range, 16–20 years; height, 172.6 ± 7.9 cm; body mass, 61.4 ± 11.8 kg; prior dance experience, 9.9 ± 3.7 years) participated in this study. To be included in the study, dancers had to be a registered student of the facility and were recruited from either the ballet or contemporary dance programme. The audition requirement of the school ensured a similar standard of dance amongst the participants. The study received approval from the Director of the dance school, and dancers were verbally informed of the purpose and procedures of this study, with a request for voluntary participation. Informed written consent was obtained from all individual participants included in the study. The online Qualtrics survey link was sent to all dancers to complete in their own time, on a home computer/tablet/phone and initially included basic demographic information.

The project was evaluated by peer review and judged to be low risk. Consequently, it was not reviewed by one of the University's Human Ethics Committees. Ethical considerations were evaluated around identifying individual dancers and the training institution involved. Cross-referencing against standard time-loss injury registration methods recorded by a physiotherapist were omitted for this reason.

3.1.2 Study design

Online survey software (Qualtrics, Provo) was used to administer the Oslo Sports Trauma and Research Centre (OSTRC) overuse injury questionnaire (Clarsen et al., 2020) to all dancers in the study once a week over a 5-week term. One non-validated survey was used to collect demographic characteristics at the study's start. A group email reminder was sent by the researcher to the dancers every Sunday to ensure that as many dancers as possible completed the questionnaire every week. The OSTRC-O2 questionnaire has four key questions, and supplementary questions were used, including free-text space to add comments.

3.1.3 The Oslo Sports Trauma and Research Centre – Overuse Injury Questionnaire (OSTRC-O2)

The OSTRC Overuse Injury questionnaire (OSTRC-O2) is a validated 4-item questionnaire developed to assess four domains which evaluate the consequences of overuse injuries on athletes, along with the degree to which athletes perceive any symptoms. The domains are (1) participation, (2) modified training/competition, (3) performance, (4) pain or symptoms. The key content of the OSTRC Overuse Injury questionnaire provides details on the dancer's perceived consequences and symptoms of injuries, and an outcome measure of a severity score. For each week, a severity score ranging from 0 to 100 for all reported overuse injuries can be obtained, based on the summation of the dancer's responses to the 4 key OSTRC questions. In accordance with the questionnaire developers, each response is assigned a value ranging from between 0 and 25, with 0 being the equivalent of no problem/modification/effect, to 25 (cannot participate at all or has severe symptoms) the maximum value for each question. Questions 1 and 4 are scored on a four-point scale, (0-8-17-25) and questions 2 and 3 are scored on a five-point scale (0-6-13-19-25) due to the number of answer options.

The weighted numeric value allocated to the response to each of these questions followed the published protocol and was summed to determine an overall severity score for each injury reported, according to the method proposed by Clarsen et al. (2013). This score allows the visualisation of changes in the consequences of problems over time for an athlete/dancer, which can be valuable for

coaches/teachers, physicians, or the athletes/dancers themselves, (Clarsen et. al, 2020). The questionnaire developers emphasise that the severity score does not satisfy the basic requirements of a continuous measure, as it does not have equal intervals between possible scores. It therefore represents an ordinal-scale variable with 25 possible outcomes. The prevalence of substantial overuse injury was determined, as suggested by Clarsen et al., (2012). An injury was categorized as substantial if they reported problems that led to a moderate or severe reduction (a weighted score of ≥13 on question 2 or 3 of the OSTRC-Q) in their ability to train, perform, or participate in dance (e.g. unable to jump or do pointe work). Scores were used to evaluate how the overuse symptoms progressed week to week.

The OSTRC-O2 questionnaire was modified for this thesis study to be dance specific, as per previous research such as that by Kenny et al. (2018). Changes were made to the sports terminology, with the phrases "training and competition" being substituted with "dance class, rehearsals and performances". The content and structure of the questionnaire was not changed in any way. As the thesis aim was to investigate the presence of overuse injuries, or musculoskeletal complaints, the OSTRC 'overuse injury' version (OSTRC-O2) rather than the 'all health problems' (OSTRC-H2) was used. This enabled observation of the specific anatomical regions susceptible to musculoskeletal complaints in this specialised population. While the original OSTRC-O questionnaire was published using the knee, shoulder and lower back as example areas, minor changes were made to the template by the developers in the subsequent version, (OSTRC-O2), published in 2020, which clarified that the questionnaire is applicable to any anatomical region, as was done in this study. Accordingly, rather than asking about a predefined anatomical area of injury, which would have required the four key questions being asked multiple times, the participants in this study were asked generally if they had an "injury".

If the student reported no injury problem/issue/niggle in the past 7 days, the questionnaire was finished. If the student reported an injury, then they were asked what day it occurred, prompted to define the injury, and answer further questions pertaining to it, including the four key OSTRC

questionnaire questions. Participants could report more than one injury problem in the previous week but were asked to reflect on the worst injury first if reporting multiple injuries. Multiple injuries sustained by a dancer in a single event were recorded as one injury with multiple diagnoses. Branch logic procedures of the survey have previously been described by the study developers (Clarsen et al., 2012). Total time required to complete the questionnaires was less than five minutes.

The additional, customised questions to capture further information were added to the survey as has been suggested by the original developers e.g. injured body part, or injury type. It is suggested that these should follow consensus-based recommendations such as the International Olympic Committee consensus statement on methods for reporting of epidemiological data on injury and illness in sport (Bahr et. al, 2020). The free text questions used in this study were deemed to be of value if the questionnaire was to be used (in future) as a practical, dancer-monitoring tool whereby teachers or clinicians could follow and analyse student reporting. This study also asked the participants which day they sustained the injury, as knowing the date of the injury or symptom onset could be important for researchers investigating relationships between training hours and injury. The original questionnaire developers also note that it is not possible to calculate the exact number of time-loss days from the four key questions alone, and that follow-up questions are needed to ascertain this accurately.

3.1.4 Measures of occurrence - injury prevalence and incidence

Injury prevalence and incidence were obtained using the OSTRC injury questionnaire with additional questions on dance training hours and time loss due to injury.

Prevalence measures were calculated for all musculoskeletal complaints for each week that the survey was conducted. This was performed by dividing the number of participants reporting any form of injury by the number of questionnaire respondents during the specified time period (i.e. each week). This included dancers who already had an injury at the start of the time period/study as well as those who suffered an injury during that period.

$$P=X/N$$

[Where *X* is the number of injury cases and *N* is the total number of dancers in the study at any point in the time window *ΔT.]*

Injury incidence rate is defined as the number of new injury cases (*I*) per unit of exposure time i.e.

$$I_r=I/\Delta T$$

[Where *ΔT* is the total time under risk of the study population.]

The incidence of overuse injuries (musculoskeletal complaints) per 1,000 hours of dance participation using the self-reported hours asked on the questionnaire is defined as the number of new injuries divided by the estimated total time all the dancers spent in dance activities (sum technique classes, rehearsals, and performances).

Survey questions asked the dancer to estimate the total number of hours spent in class, rehearsal, performance, and other physical activity during the past seven days. Included in other physical activity were “working a job on your feet” and “shopping”, which was considered relevant since higher levels or duration of loading applied to the lower limbs can affect injury susceptibility. Additional questions included asking whether the dancer had sought medical attention for the problem and the diagnosis for the injury/problem. Finally, dancers were also asked if it was the first-time reporting that injury/problem through the weekly survey to help determine weekly incidence.

Acute injuries were defined as those whose onset was connected to a specific inciting event, whereas overuse injuries were not related to a specific incident and were either gradual or rapid in onset (Kenny et al., 2018). If an overuse injury was recurring in the same location, it was still treated as a single case despite periods where symptoms subsided. As per the IADMS definition, time-loss injuries were defined as loss of activity for one or more days beyond the day of onset.

3.1.5 Data Handling and Statistical analysis

Data were compiled and analysed using R: A Language and Environment for Statistical Computing, R Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2023, {https://www.R-project.org}. Summary statistics are reported for the participant cohort. Body Mass Index (BMI) was calculated by dividing weight (kg) by the square of height (m). All other demographic information was collected directly from participants. Summary statistics include mean values, standard deviation, and range for continuous variables and frequency statistics for categorical variables.

Prevalence was calculated for the cohort using the total number of injuries reported divided by the cohort size. This was calculated by week and for the entire five-week study period. Prevalence is reported as a rate per person as well as per 100 people. Incidence was calculated using the total number of new injuries reported from weeks 2 to 5 of the study period. Raw incidence is reported as a rate per person whilst incidence rate is reported as a rate per 1,000 dance hours.

The Spearmans rank-order correlation was used to observe whether there was a correlation between the incidence of musculoskeletal complaints and total dance school hours from weeks 2 to 5. To test for the association between total class time and incidence of musculoskeletal injuries after adjusting for other variables, a Quasi-Poisson regression model was used to model incidence data from weeks 2 to 5 of the study. This model is an extension to a linear regression model but is suitable for modelling count data while also allowing for overdispersion. In addition to total class time, adjustment variables Age, Gender, Height, Weight, Dance Type and Years Danced. These variables were taken from the participant demographic survey. Odds ratios were calculated for all variables along with associated p-values.

Severity scores for the cohort were calculated as per Clarsen et al (2013). Injuries were defined as substantial problems if participants reported having to reduce training volume or performance time or were completely unable to dance due to their injury (Clarsen et al., 2013).

3.2 Results

3.2.1 Response Rate

Over the five weeks of the study, 21 participants completed at least one survey response and generated a total of 70 responses across the entire study period. During cleaning six responses were removed, 3 responses with no participant ID, 2 invalid responses and 1 duplicated response, giving a final cleaned sample of 64 responses. Most (90%) of participants completed the survey in the first week, however the number of responses reduced in the following weeks with only 43% of participants completing the survey in the final week. Response rates are shown in figure 1. The average response rate was subsequently 61% across the five weeks of this study.

Within this data collection period, only 6 participants completed all 5 questionnaires across the entire 5-week study period. Furthermore, five participants completed only a single week of entry for the study. Of these participants, three reported an injury in their single entry, and two reported no injury. Survey response rates can be seen in figure 1.

3.2.2 Participant characteristics

Only 18 of the 21 participants provided demographic information. Of these, the cohort were young with an average age of 17.6 years. The majority (72%) of participants were female with only six males (28%) in the cohort. There was high variation in both the height and body mass of the participants with the range of height from 157.5 cm to 187.5 cm (standard deviation: 7.9cm) and the range of body mass from 48 kg to 92 kg (standard deviation: 11.8kg). This variation is reflected in the body mass index.

Most of the dancers (78%) had ballet as their primary dance style, with only 4 reporting contemporary. Dancers were most commonly either in their first or second year technique year with only 4 participants in their third year. Within the cohort of participants, a total of eight dancers had been dancing for >10 years, with one dancer having 15 years of prior training before commencing full-time pre-professional training. Participant characteristics are reported in table 3.1.

Figure 1: Survey response rate by survey week

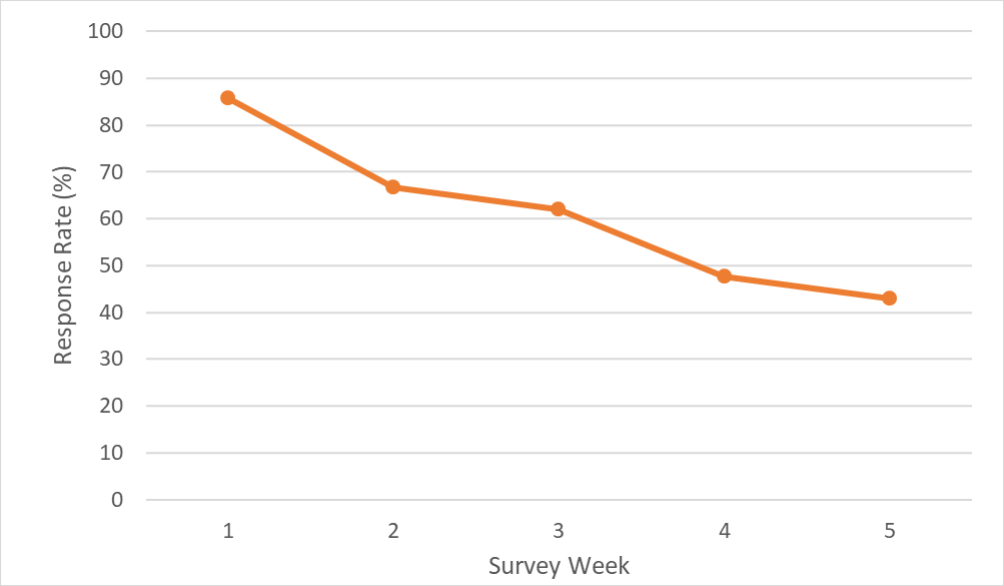


Table 3.1. Characteristics of participants and dance experience. Figures are number (% of non-missing values) unless otherwise stated

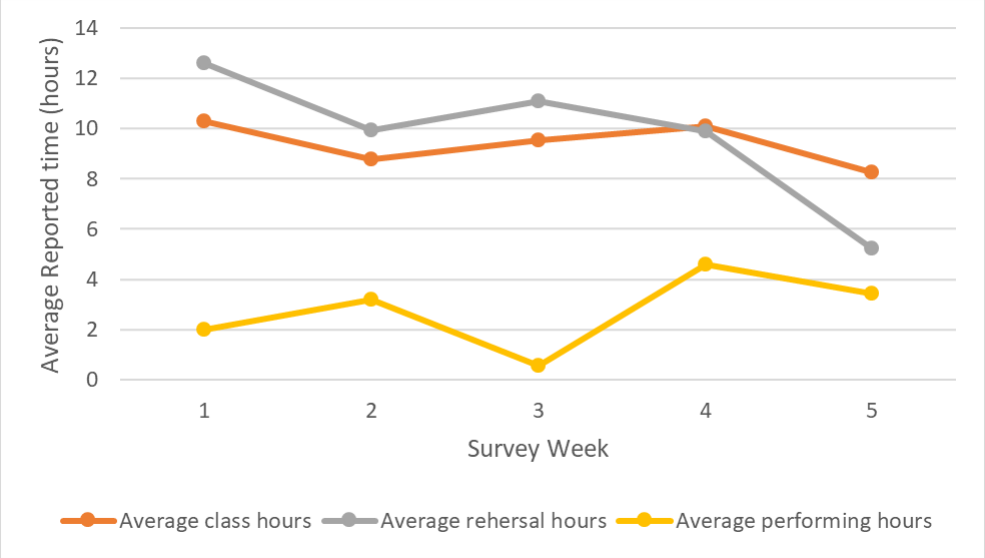
	Participants (*n* = 18)
Age (Years)	
Mean (SD)	17.6 (1.3)
Minimum-maximum	16-20
Sex	
Male	5 (27.7%)
Female	13 (72.2%)
Height (cm)	
Mean (SD)	172.6 (7.9)
Minimum-maximum	157.5-187.5
Body Mass (kg)	
Mean (SD)	61.4 (11.8)
Minimum-maximum	48-92
Body Mass Index[1]	
Mean (SD)	20.5 (2.6)
Minimum-maximum	16.7-27.5
Previous years of dance training	
Mean (SD)	9.9 (3.7)
Minimum-maximum	0-15
Primary dance style	
Ballet	14 (77.8%)
Contemporary	4 (22.2%)
Technique level	
First year	6 (33.3%)
Second year	8 (44.4%)
Third year	4 (22.2%)

[1]Body Mass Index calculated from height and body mass using the equation BMI = kg/m^2

3.2.3 Dance hours

Across all five weeks of data collection, the average total dance time (class, rehearsal, and performance) was 30.9 hours per week. On average, most time was spent in rehearsal (10.2 hours per week), closely followed by class time (9.5 hours per week), and the least amount of time was spent performing (2.6 hours per week). Figure 2 shows the trend of hours spent on each activity across the five weeks. There was large variability in both rehearsal and performance hours which show inverse trends for most of the five-week study period.

Figure 2. Weekly dance hours by activity



3.2.4 Additional Physical Activity

The additional physical activity exposure outside reported by study participants outside of school was not separated into the duration (hours) of each additional activity but was a self-reported accumulation of their weekly activities outside the school. The average number of hours spent in physical activity other than the dancer's prescribed hours in class, rehearsal or performance was 5.0 hours. Walking to school was the most popular physical activity outside dance school classes reported among participants, featuring in 64% of weekly survey responses and mentioned at least once by over 80% of participants. Pilates, cardio, and shopping were also popular activities, reported often and by many participants. Physical activities reported by participants are shown in Table 3.2.

Dance hours in the school setting made up the majority of participants' reported physical activity however four out of five weeks physical activity outside of school made up approximately one fifth of participants' reported physical activity. This is shown in figure 3.

Table 3.2. Physical activity reported by participants outside of dance school

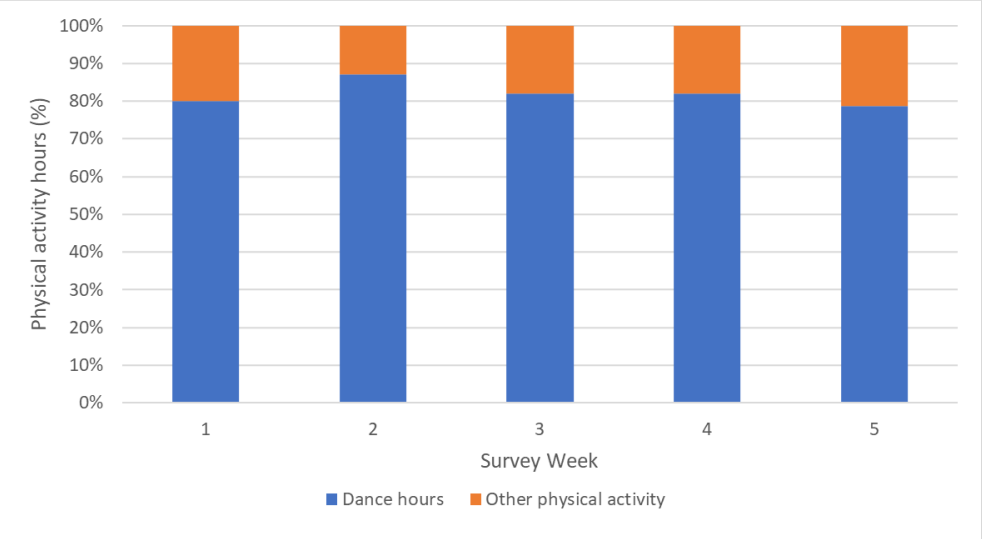
Physical Activity	Activity reported[1] (N = 64) N (%)	Participants[2] (N = 21) N (%)
Gym session - weights	15 (23.4%)	11 (52.4%)
Gym session – cardio	22 (34.4%)	11 (52.4%)
Pilates	29 (45.3%)	12 (57.1%)
Yoga	5 (7.8%)	2 (9.5%)
Running	9 (14.1%)	6 (28.6%)
Playing sport recreationally	2 (3.1%)	1 (4.7%)
Other dance class	8 (12.5%)	5 (23.8%)
Dancing in a night club	9 (14.1%)	7 (33.3%)
Walking to and from school	41 (64.1%)	17 (81.0%)
Working a job on your feet	20 (31.3%)	8 (38.1%)
Housework	11 (17.2%)	8 (38.1%)
Shopping	21 (32.8%)	11 (52.4%)

[1]Activity reported: number of times physical activity reported across all survey responses; [2]Participants: number of participants who reported at least one session; Multiple responses allowed therefore total will not equal 100%

3.2.5 Prevalence and incidence of musculoskeletal complaints

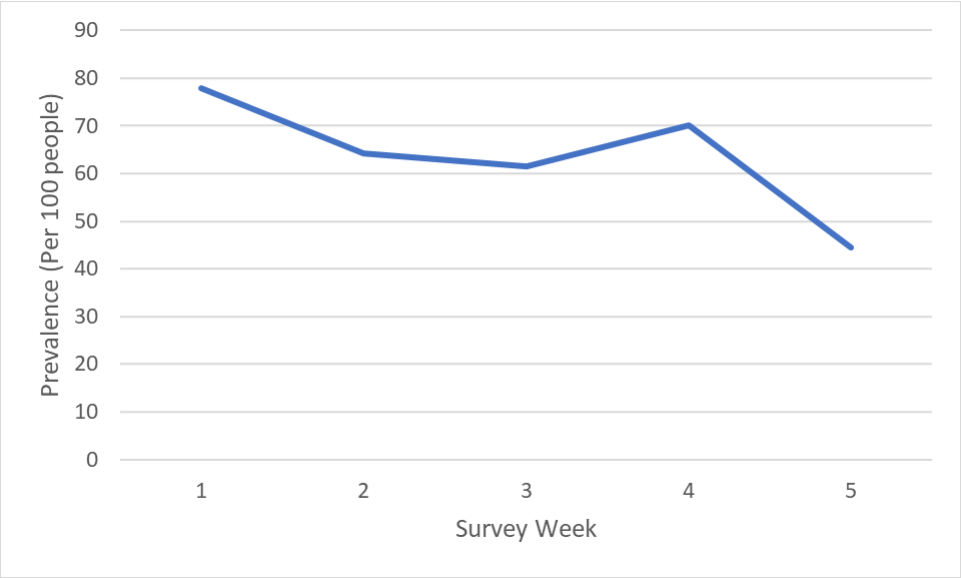
Almost all participants (95%) experienced at least one musculoskeletal complaint during the study. A total of 42 musculoskeletal complaints were reported, with 14 complaints present at the beginning of the study (figure 4).

Figure 3. Percentage of average physical activity hours spent in and out of the dance school setting



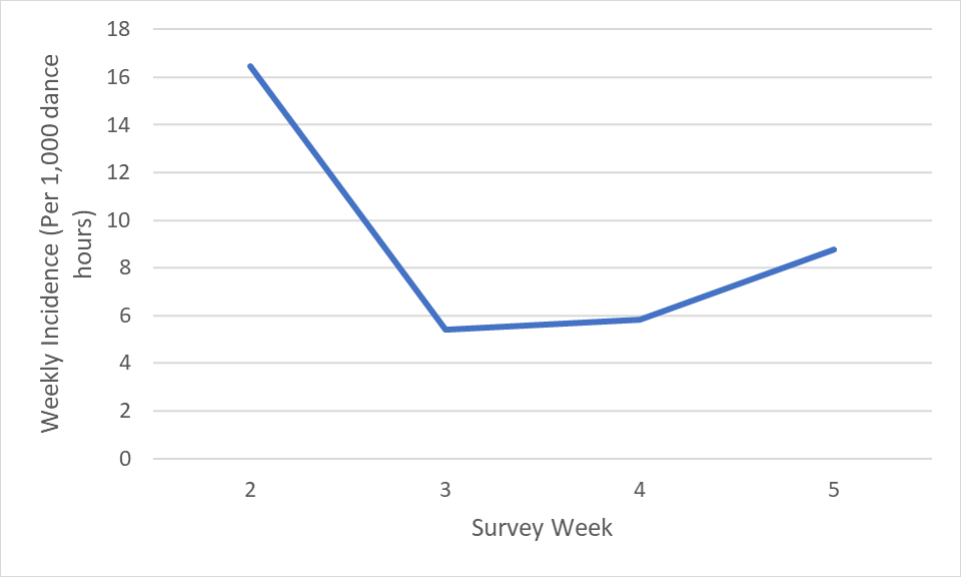
The total prevalence across the five-week study period was 2.0 injuries/participant or 200 injuries/100 people. The average weekly prevalence varied but was highest in the first week and lowest in the last week. No participants reported more than one injury in a single week.

Figure 4. Average weekly prevalence of musculoskeletal complaints



Approximately 46% of reported injuries from weeks 2 to 5 were new injuries and the injury incidence was 0.6 injuries per person or 62 injuries per 100 people. Using the total class hours over the study period, this generated an incidence rate of 0.0095 injuries/dance hour, 9.5 injuries/1000 dance hours. The incidence rate changed drastically over weeks 2 to 5, reducing sharply between weeks 2 and 3 before increasing slightly from weeks 3 to 5.

Figure 5. Average weekly incidence of musculoskeletal complaints



3.2.6 Correlation between dance hours and incidence of musculoskeletal complaints

Spearman's rank correlation coefficient (ρ) was estimated as 0.176 when calculated with an $\alpha = 0.05$ comparing incidence of musculoskeletal complaints and total dance school hours from weeks 2 to 5. This indicates a weak but positive association between the two variables. Testing an alternative hypothesis that the true ρ is not equal to 0, a p-value of 0.24 was calculated from the data. This indicates that that null hypothesis, true ρ is equal to 0, holds and there is no significant correlation between incidence of musculoskeletal complaints and dance hours. Therefore, this data indicates that whilst there was evidence of a positive relationship between incidence of musculoskeletal complaints and dance hours, it was not statistically significant.

Modelling was competed using complete case data, where only responses with data for all variables was used limiting the sample size to 41 using incidence data from weeks 2 to 5 of the study. The dispersion parameter for the model was estimated to be 0.831 and the residual deviance of the model was 24.0 on 33 degrees of freedom.

After adjusting for other variables, results of modelling were consistent with the results of the Spearman correlation analysis. There was indication of a positive relationship between Total Class

Time and incidence of injuries, with an odds ratio of 1.06 (95% CI: 0.99, 1.16). However, this was also not statistically significant. Contemporary dance style, higher body weight, and more years dance experience were also suggestive of a higher odd of injury whilst age and height were potentially protective although no variables were statistically significant. Results of modelling are presented in table 3.3.

Table 3.3. Results of modelling of association between dance hours and injury incidence

Variable*	Level	Odds Ratio (95% CI)	P-value
Total Class Time	-	1.06 (0.99, 1.16)	0.136
Age	-	0.84 (0.22, 2.66)	0.773
Gender	Female Male	1.00 (Reference) 0.94 (0.05, 10.6)	- 0.964
Height	-	0.88 (0.72, 1.06)	0.887
Weight	-	1.11 (0.93, 1.35)	0.274
Dance Type	Ballet Contemporary	1.00 (Reference) 1.60 (0.06, 53.2)	- 0.786
Years Danced	-	1.19 (0.90, 1.58)	0.233

*Numerical variables are presented as odds ratio increase/decrease per one unit change. Categorical variables are presented as odds ratio compared to the reference level.

3.2.7 Affected anatomical regions

Table 3.4 details the anatomical regions affected by musculoskeletal complaints during the study period. Lower legs (38%) and feet and toes (26%) were most commonly reported and reported by most participants (33% and 29%). Reports most commonly cited one affected site but between one and three regions were cited across survey entries. No injuries were reported for the upper arm, wrist, hand/finger, chest/ribs, abdomen, hip/groin, or 'other'.

Across all survey entries where participants reported injuries, less than half (45%) reported participants seeking medical support. In all entries where the participant reported seeking medical support, all mentioned that the participant had seen a Physiotherapist. Acupuncturist, Massage Therapist and Osteopath were each mentioned in one survey entry. Attempts were made to define injuries as either overuse or acute according to diagnosis information provided by participants however this was not possible since less than half (45%) of injuries were reported with a diagnosis. This data was of varying quality including several reports of bone stress, inconclusive diagnoses and

one report of "N/A". As such, there was insufficient information to utilise this data. Reporting the day of injury was considered unnecessary as the study was observing ongoing, gradual onset complaints, but this data could be useful for some aspects of research, e.g. investigating acute injury.

Table 3.4. Anatomical locations affected by musculoskeletal complaints reported by participants

Anatomical Region	Region reported[1] (N = 42) N (%)	Participants[2] (N = 21) N (%)
Head/face	4 (9.5%)	3 (14.3%)
Neck	4 (9.5%)	2 (9.5%)
Shoulder (including clavicle)	1 (2.4%)	1 (4.8%)
Elbow	1 (2.4%)	1 (4.8%)
Thoracic spine	4 (9.5%)	4 (19.0%)
Lumbar spine	4 (9.5%)	4 (19.0%)
Pelvis and buttocks	2 (4.8%)	2 (9.5%)
Thigh	1 (2.4%)	1 (4.8%)
Lower leg	16 (38.1%)	7 (33.3%)
Knee	2 (4.8%)	2 (9.5%)
Ankle	4 (9.5%)	4 (19.0%)
Foot/toes	11 (26.2%)	6 (28.6%)

[1]Region reported: number of times anatomical region reported across all survey responses; [2]Participants: number of participants who reported anatomical region at least once; Multiple responses allowed therefore total will not equal 100%

3.2.8 Pain, Participation and Modification

Over the five-week study period, almost 90% of dancers with musculoskeletal injuries (88%) experienced some level of pain whilst dancing. Of those who reported some level of pain (n = 37), participants most commonly reported either mild pain (57%) or moderate pain (35%). Only 8% of participants reported severe pain.

Of those with injuries, almost all (98%) could continue to participate in dancing. Those who continued to participate (n = 41) did so mostly with some kind of problem (41%) or reduced capacity (22%).

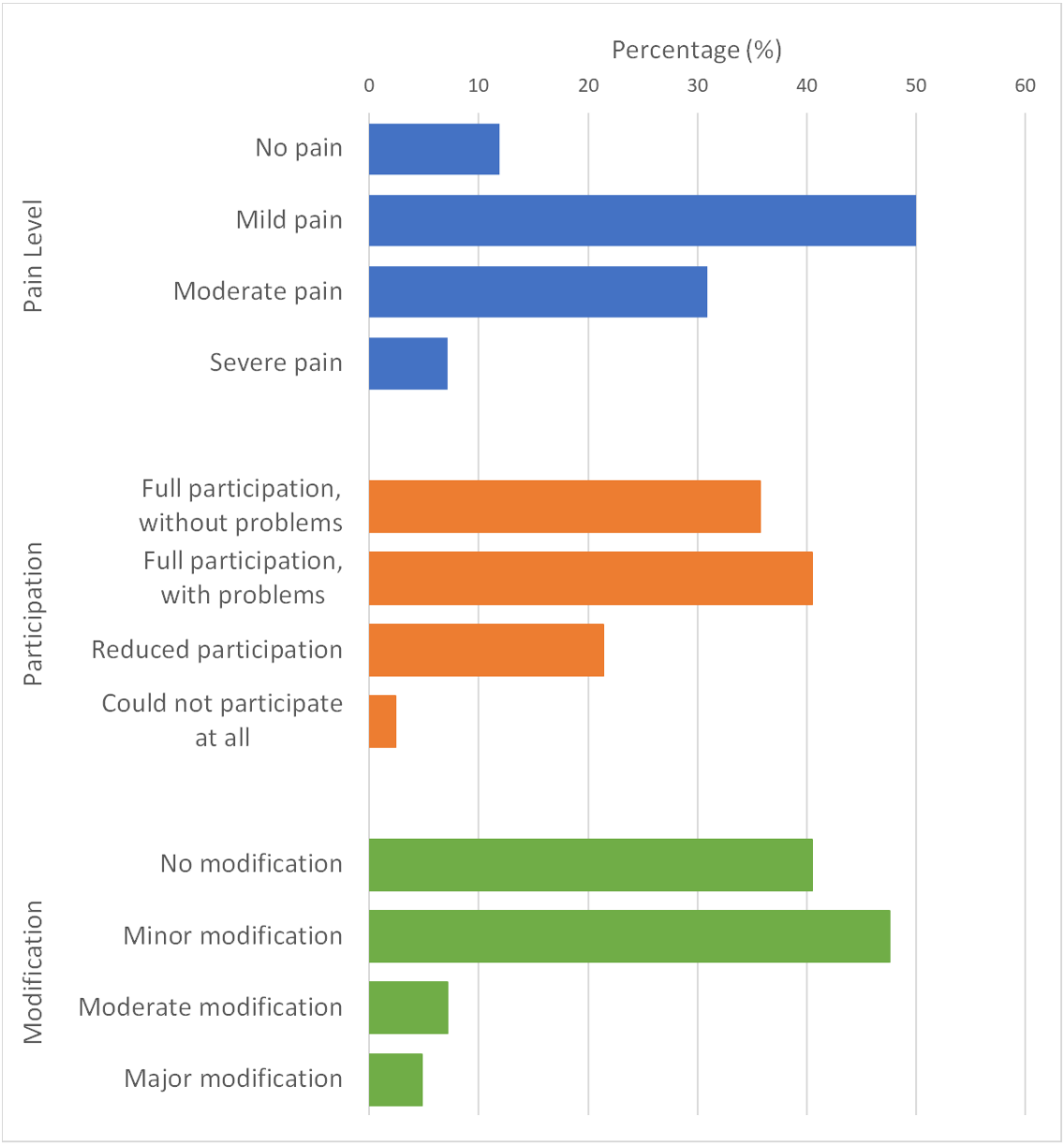
For the majority of injured dancers (60%), some level of modification was required. For those requiring modifications (n = 25) mild modifications were most commonly required (80%) and moderate or major modifications were only required 20% of the time.

3.2.9 Substantial musculoskeletal complaints and days off

According to respondents' reports of reductions in training and performance, a total of 10 survey entries (16%) were defined as substantial injuries from six participants (29%). One participant noted a substantial injury for three consecutive weeks, two participants for two consecutive weeks, and three participants for one week only. Of those with substantial injuries, only two noted taking time off dancing due their injury, each taking 3 days in one week. These injuries were reported as whiplash to the neck and avulsion fracture to the great toe.

Severity scores were used to track injury progress over time. Where data were available, 50% participants saw a decrease in severity score in the consecutive week following the first instance of a reported substantial injury during the study period. One participant (17%) reported a gradual reduction in severity score over the study period whilst two participants (33%) either saw an initial increase in score or no difference before their severity scores reduced. One (17%) participant appeared to have an initial decrease in severity score before it increased again.

Figure 6. Perceived pain levels, participation and modification reported by participants who reported musculoskeletal injury



3.3 Discussion

This research used an online surveillance questionnaire to observe musculoskeletal complaints among dancers in pre-professional training, assessing their impact on performance, dance modifications, and pain levels. Almost all participants (95%) experienced at least one musculoskeletal complaint over the study's duration, and the overall injury prevalence during the study period was 9.5 injuries per 1000 hours. Most of the dancers with musculoskeletal injuries reported experiencing some level of pain while dancing, some being in minor pain without the need to modify dancing or participation, while

others were in moderate pain and needed to reduce their participation and performance, such as omitting pointe in class, or not doing jumps. There was evidence of a positive relationship between mean weekly dance hours spent in class, rehearsals and performances and the prevalence of musculoskeletal complaints, but it was not statistically significant. The dancers reported self-management of their musculoskeletal symptoms by reducing participation and/or modifying their dancing, largely without medical staff input.

3.3.1 Prevalence, incidence, and severity

With a high level of dedication to their art form, it is possible that only a small proportion of injuries to dancers are ever reported (Boeding at al., 2019). Accordingly, the OSTRC-O2 questionnaire is designed to indicate a level of severity for overuse injuries or musculoskeletal complaints, which is reflected in the athletes/dancer's self-assessment of their pain and the impact that the problem/s has had on their participation, modification, and performance. Therefore, all musculoskeletal complaints, regardless of whether the dancer sought help from a medical professional for diagnosis or treatment, or caused time loss from dance, were detected, and recorded in this study. There was a prevalence of 2.0 injuries per participant or 200 musculoskeletal complaints per 100 people over the entire course of the study. While the incidence rate was high at 9.5 injures per 1000 dance hours, this rate fluctuated and did not appear to prevent participation in dancing or modification. For instance, one dancer documented a musculoskeletal complaint in their thoracic spine, commenting they had “stiffness” in their dance movements, yet they still reported that they could participate fully. This result aligns with research showing that most dancers “dance through” their injuries and may fear being ordered to stop dancing or being replaced in roles for performances (Gottschlich & Young, 2011).

Severity of injury traditionally defined as time loss alone will underestimate the true impact of overuse injuries (Kenny, 2017). It is known that severity of injuries amongst pre-professional dancers is frequently underreported, and for this reason different severity measures are required to be used (Lee et al, 2017). Alternative methods for severity determination include a scale of severity, from no

days off, activity modified, ≤ 7 days off, > 7 days off or year ending (Bowerman et al., 2014; Lee et al., 2017). Only 16% of the reported musculoskeletal complaints within our study were defined as a substantial musculoskeletal complaint and caused the participants to require a full day off from dancing.

The Oslo overuse questionnaire would appear to be a useful and practical surveillance tool for monitoring the severity of an injury, by using the "substantial" categorisation (see Appendix F). However, as the questionnaire developers have stated, the severity and substantial health problems scale are two novel outcomes proposed with the original OSTRC questionnaires and are yet to be fully validated (Clarsen et al., 2020). In this study, it was observed that if a dancer recorded a "0" score indicating zero musculoskeletal complaints, but the following week reported a score of 31/100 following a recorded musculoskeletal event, then this delivered timely observation of such events. Severity scores are also able to indicate a downward trajectory of severity scores, indicating a dancer was improving in self-perceived symptoms. Therefore, this tool could be valuable for teachers/coaches and clinicians in helping dancers decide on daily workload and for the dancers/athletes to follow their own progression over a term or year.

3.3.2 Anatomical locations and medical diagnosis

The OSTRC overuse questionnaire is preferable in studies that want to focus on overuse injuries in one specific injury location, (e.g. knee), particularly if used to collect data for risk factor studies and/or randomised controlled trials (Clarsen et al., 2020). In this study, participants were asked a general rather than specific question as to where their injury or musculoskeletal complaint was. As with previous research (Drysdale et al., 2023), the lower legs (80%) feet and toes (55%) ankles (30%) and lumbar spine (25%) were the most commonly injured. It has previously been observed that bony stress injuries (Drysdale et al., 2023) and injuries to the knee (Ekegren et al., 2014) are associated with the greatest time loss per injury for dancers. Accordingly, one participant within our study who reported an (un-diagnosed) stress fracture in the foot had three total days off dancing, the longest

duration reported in our study. This indicates the determination of dancers to keep involved and participating, even while working around an injury.

Research that has shown that fewer than 20 percent of dancers' injuries may be evaluated by a physician (Gottschlich & Young, 2011) which is supported by these results, where less than half (45%) the participants in this study sought help from a medical professional or the like for their musculoskeletal complaints. This may be a result of a dancer expressing a lack of trust in primary physicians due to their limited dance knowledge (Air et al., 2014). For participants who sought treatment from a physiotherapist, it served to not only diagnose the problem but also provided a positive influence on injury management for the young dancer. One study participant reported that the physiotherapist was "monitoring their jumping due to calf tightness and the potential of shin splints" suggesting an on-going positive relationship with the physician. Previous studies have demonstrated that an onsite physiotherapist in a professional dance company typically results in a decrease in annual injuries (Solomon et al., 1999) because they are able to triage the dancer and work on symptoms before they become a severe injury. Physiotherapists like these have specific expertise and experience in dance and have been reported to have a positive influence in load management for dancers (Boeding et al, 2019). It cannot be said whether the on-site physiotherapist with this particular training institution had a positive influence in helping the dancers manage their dance training load. Instead within our study participants predominantly did not seek "off-site" advice, other than massage and as such effective load and injury management may not have been implemented, however this proposition requires further research in order to be confirmed.

3.3.3 Correlation between dance training hours and the incidence of new injuries

A finding of this study was a positive association between mean weekly dance hours spent in class, rehearsals and performances and the prevalence of musculoskeletal complaints, however it was not considered statistically significant. It is known that professional dancers endure high work volumes, often required to dance 6 to 8 hours a day during rehearsal periods (Wyon, 2010) and that student dancers may spend up to 30 hours per week in dance training. This study cohort danced on average

30.9 hours per week, which may be considered a high load with ~5-6 hours of dance completed per day. Increased exposure to rehearsal and performance, such as at the end of a year, has been shown to increase the incidence of injuries (Lee et al., 2016) which would align with our findings as we followed dancers during the last part of their academic year and performance season. This study was only completed for 5 weeks at the end of the year between October and December 2022. Therefore, it may not be clear if the dancers were dancing longer hours or experiencing a greater number of musculoskeletal complaints than at other periods during their dancing year as a result of performance preparation. It should be noted that these results will only be representative of this time frame of data collection.

A cyclical pattern of increased injury has been reported in pre-professional ballet dancers during increased periods of training intensity, an outcome associated with increased volumes of dance fatigue and stress of performances (Gamboa et al., 2008; Soloman et al., 1999). Class, rehearsal, and performances all have different requirements in intensity and endurance demands for a dancer. Studies have reported an increased demand on fast glycolytic and aerobic systems during dance performances, above that noted in dance classes (Wyon et al., 2005). It has been hypothesized that this fluctuation in physical demand and subsequent over-training or under-training across dance exposures can contribute to injury risk (Lee et al, 2014).

Results from our study would suggest that the OSTRC questionnaire could be a useful tool if investigating the relationships between dancing load and injury, whether for acute or overuse injuries. Details provided by the survey can include the exact date of injury or symptom onset and may be beneficial in managing symptoms and preventing further injury development or progression. However, there are many training apps that now allow athletes to report an injury to their coaches, which would include the location, means of occurrence and severity level. These apps are also able to monitor time spent in physical activity. Whether these types of apps could be used for future research in the field of dance is an area of potential investigation for future researchers.

3.3.4 Additional physical activity

All participants in our study added an average 5 hours of additional physical activity to their weekly dancing load. These results reflect those of da Rosa et al (2018) who also found that dancers have high levels of motivation and participation in physical activity. Additional physical activity included extra dance classes outside the training school, running, Pilates, yoga, and gym training sessions. This extra activity could be explained by the dancers' desire to improve their physical capabilities and improve their dancing. Notably, eleven of the participants incorporated cardiovascular exercise into their weekly schedule. Ballet dancers are required to have sufficient cardiorespiratory capacity in order to dance well. Ballet classes are less metabolically intense than performance (< 50% V̇O2max) (Shaw et al., 2021) with oxygen requirements of barre exercise, which can be considered low-level exertion, estimated to be between 16.5 to 18.5 $ml \cdot kg^{-1} \cdot min^{-1}$ while centre work has been estimated to be between 20.1 to 24.3 $ml \cdot kg^{-1} \cdot m$ (Cohen et al., 1982). Recent studies show VO_2 max rates are much higher in performance and may reach levels of 80% VO_2 max (Shaw et al., 2021). These study authors note that metabolic and musculoskeletal adaptations required for dancers' fitness are unlikely to occur from ballet alone, and that dancers should be provided with opportunities and resources to engage in supplementary physical training to increase their aerobic capacity (Shaw et.al, 2023).

While some dancers added extra physical activity consistently to their weekly programme, others were less regular, and in a few instances, participants only reported walking to and from school or shopping as their additional physical activity. This variability in the participation of additional physical activity was also shown in another study of university level dance students (Hanna et al., 2017). Therefore, in our cohort, it may have been that these individuals with low additional physical activity perceived that the daily hours of dance were sufficient, and no additional load was required. Hanna et al. (2017) also reported that all dance students in their study either met or exceeded physical activity recommendations, although they noted that the dancer's knowledge of the benefits of physical activity was surprisingly low. Our study did not ascertain why the participants were adding to their cumulative weekly physical activity, which would be of interest in future research.

3.3.5 Dancing with pain

Over half the dancers in the current study continued to participate in training and performance despite mild to moderate levels of pain, even if with some kind of reduced capacity. This appears consistent with other research that has found that the more traditional forms of injury registration may not capture the true extent of pain or overuse symptoms experienced by dancers (Kenny et at al., 2018). Dancers are known to have a high rate of pain tolerance and will typically remain silent when in pain in order to continue dancing within the high-pressure environment (Thomas & Tarr, 2009, Soundry & Lim, 2023). Rather than seeking medical attention and adjusting their rehearsal and performance schedules, they can become accustomed to training and performing with pain (Boeding et al, 2019). The OSTRC questionnaire asks what level of pain the athlete or dancer is experiencing, using a 5-point Likert scale, which is a subjective albeit honest measure. Many participants reported dancing with mild to moderate pain and three participants indicated they had severe pain, causing only two of these to stop dancing altogether. This desire to keep dancing as demonstrated by one participant, even while in severe pain, is in keeping with previous literature which has suggested that continual exposure to pain may enable dancers to mistake persistent pain as performance pain or missing indicators of chronic/overuse injury (Anderson & Hanrahan, 2008).

This study observed that the dancers would modify their class or rehearsals to a minor extent but would not reduce their participation or intensity across the week as they were building up to performance. Similar results have been observed in the literature again suggesting that dancers are likely to restrict or modify their dancing rather than take time off and/or undergoing rehabilitation (Critchley et al., 2023). These findings point to a cultural norm in dance that requires a dancer to remain "present" in a dance studio even when they are injured, even if that means "marking" or simply observing rather than performing.

3.3.6 Dancer self-management

It is well known that dancers are concerned with working their bodies correctly, as part of rigorous attempts at attaining correct technique and form (Clause & McDonald, 2017). The participants of this

study demonstrated a high degree of self-efficacy in managing injury or musculoskeletal complaints, similar to previous results from surveys of dancers (Vassallo et al., 2018, Soundry & Lim, 2023). Such comments as "not doing big jumps and keeping jumps low" demonstrated that as dancers, the participants understood the need to allow their bodies to rest and to reduce the impact load during an injury or musculoskeletal complaint. For instance, for some dancers, a "niggle" was recognised as just that with such comments as "I wouldn't describe it as a niggle or injury, but I have had very tight thighs due to cross training so have had to minorly modify some movement as to not put too much pressure and stretch on my thighs and consequentially my knees". This contrasts with previously reported findings that note the drive for perfection originates from the dancer themselves, and that dancers often do not have enough experience or confidence to reduce their training load and plan rest periods on their own (Carr & Wyon, 2003). A dancer's ability to recognise their own injury state is described well by McGrath et al., (2023) who suggests that dancers may find it hard to implement their own safe dance practice due to a learned behaviour around dancing through pain and injuries, partly cultivated by the environment around them. The difference in age of the cohort of previous study (18 to 23 years) compared to our study (16 to 20 years) could have been a factor in these divergent findings, as they were university level dancers, with an older age and maturity level. However, the perception of injury stigma and the ability to self-judge participation in dance and rehearsals is an area warranting further research.

3.3.7 Weekly response rate, sample size and statistical analysis

The sample size of this study was small, so a power analysis should be performed to determine the optimal study size should a larger study be undertaken in future, in order to get statistically valid results. This would be particularly useful for evaluating the correlation between dance hours and injuries.

The average weekly response rate of 61% for this study was lower than previous studies, for example van Winden et al. (2018) reported a 79.7% response rate, while Critchley et al, (2022) reported an extremely high response rate of 91.4% across the five years of their study and Liederbach et al (2018)

had an overall response rate to the weekly Dance OSTRCQ of 99%. It is possible that the study participants thought that they were only to fill out the questionnaire if they had an injury, which would potentially make the non-respondents actually no injury groups. No pre-testing of the question routing was undertaken, and perhaps the flow of questions was confusing for participants.

This study relied on the school staff, teachers, and physiotherapists to support and remind the study participants to fill out the weekly questionnaire. A greater response rate may have been possible to achieve with more visits to the school by the researcher, to encourage and remind the students. It has been suggested that a close and personal interaction with participants is crucial to motivate them to complete the questionnaire on a weekly basis (Clarsen et al., 2020). This has also been emphasised by Hausken-Sutter et al 2021) who note that researcher presence throughout the application process is crucial for the quality of the data, the response rate, and data validity. The low response rate in this study raises concerns about whether using a training app would be a better way to collect data when researching a younger cohort.

3.3.8 Conclusion

In conclusion, élite, pre-professional dance students often experience musculoskeletal complaints during full-time dance training, with long training hours and physical activity influencing the incidence. Traditional "time loss" definitions don't apply to dance, as dancers self-manage symptoms while maintaining participation. This study identified that nearly all the pre-professional dancers (95%) in a New Zealand dance school had a musculoskeletal complaint during the data collection period of their end of year performance season. Half of the study cohort (54%) danced with minor to moderate pain. Eight participants reported a severe musculoskeletal complaint but only three of these dancers had full days off dancing, suggesting a strong desire to continue to dance even while injured. This research has also shown that there is a positive association between mean weekly hours spent in dance class, rehearsals and performances and musculoskeletal complaints, although was not a statistically strong correlation.

The anatomical regions most affected by musculoskeletal complaints were lower extremity, in keeping with previous research, accounting for 56.7% of the reported complaints. In addition, most participants did not seek medical attention for their musculoskeletal complaints (66%) but reportedly self-managed managed their symptoms and dance exposure accordingly.

Chapter 4: Conclusion and Recommendations

4.1 Achievement of aims and hypothesis

The aim of this research was to use the OSTRC-O2 questionnaire to assess the prevalence, incidence, and severity of musculoskeletal complaints in élite, pre-professional New Zealand dancers, assessing their impact on performance, dance modifications, and pain levels. The online weekly survey provided a simple means to collect and monitor information on musculoskeletal complaints. The high incidence of musculoskeletal complaints in full-time, pre-professional training dancers found in our study is in alignment with previous literature, although high. Within our study cohort, a weak correlation between the number of musculoskeletal complaints and hours of dance training was observed. All dancers added to their weekly dance load with further physical activity, adding the cumulative load, which may be a risk factor for this demographic of dancers. Levels of cumulative physical activity across the week should be monitored by staff and institutions to protect young dancers from potential injury.

It is apparent that many dancers continue to dance with mild to moderate levels of pain yet show an awareness of managing their dance participation and performance, allowing modifications around the cited injuries. This study found that dancers have a high degree of autonomy in managing their musculoskeletal complaints, and do their best to maintain participation in class, rehearsals, and performance, even if modified.

4.2 Strengths

The OSTRC-O2 questionnaire would appear to be an appropriate tool for use within a pre-professional dance student population. It has the potential for longitudinal data collection which can provide opportunities to explore risk factors and prognoses of musculoskeletal complaints over time. Online delivery meant ease of use and access for the participants. Due to the weekly reporting, this surveillance system allows both dancers and the support teams around them to report, screen and monitor in real-time any musculoskeletal complaints that a dancer might experience. This real-time,

ongoing reporting by dancers of emerging musculoskeletal complaints and the indication of severity allows problems/injuries to potentially be captured before they escalate to full-time-loss injuries. Overall, this could lead to improvements in dancer health and performance outcomes.

4.3 Limitations and considerations for future research

To assess the prevalence of musculoskeletal complaints in pre-professional dancers, this study used the OSTRC-O2 questionnaire, that has previously been validated and used as a dance-specific questionnaire. However, a limitation of the OSTRC-O2 is that the four questions only pertain to participation, modification, performance, and pain. Additional questions must be used to collect additional information regarding the dancer's training load, additional activity, and details about the reported musculoskeletal complaint.

This questionnaire is reliant on participant recall and honesty, and it is known that dancers are more likely to under-report overuse injuries. A survey like this is highly subjective and depends on accurate recall of the participant and their reporting reliability. For instance, a dancer needs experience and self-awareness to distinguish between what constitutes a valid musculoskeletal complaint or injury and what might be delayed-onset muscle soreness (DOMS). DOMS is the normal, transient experience of muscle pain due to physical exertion, often related to the eccentric forces on a muscle, while in contrast a true muscle strain will take longer to recover from and could affect function during its recovery period. Additionally, it has been observed that due to the transient nature of musculoskeletal complaints, the more frequently dancers are asked to report all-complaint injuries, the greater the total number of injuries reported (Liederbach et al., 2018). Another point of note is that the perceptions of the study participants are dependent on contextual factors such as, in this instance, the dancer's experience, whether they were a ballet or contemporary major, the year level and therefore technical level and time of the academic year. Age and year level may influence the participants judgement based on experience of injury severity and the need to modify their dancing (Kenny et al., 2018) while the culture around their employment could alter responses based on the perceived consequences of admitting an injury (Soundry & Lim, 2023; Solomon et al., 1999). This

means data collected from different cohorts of dancers may not be comparable, and investigations in two separate cohorts would be required to accurately determine these differences.

This thesis was a small study of self-reported musculoskeletal complaints of pre-professional dancers and did not undertake a parallel clinical analysis of injuries by a medical professional (e.g., dance school physiotherapist). Injury definition (i.e., specifying what tissue damage has occurred) would have required the input of a medical professional and added an extra layer of interpretation of the results, giving more detail for analysis. For future studies, all recordable musculoskeletal complaints should be validated on a tissue injury level by a physiotherapist, using the Oxford Sports Injury Classification System (OSICS) and could then be assigned a clinical code (Rae & Orchard, 2007). This would have improved the accuracy in determining the gradual onset or recurrent injuries versus those of sudden onset and may have helped the dancers understand the difference between DOMS and a more serious tissue injury. In terms of reporting severity, the dancer would still report the effects on their dance participation, so it may not have altered the severity results we obtained.

Another drawback of the weekly self-reporting using the OSTRC-O2 questionnaire is survey fatigue. This factor likely impacted participation rates throughout the 5-week study, especially with the study timing occurring around the dancer's end of year performance season where the dancers were potentially putting in longer days than usual term-time. Future research could consider longer reporting periods of one month between questionnaires to reduce the frequency of completing the questionnaire. It has been noted by the questionnaire developer that for certain research questions, such as a long build up to an event, it may be acceptable to distribute the questionnaire less frequently and fortnightly or monthly distribution timings may be used. This may mean that short-duration injury or musculoskeletal complaints may not be detected but moderate and severe complaints will be identified with data that will be comparable to when weekly information is collection (Clarsen et al., 2020).

The limited data set could have been mitigated by working with a larger group of participants or choosing to follow the participants across a longer period of the academic year, following a power analysis of the needed sample size. Following the dance students over a longer study period would include different performance cycles which might produce more visible fluctuations in musculoskeletal symptoms and hence greater insights into risk factors of injuries and musculoskeletal complaints.

Furthermore, more accurate dance hours could be provided if every dance session and supplementary physical activities were registered individually in terms of hours undertaken. Some studies investigating injuries among dancers have used individual class, rehearsal, and performance schedules to accurately reflect dance exposure hours (Caine et al., 2016). It has been noted, however, in surveys such as these, that methods for calculating training hours are indicative only of times a dancer may be required for class or rehearsal and cannot be a precise method for physical exertion and load (Shaw et al., 2023). Furthermore, the intensity of their activities is not known within reported attendance hours or exposure. For example, a rehearsal may involve a lot of waiting time, while others are dancing, therefore not requiring a high physical expenditure for much of the time.

To confirm the finding of a positive association between dance hours and injury, accurate details on exposure and load during the dance session or physical activity is required. Additionally, asking participants to estimate time spent in dance or physical activity is not potentially accurate. Future research may consider the use of monitoring devices such as smart watches or phones and associated training software, accelerometers or using RPE with participants, to aid formal load quantification.

4.4 Recommendations based on study results

Given the high rates of musculoskeletal complaints reported by the participants in this study, it is evident that overuse injuries are a prevalent issue for élite, pre-professional dancers here in New Zealand. Future research should be directed at identifying potential causes of such high rates and

possible strategies to prevent and manage musculoskeletal complaints among young dancers. Details of practical recommendations as a result of this pilot study are provided below.

- Clinicians and dance teachers should carefully monitor training loads and modify them accordingly, across the day and across weeks/months by timetabling in sufficient rest periods for young dancers.
- The tailoring and provision of long-term, evidence-based strength training and injury prevention programmes is essential, with an emphasis on dancers' physical fitness beyond dance-based skills. Physical fitness is associated with improved dance performance and decreased injury incidence and is necessary for higher levels of metabolic and musculoskeletal adaptations needed for a long career in dance (Dang et al.,2023, Shaw et al., 2021).
- With the help of specialised clinical professionals, dancers should be educated on the importance of adequate recognition of injury states, treatment paradigms and recovery to avoid ongoing injury niggles. Dancers can find it difficult to distinguish performance pain from pain that means an injury is present (Soundry & Lee, 2023). Meaningful tissue impairment is challenging to diagnose without the help of experienced clinical professionals (Clause & McDonald, 2017). Self-management has been identified as a theme for dancers in their ability to recognise, and manage injuries, as such education would be very valuable for young dancers (Clause & McDonald, 2017).
- There are many known risk factors for pre-professional dancers such as dancer fitness and physical capabilities and training load across the academic year. Screening throughout a dancer's training, including pre-screening of physical capabilities, could help a dancer identify the areas of improvement that may reduce injury risk (Gamboa et al., 2008, Liederbach, 1997).

References

Air, M. E., Grierson, M. J., Davenport, K. L., & Krabak, B. J. (2014). Dissecting the doctor-dancer relationship: health care decision making among American collegiate dancers. *PM&R*, 6(3), 241-249.

Allen, N., Nevill, A., Brooks, J., Koutedakis, Y., & Wyon, M. (2012). Ballet injuries: injury incidence and severity over 1 year. *Journal of Orthopaedic & Sports physical therapy*, 42(9), 781-A1

Anand Prakash, A., K, M., & Akilesh, V. (2023). Umbrella review of musculoskeletal injury burden in dancers: implication for practice and research. *The Physician and Sports Medicine*, 1-14.

Anderson, R., & Hanrahan, S. J. (2008). Dancing in pain: pain appraisal and coping in dancers. *Journal of Dance Medicine & Science*, 12(1), 9-16.

Azevedo, A. M., Oliveira, R., Vaz, J. R., & Cortes, N. (2020). Oxford foot model kinematics in landings: A comparison between professional dancers and non-dancers. *Journal of Science and Medicine in Sport*, *23*(4), 347-352.

Bahr, R. (2009). No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *British Journal of Sports Medicine*, *43*(13), 966-972.

Baker Jenkins, J., Wyon, M., & Nevill, A. (2013). Can turnout measurements be used to predict physiotherapist-reported injury rates in dancers? *Medical Problems of Performing Artists*, *28*(4), 230-235.

Biehler-Gomez, L., & Cattaneo, C. (2020). *Interpreting bone lesions and pathology for forensic practice.* Academic Press, Elsevier.

Boeding, J. R., Visser, E., Meuffels, D. E., & de Vos, R. J. (2019). Is training load associated with symptoms of overuse injury in dancers? A prospective observational study. *Journal of Dance Medicine & Science*, 23(1), 11-1

Bowerman, E., Whatman, C., Harris, N., Bradshaw, E., & Karin, J. (2014). Are maturation, growth and lower extremity alignment associated with overuse injury in elite adolescent ballet dancers? *Physical Therapy in Sport,* 15(4), 234-241.

Bronner, S., Ojofeitimi, S., & Mayers, L. (2006). Comprehensive surveillance of dance injuries a proposal for uniform reporting guidelines for professional companies. *Journal of Dance Medicine & Science*, *10*(3-4), 69-80.

Butler DS, Moseley GL. (2013) *Explain Pain. NOI* Group Publications.

Caine, D., Bergeron, G., Goodwin, B. J., Thomas, J., Caine, C. G., Steinfeld, S., ... & André, S. (2016). A survey of injuries affecting pre-professional ballet dancers. *Journal of Dance Medicine & Science*, *20*(3), 115-126.

Carr, S., & Wyon, M. A. (2003). The influence of goal orientation, trait anxiety, and perfectionism on dance students' current perceptions of the motivational climate. J Dance Med Sci, 7, 105-14.

Clarkson, P. M., Freedson, P. S., Keller, B., Carney, D., & Skrinar, M. (1985). Maximal oxygen uptake, nutritional patterns, and body composition of adolescent female ballet dancers. *Research Quarterly for Exercise and Sport*, *56*(2), 180-185.

Clarsen, B., & Bahr, R. (2014). Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! *British Journal of Sports Medicine*, *48*(7), 510-512.

Clarsen, B., Bahr, R., Myklebust, G., Andersson, S. H., Docking, S. I., Drew, M., ... & Verhagen, E. (2020). Improved reporting of overuse injuries and health problems in sport: an update of the Oslo sport trauma research center questionnaires. *British Journal of Sports Medicine, 54*(7), 390-396.

Clarsen, B., Myklebust, G., & Bahr, R. (2012). Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *British Journal of Sports Medicine, 54*(7), 390-396.

Claus, A. P., & MacDonald, D. A. (2017). Interpreting pain symptoms and how pain affects neuromuscular control in dancers: if I'm in pain, how should I train? *Journal of Dance Medicine & Science*, *21*(1), 5-12

Cohen, J. L., Segal, K. R., Witriol, I. R. A., & McArdle, W. D. (1982). Cardiorespiratory responses to ballet exercise and the VO2max of elite ballet dancers. *Medicine and Science in Sports and Exercise,* 14(3), 212-217.

Critchley, M. L., Bonfield, S., Ferber, R., Pasanen, K., & Kenny, S. J. (2023). Relationships Between Common Preseason Screening Measures and Dance-Related Injuries in Preprofessional Ballet Dancers. *Journal of Orthopaedic & Sports physical therapy,* 53(11), 703-711.

Critchley, M. L., Ferber, R., Pasanen, K., & Kenny, S. J. (2022). Injury epidemiology in pre-professional ballet dancers: A 5-year prospective cohort study. *Physical Therapy in Sport*, 58, 93-99.

Dang, Y., Chen, R., Koutedakis, Y., & Wyon, M. A. (2023). The efficacy of physical fitness training on dance injury: a systematic review. *International Journal of Sports Medicine,* 44(02), 108-116.

Drysdale, L., Gomes, Z., Toohey, L., Pumpa, K., & Newman, P. (2023). Musculoskeletal Injury in an Australian Professional Ballet Company, 2018-2021: 953 Medical-Attention and 706 Time-Loss Injuries Over 4 Years. *Journal of Orthopaedic & Sports physical therapy,* 53(11), 712-722.

Eckard, T. G., Padua, D. A., Hearn, D. W., Pexa, B. S., & Frank, B. S. (2018). The relationship between training load and injury in athletes: a systematic review. *Sports Medicine*, *48*, 1929-1961.

Ekegren, C. L., Quested, R., & Brodrick, A. (2014). Injuries in pre-professional ballet dancers: incidence, characteristics and consequences. *Journal of Science and Medicine in Sport*, *17*(3), 271-275.

Finch, C., Valuri, G., & Ozanne-Smith, J. (1998). Sport and active recreation injuries in Australia: evidence from emergency department presentations. *British Journal of Sports Medicine*, *32*(3), 220.

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., ... & Meeuwisse, W. H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scandinavian Journal of Medicine & Science in Sports*, *16*(2), 83-92.

Fuller, M., Moyle, G. M., Hunt, A. P., & Minett, G. M. (2019). Ballet and contemporary dance injuries when transitioning to full-time training or professional level dance: a systematic review. *Journal of Dance Medicine & Science*, *23*(3), 112-125.

Gabbett, T. J. (2018). Debunking the myths about training load, injury and performance: empirical evidence, hot topics and recommendations for practitioners. *British Journal of Sports Medicine*, bjsports-2018.

Gabbett, T. J. (2016). The training—injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine, 50*(5), 273-280.

Gamboa, J. M., Roberts, L. A., Maring, J., & Fergus, A. (2008). Injury patterns in elite preprofessional ballet dancers and the utility of screening programs to identify risk characteristics. *Journal of Orthopaedic & Sports physical therapy*, *38*(3), 126-136.

Gildea, J. E., Hides, J. A., & Hodges, P. W. (2014). Morphology of the abdominal muscles in ballet dancers with and without low back pain: a magnetic resonance imaging study. *Journal of Science and Medicine in Sport*, 17(5), 452-456.

Gottschlich, L. M., & Young, C. C. (2011). Spine injuries in dancers. *Current Sports Medicine Reports*, *10*(1), 40-44.

Gray, R. (2015). *Routledge Handbook of Sport Expertise: Movement automaticity in sport.* Routledge.

Harrast, M. A. (Ed.). (2019). *Clinical Care of the Runner: Assessment, Biomechanical Principles, and Injury Management*. Elsevier Health Sciences.

Hausken-Sutter, S. E., Pringle, R., Schubring, A., Grau, S., & Barker-Ruchti, N. (2021). Youth sport injury research: a narrative review and the potential of interdisciplinarity. *BMJ open sport & exercise medicine,* 7(1), e000933.

Hamilton, D., Aronsen, P., Løken, J. H., Berg, I. M., Skotheim, R., Hopper, D., ... & Briffa, N. K. (2006). Dance training intensity at 11–14 years is associated with femoral torsion in classical ballet dancers. *British Journal of Sports Medicine*, 40(4), 299-303.

Hamilton, L. H., Hamilton, W. G., Meltzer, J. D., Marshall, P., & Molnar, M. (1989). Personality, stress, and injuries in professional ballet dancers. *The American Journal of Sports Medicine*, *17*(2), 263-267.

Hanna, K., Hanley, A., Huddy, A., McDonald, M., & Willer, F. (2017). Physical activity participation and nutrition and physical activity knowledge in university dance students. *Medical Problems of Performing Artists*, *32*(1), 1-7.

Hansberger, B. L., Acocello, S., Slater, L. V., Hart, J. M., & Ambegaonkar, J. P. (2018). Peak lower extremity landing kinematics in dancers and nondancers. *Journal of Athletic Training*, *53*(4), 379-385.

Hendry, D., Campbell, A., Ng, L., Harwood, A., & Wild, C. (2019). The difference in lower limb landing kinematics between adolescent dancers and non-dancers. *Journal of Dance Medicine & Science*, *23*(2), 72-79.

Hincapié, C. A., Morton, E. J., & Cassidy, J. D. (2008). Musculoskeletal injuries and pain in dancers: a systematic review. *Archives of Physical Medicine and Rehabilitation*, *89*(9), 1819-1829.

Honrado, J., Bay, R. C., & Lam, K. C. (2021). Epidemiology of patients with dance-related injuries presenting to emergency departments in the United States, 2014-2018. *Sports Health,* 13(5), 71-475.

Jeffries, A. C., Wallace, L., Coutts, A. J., Cohen, A. M., McCall, A., & Impellizzeri, F. M. (2020). Injury, illness, and training load in a professional contemporary dance company: a prospective study. *Journal of Athletic Training*, *55*(9), 967-976.

Junck, E., Richardson, M., Dilgen, F., & Liederbach, M. (2017). A retrospective assessment of return to function in dance after physical therapy for common dance injuries. *Journal of Dance Medicine & Science*, *21*(4), 156-167.

Keay, N., Overseas, A., & Francis, G. (2020). Indicators and correlates of low energy availability inmale and female dancers. *BMJ Open Sport & Exercise Medicine*, 6(1), e000906.

Karreman, D. E., Keizer-Hulsebosch, S. C., & Stubbe, J. H. (2019). Performing artist and Athlete Health Monitor: user experience, content and conditions for use of an online dance-health surveillance system in a professional ballet company. *BMJ Open Sport—Exercise Medicine*, *5*(1).

Kaufmann, J. E., Nelissen, R. G., Exner-Grave, E., & Gademan, M. G. (2021). Does forced or compensated turnout lead to musculoskeletal injuries in dancers? A systematic review on the complexity of causes. *Journal of Biomechanics*, *114*, 110084.

Kellmann, M. (2010). Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. *Scandinavian Journal of Medicine & Science in Sports,* 20, 95-102.

Kenny, S. J., Critchley, M. L., Whittaker, J. L., Vijayan, V. W. K., & Emery, C. A. (2021). Association between pre-participation characteristics and risk of injury amongst pre-professional dancers. *Physical Therapy in Sport,* 52, 239-247.

Kenny, S. J., Palacios-Derflingher, L., Whittaker, J. L., & Emery, C. A. (2018). The influence of injury definition on injury burden in preprofessional ballet and contemporary dancers. *Journal of Orthopaedic & Sports physical therapy*, 48(3), 185-193.

Kenny, S. J., Palacios-Derflingher, L., Shi, Q., Whittaker, J. L., & Emery, C. A. (2019). Association between previous injury and risk factors for future injury in preprofessional ballet and contemporary dancers. *Clinical Journal of Sport Medicine*, 29(3), 209-217.

Kenny, S. J., Whittaker, J. L., & Emery, C. A. (2015). Risk factors for musculoskeletal injury in preprofessional dancers: a systematic review. *British Journal of Sports Medicine, 50*(16), 997-1003.

Koutedakis, Y., & Jamurtas, A. (2004). The dancer as a performing athlete: physiological considerations. *Sports Medicine*, *34*, 651-661.

Koutedakis, Y., Stavropoulos-Kalinoglou, A., & Metsios, G. (2005). The significance of muscular strength in dance. *Journal of Dance Medicine & Science*, *9*(1), 29-34.

Laws, H. (2005). Fit to Dance 2-Report of the second national inquiry into dancers' health and injury in the UK. Pureportal.coventry.ac.uk.

Leanderson, C., Leanderson, J., Wykman, A., Strender, L. E., Johansson, S. E., & Sundquist, K. (2011). Musculoskeletal injuries in young ballet dancers. *Knee surgery, Sports traumatology, Srthroscopy*, *19*, 1531-1535.

Lee, L., Reid, D., Cadwell, J., & Palmer, P. (2017). Injury incidence, dance exposure and the use of the movement competency screen (MCS) to identify variables associated with injury in full-time pre-professional dancers. *International Journal of Sports Physical Therapy*, *12*(3), 352.

Liederbach, M., & Richardson, M. (2007). The importance of standardized injury reporting in dance. *Journal of Dance Medicine & Science*, *11*(2), 45-48.

Liederbach, M., & Compagno, J. M. (2001). Psychological aspects of fatigue-related injuries in dancers. *Journal of Dance Medicine & Science*, *5*(4), 116-120.

Liederbach, M., Hagins, M., Gamboa, J. M., & Welsh, T. M. (2012). Assessing and reporting dancer capacities, risk factors, and injuries: recommendations from the IADMS standard measures consensus initiative. *Journal of Dance Medicine & Science*, *16*(4), 139-153.

Luke, A. C., Kinney, S. A., D'Hemecourt, P. A., Baum, J., Owen, M., & Micheli, L. J. (2002). Determinants of injuries in young dancers. *Medical Problems of Performing Artists*, *17*(3), 105-112.

Magrath, J., Paglione, V., Morrison, L., & Kenny, S. J. (2023). 'It shouldn't be necessary, but it happens a lot': Undergraduate contemporary dancers' perceptions of pain, injury, and fatigue. *Theatre, Dance and Performance Training*, 14(4), 492-510.

Malkogeorgos, A., Zaggelidou, E., Zaggelidis, G., & Christos, G. (2013). Physiological elements required by dancers. *Sport Science Review,* 22.

Mendes-Cunha, S., Moita, J. P., Xarez, L., & Torres, J. (2023). Dance-related musculoskeletal injury leading to forced time-loss in elite pre professional dancers–a retrospective study. *The Physician and Sportsmedicine*, 1-9.

Molnar, M., & Karin, J. (2017). The complexities of dancers' pain. *Journal of Dance Medicine & Science*, 21(1), 3-4.

Murgia, C. (2013). Overuse, tissue fatigue, and injuries. *Journal of Dance Medicine & Science*, *17*(3), 92-100.

Negus, V., Hopper, D., & Briffa, N. K. (2005). Associations between turnout and lower extremity injuries in classical ballet dancers. *Journal of Orthopaedic & Sports Physical Therapy*, *35*(5), 307-318.

Nilsson, C., Leanderson, J., Wykman, A., & Strender, L. E. (2001). The injury panorama in a Swedish professional ballet company. *Knee Surgery, Sports Traumatology, Arthroscopy*, 9(4), 242-246.

Noh, Y. E., Morris, T., & Andersen, M. B. (2005). Psychosocial factors and ballet injuries. *International Journal of Sport and Exercise Psychology*, *3*(1), 79-90.

Phillips, C. (1999). Strength training of dancers during the adolescent growth spurt. *Journal of Dance Medicine & Science*, 3(2), 66-72.

Poggini, L., Losasso, S., & Iannone, S. (1999). Injuries during the dancer's growth spurt: etiology, prevention, and treatment. *Journal of Dance Medicine & Science*, 3(2), 73-79.

Rae, K., & Orchard, J. (2007). The orchard sports injury classification system (OSICS) version 10. *Clinical Journal of Sport Medicine*, *17*(3), 201-204.

Rafferty, S. (2010). Considerations for integrating fitness into dance training. *Journal of Dance Medicine & Science*, *14*(2), 45-49.

Raja, S. N., Carr, D. B., Cohen, M., Finnerup, N. B., Flor, H., Gibson, S., ... & Vader, K. (2020). The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises. *Pain*, 161(9), 1976-1982.

Ramel, E. M., Moritz, U., & Jarnlo, G. B. (1999). Validation of a pain questionnaire (SEFIP) for dancers with a specially created test battery. *Medical Problems of Performing Artists*, *14*(4), 196-203.

Redding, E., Weller, P., Ehrenberg, S., Irvine, S., Quin, E., Rafferty, S., ... & Cox, C. (2009). The development of a high intensity dance performance fitness test. *Journal of Dance Medicine & Science*, 13(1), 3-9.

Rogalski, B., Dawson, B., Heasman, J., & Gabbett, T. J. (2013). Training and game loads and injury risk in elite Australian footballers. *Journal of Science and Medicine in Sport*, *16*(6), 499-503.

da Rosa, A. F., Reis, N. M., Vieira, M. D. C. S., Folle, A., & de Azevedo Guimarães, A. C. (2018). The practice of dance as extracurricular activity is related to higher motivation and physical activity level in students. *Motricidade*, *14*(2-3), 3-10.

Sanchis-Moysi, J., Dorado, C., Olmedillas, H., Serrano-Sanchez, J. A., & Calbet, J. A. (2010). Bone and lean mass inter-arm asymmetries in young male tennis players depend on training frequency. *European Journal of Applied Physiology*, 110, 83-90.

Sawahara, H., & Kuno-Mizumura, M. (2016, November). Postural Stability During Drop Landing in Modern Dancers and Ballet Dancers. In *ISBS-Conference Proceedings Archive*.

Schantz, P., & Åstrand, P. O. (1984). Physiological characteristics of classical ballet. *Medicine and Science in Sports and Exercise*, *16*(5), 472-476.

Shaw, J. W., Maloney, B., Mattiussi, A. M., Brown, D. D., Springham, M., Pedlar, C. R., & Tallent, J. (2023). The development and validation of an open source accelerometery algorithm for measuring jump height and frequency in ballet. *Journal of Sports Sciences*, 41(5), 463-469.

Shah, S., Weiss, D. S., & Burchette, R. J. (2012). Injuries in professional modern dancers: incidence, risk factors, and management. *Journal of Dance Medicine & Science*, *16*(1), 17-25.

Smith, P. J., Gerrie, B. J., Varner, K. E., McCulloch, P. C., Lintner, D. M., & Harris, J. D. (2015). Incidence and prevalence of musculoskeletal injury in ballet: a systematic review. *Orthopaedic Journal of Sports Medicine*, *3*(7), 2325967115592621.

Smith, A. J., & Micheli, L. J. (2006). Dance injuries. *Medicine and Sport Science,* 51, 130-140.

Soligard, T., Schwellnus, M., Alonso, J. M., Bahr, R., Clarsen, B., Dijkstra, H. P., ... & Engebretsen, L. (2016). How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *British Journal of Sports Medicine*, 50(17), 1030-1041.

Solomon, R., Solomon, J., Micheli, L. J., & McGray, E. (1999). The" cost" of injuries in a professional ballet company: a five-year study. *Medical Problems of Performing Artists*, *14*(4), 164-169.

Soundy, A., & Lim, J. Y. (2023). Pain perceptions, suffering and pain behaviours of professional and pre-professional dancers towards pain and injury: a qualitative review. *Behavioral Sciences*, *13*(3), 268.

Steinberg, N., Siev-Ner, I., Peleg, S., Dar, G., Masharawi, Y., Zeev, A., & Hershkovitz, I. (2011). Injury patterns in young, non-professional dancers. *Journal of Sports Sciences*, *29*(1), 47-54.

Steinberg, N., Aujla, I., Zeev, A., & Redding, E. (2013). Injuries among talented young dancers: findings from the UK Centres for Advanced Training. *International Journal of Sports Medicine*, 238-244.

Steinberg, N., Siev-Ner, I., Peleg, S., Dar, G., Masharawi, Y., Zeev, A., & Hershkovitz, I. (2012). Extrinsic and intrinsic risk factors associated with injuries in young dancers aged 8–16 years. *Journal of Sports Sciences*, *30*(5), 485-495.

Tarr, J., & Thomas, H. (2021). Good Pain, Bad Pain: Dancers, Injury, and Listening to the Body. *Dance Research*, *39*(1), 53-71

Thomas, H., & Tarr, J. (2009). Dancers' perceptions of pain and injury: positive and negative effects. *Journal of Dance Medicine & Science*, *13*(2), 51-59.

Timpka, T., Jacobsson, J., Bickenbach, J., Finch, C. F., Ekberg, J., & Nordenfelt, L. (2014). What is a sports injury? *Sports Medicine*, *44*, 423-428.

Turner, C., Crow, S., Crowther, T., Keating, B., Saupan, T., Pyfer, J., ... & Lee, S. P. (2018). Preventingnon-contact ACL injuries in female athletes: What can we learn from dancers? *Physical Therapy in Sport*, *31*, 1-8.

Twitchett, E., Angioi, M., Koutedakis, Y., & Wyon, M. (2010). The demands of a working day among female professional ballet dancers. *Journal of Dance Medicine & Science*, 14(4), 127-132.

Van Winden, D. P., Van Rijn, R. M., Richardson, A., Savelsbergh, G. J., Oudejans, R. R., & Stubbe, J. H. (2019). Detailed injury epidemiology in contemporary dance: a 1-year prospective study of 134 students. *BMJ open Sport & Exercise Medicine*, *5*(1), e000453.

Vassallo, A. J., Pappas, E., Stamatakis, E., & Hiller, C. E. (2018). Differences in the occurrence and characteristics of injuries between full-time and part-time dancers. *BMJ Open Sport Exercise Medicine*, *4*(1).

Vetter, R. E., & Dorgo, S. (2009). Effects of partner's improvisational resistance training on dancers' muscular strength. *The Journal of Strength & Conditioning Research,* 23(3), 718-728.

Volkova, V. G., Räisänen, A., Benson, L. C., Ferber, R., & Kenny, S. J. (2023). Systematic review of methods used to measure training load in dance. *BMJ Open Sport—Exercise Medicine*, *9*(3).

Weiss, D. S., Shah, S., & Burchette, R. J. (2008). A profile of the demographics and training characteristics of professional modern dancers. *Journal of Dance Medicine & Science*, *12*(2), 41-46.

Wilson, J. C., Quinn, B. J., Stratton, C. W., Southwick, H., & MacDonald, J. P. (2015). Athletes doing arabesques: important considerations in the care of young dancers. *Current Sports Medicine Reports*, *14*(6), 448-454.

Wyon, M. (2010). Preparing to perform: periodization and dance. *Journal of Dance Medicine & Science*, *14*(2), 67-72.

Wyon, M. (2005). Cardiorespiratory training for dancers. *Journal of Dance Medicine & Science*, *9*(1), 7-12.

Wyon, M. A., Weller, P., Ehrenberg, S., Irvine, S., Quin, E., Rafferty, S., ... & Cox, C. (2009). The development of a high intensity dance performance fitness test. *Journal of dance Medicine & Science*, 13(1), 3-9.

Appendices

(Appendix F: Examples of Severity Scores over time by participant, substantial injuries shown in red)

Appendix A: Information Sheet for Participants

Information Sheet

Opportunity to participate in research on overuse injuries in pre-professional dance students.

Massey University thesis project: 24 October – 4 December

Researcher: Ellena Conland

A survey of the prevalence, incidence and severity of overuse injury in pre-professional dance students.

My name is Ellena Conland and I am a post-graduate student at Massey University, currently completing a Masters in Health Science, (Sport and Exercise).

I am conducting a research project, the aim of which is to observe the incidence, prevalence and severity of overuse injuries in pre-professional dance students, which will be conducted at the New Zealand School of Dance.

I am using a questionnaire that is used for both the sporting population and also the dance population. It is called the Oslo Sports Trauma and Research Centre Overuse Injury survey, (OSTRC – O2) and can be completed digitally on your phone or computer.

The aim of this survey is to find out about your long-term injuries, or overuse injuries, that you may experience on an on-going, daily basis, and how they might interfere with your dancing. The survey asks about:

- your participation, modification and performance in classes, rehearsals and dance performances
- your pain levels
- whether you've needed days off dancing in the previous week
- injury diagnosis and treatment
- total hours spent dancing over the previous week

The duration of the study covers the last part of Term 4, and will be completed on a weekly basis, at the end of the week, so you can report on the week you have just had dancing.

Completing the questionnaire will take only a few minutes, and consists of 16 questions, mostly tick boxes.

Participation in this research is voluntary. The answers that you give in this survey will remain anonymous and confidential. Data will remain on a password-protected survey software system, (Qualtrics XM) and the individual responses and raw data will only be viewed by me for the purpose of this research project. The data will be de-identified and destroyed after five years. No personally identifiable data or responses will be shared with the New Zealand School of Dance.

You have an absolute right at any stage of the project not to respond and to withdraw your permission to take part in the study. Feel free to ask me any questions about the project at any stage. I am happy for you to have a copy of the final study paper, once finished.

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document, are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise

with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz.

Appendix B: Basic Demographics Survey

Basic demographics survey

1. Are you enrolled in the Ballet or Contemporary programme
2. What was your year level at the start of 2022?
3. What is your biological sex?
4. How old were you on the 1st of August 2022?
5. Please state your height in cms:
6. Please state your weight in kgs:
7. How many years of dancing had you completed prior to starting full-time training?
8. Please add your email that you would like to use for the survey:

Appendix C: OSTRC –02 Questionnaire

Injury survey

Introduction

This survey asks you about any long-term or overuse injuries that you may be experiencing on a daily basis. We would like to understand how these injuries may be affecting your dancing and training.

Completing the questionnaire will take only a few minutes (~5-10 minutes), and consists of 18 questions, mostly tick boxes.

We will ask that you complete the survey at the end of each week. When completing the survey, please provide your responses based on the dancing you have done in the **last 7 days.**

Information

Please answer all questions regardless of whether or not you have any current injury problems/issues. Please select the response that is most appropriate for you. If you are unsure, then please try to answer the question as best as you can.

Tracking responses

Can you please provide your email address as your survey ID? Remember, this is just to track your responses over the weeks. Identification of survey participants is only for statistical purposes and will only be seen by the researcher.

Question 1

Have you experienced any injury problems/issues/niggles in the past 7 days? For example, pain, aching, stiffness, clicking/catching, swelling, instability/giving way, locking, or any other complaints?

Question 2

If, yes, what day did this injury, issue or niggle occur?

- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday
- Sunday

Question 3

If so, what is the location of your injury? If you are experiencing multiple injury sites, then please select the main area/s:

- Head/face
- Neck
- Shoulder (including clavicle)
- Upper arm
- Elbow
- Wrist
- Hand/fingers
- Chest/ribs
- Abdomen
- Thoracic spine
- Lumbar spine
- Pelvis and buttocks
- Hip and groin
- Thigh
- Knee
- Lower leg
- Ankle
- Foot/toes
- Other

Question 4

Have you had any difficulties **participating** in normal dance classes, rehearsals, and/or performances due to your injury during the past 7 days? Please explain.

- Full participation without injury problems 0
- Full participation, but with injury problems 8
- Reduced participation, but with injury problems 17
- Cannot participate due to injury problem 25

Question 5

To what extent have you **modified** your classes, rehearsals, or performances due to your injury problems during the past 7 days? Please explain.

- No reduction 0
- To a minor extent 6
- To a moderate extent 13
- To a major extent 19
- Cannot participate at all 25

Question 6

To what extent has this injury affected your overall **performance** in class, rehearsals, or performance during the last 7 days? Please explain.

- No effect 0
- To a minor extent 6
- To a moderate extent 13
- To a major extent 19
- Cannot participate at all 25

Question 7

To what extent have you experienced injury related **pain** in your dancing during the past 7 days?

- No pain 0
- Mild pain 8
- Moderate pain 17
- Severe pain 25

Question 8

How many days in the last 7 days have you had to completely miss dancing due to your injury/pain?

- 1
- 2
- 3
- 4
- 5
- 6
- 7

Question 9

Is this the first time that you have reported this problem through this monitoring system?

- Yes, this is the first time I have complete this survey
- Yes, this is the first time I have completed it during this project
- No, I have reported this problem in one of the previous 4 weeks
- No, I have reported the same problem previously, but it was more than 4 weeks ago.

Question 10

Have you sought medical attention for this problem?

- Yes
- No

Question 11

What kind of medical practitioner have you seen about this problem? Select all that apply

- Physiotherapist
- Osteopath
- Massage therapist
- Doctor
- Acupuncturist
- Other

Question 12

Please provide a diagnosis for this problem:

Question 13

Would you like to report on another injury experienced this week?

- Yes
- No

(repeat of survey questions)

Dance Exposure

The next three questions are about the number of hours you have spent dancing in the last 7 days.
The last question is about the amount of time you have spent doing other forms of physical activity during the last 7 days. This includes purposeful, recreational, or incidental exercise. Examples of this are gym sessions/classes, yoga, Pilates classes, running, walking to and from school, hours you worked on your feet, shopping, housework, etc.

Question 25

State the total number of hours that you spent in CLASS during the past 7 days

Question 26

State the total number of hours you spent in REHEARSAL during the past 7 days:

Question 27

State the total number of hours you spent in PERFORMANCE during the past 7 days:

Question 28

State the total number of hours you spent in OTHER PHYSICAL ACTIVITY during the past 7 days:

Question 29

What was the main type/s of physical activity that you did outside of your dancing hours in the last 7 days? (tick as many as apply)

- Gym session – weights
- Gym session – cardio
- Pilates
- Yoga
- Running
- Playing sport recreationally
- Other dance class
- Dancing in a night club
- Walking to and from school
- Working a job on your feet
- Housework
- Shopping

Thank you for completing your weekly survey. We really appreciate your time and effort on this project.

Appendix D: Individual participant weekly severity and substantial injury scores

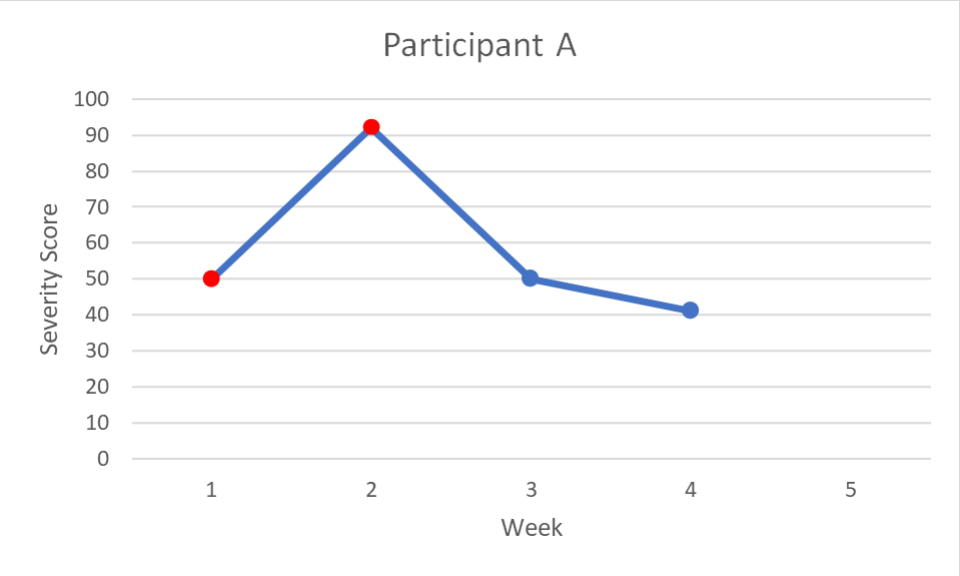
Dancer #	Week	Participation	Modification	Performance	Pain	Severity	Substantial
	Week 1	0	0	6	8	14	
	Week 2	0	0	6	8	14	
1	Week 5	0	0	0	17	17	
2	Week 1	0	0	0	8	8	
	Week 1	17	6	13	8	44	13
	Week 2	17	19	19	25	80	38
	Week 3	17	13	6	8	44	13
3	Week 4	17	6	6	8	37	
	Week 1	0	0	0	8	8	
4	Week 4	0	0	0	0	0	
	Week 1	8	6	6	17	37	
	Week 2	8	6	6	17	37	
	Week 3	8	6	13	8	35	13
5	Week 4	17	6	13	8	44	13
6	Week 1	8	0	0	8	16	
	Week 1	8	13	13	17	51	26
	Week 3	8	0	6	17	31	
	Week 4	8	0	13	17	38	13
7	Week 5	0	0	0	8	8	
	Week 1	0	0	0	8	8	
	Week 2	0	0	0	8	8	
8	Week 3	0	0	0	8	8	
	Week 1	17	13	19	0	49	32
	Week 2	17	6	13	17	53	13
	Week 3	8	6	0	17	31	
	Week 4	17	6	0	17	40	
9	Week 5	17	6	0	0	23	
	Week 1	8	6	6	8	28	
	Week 2	8	6	0	8	22	
	Week 3	0	0	0	0	0	
	Week 4	0	0	0	0	0	
10	Week 5	0	0	0	0	0	
11	Week 1	0	6	6	0	12	
	Week 1	8	6	6	17	37	
	Week 2	8	6	0	8	22	
	Week 3	8	6	0	8	22	
	Week 4	8	6	0	8	22	
12	Week 5	8	6	0	8	22	
13	Week 1	0	6	0	8	14	
	Week 1	8	8	6	17	39	
	Week 2	0	6	0	0	6	
14	Week 3	0	0	6	0	6	

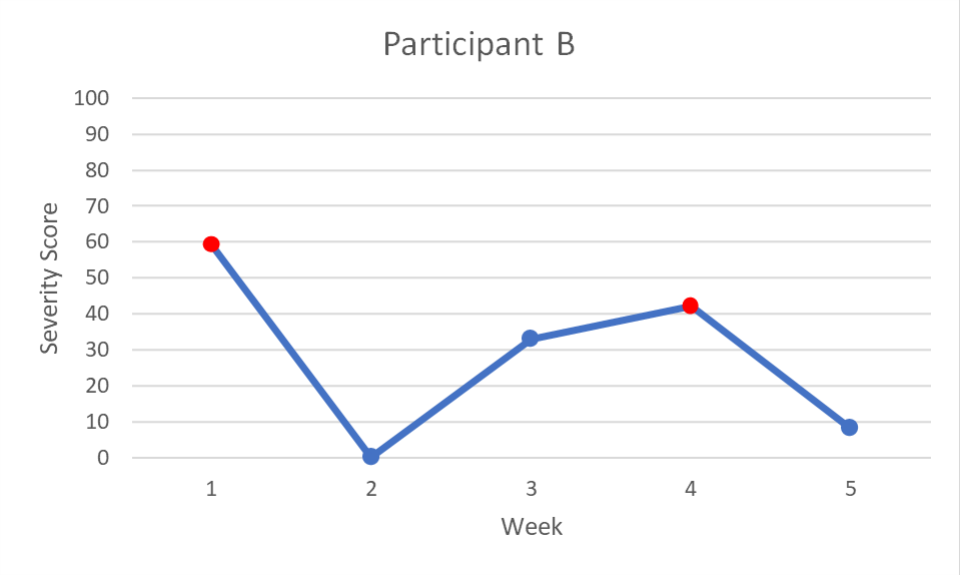
Dancer #	Week	Participation	Modification	Performance	Pain	Severity	Substantial
	Week 1	0	0	0	0	0	
	Week 2	0	0	0	8	8	
	Week 3	0	0	0	0	0	
15	Week 5	8	6	0	17	31	
	Week 2	17	6	13	17	53	13
16	Week 3	8	0	0	8	16	
	Week 1	8	6	13	0	27	13
	Week 2	25	19	19	25	88	38
17	Week 3	0	0	0	0	0	
18	Week 1	0	0	0	0	0	
	Week 1	0	0	0	0	0	
	Week 2	0	0	0	0	0	
	Week 3	0	0	0	0	0	
	Week 4	0	6	0	0	6	
19	Week 5	0	0	0	0	0	
	Week 3	0	6	0	6	12	
20	Week 5	0	0	0	0	0	

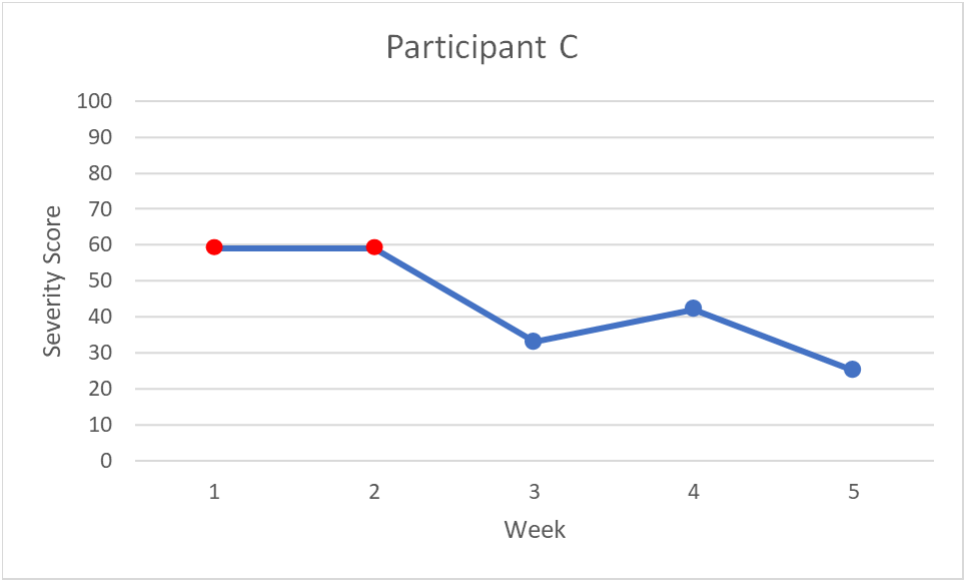
Appendix E: Example of musculoskeletal complaints recorded during the study period

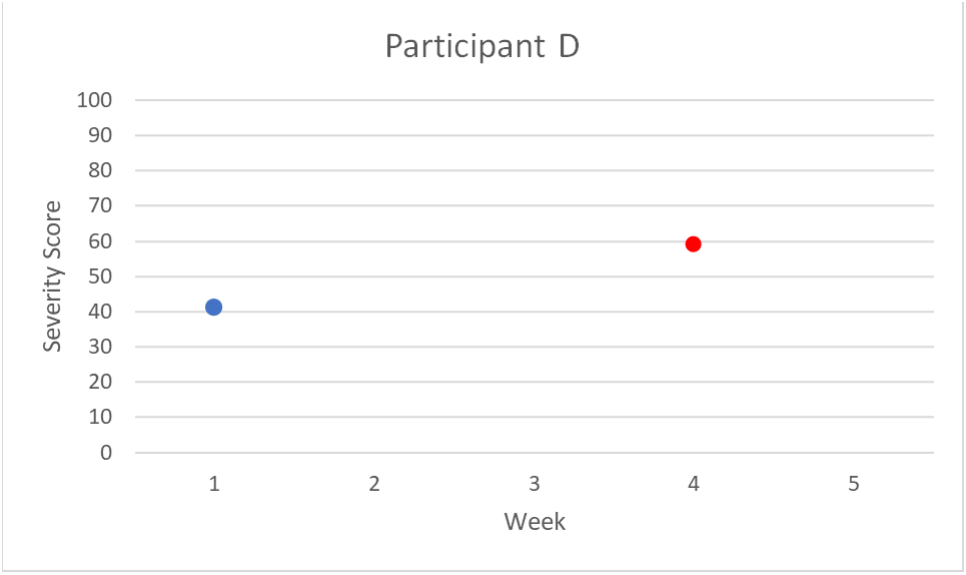
Anatomical area of musculoskeletal complaints	Self-reported result of this on the dancer – participation and modification	Effect on performance	Did they seek medical attention for the problem
Rolled ankle	No jumping	More cautious and not pushing as much	Yes, a physiotherapist
Ankle impingement	Full participation, however, some pain and unable to jump with pointe shoes on due to pain and fear of it getting worse. Modified by taking my pointe shoes off for allegro.		No
Bone stress			No
Neck/shoulder/clavicle and thoracic spine	Fast head movements and jerk motions were hard to accomplish		No
Foot/toes	Slight niggle in left metatarsals		No
Knee			No
Ankle and Foot/toes			No
Lower leg and elbow			No
Lower leg			No
Foot/toes	I've been in a moon boot for potential bone stress in my right foot and last week I was only allowed to do the barre and beginning of centre and just mark rehearsals. I have been allowed to do the first half of class but have only been allowed to mark rehearsals and no pointe	I haven't been able to finish class and haven't been able to do things full out. This means that I can't do the material to the best of my ability.	Yes, a physiotherapist. I had early signs of bone stress in my right foot. This has been an injury I have had for a couple weeks now. This past week has been more about easing back into it

Appendix F: Examples of the Severity Scores used to Track the Consequences of Overuse Problems in 6 Randomly Selected Dancers






Participant C
100
90
80
70
60
50
40
30
20
10
0
Severity Score
1
2
3
4
5
Week


Participant D
100
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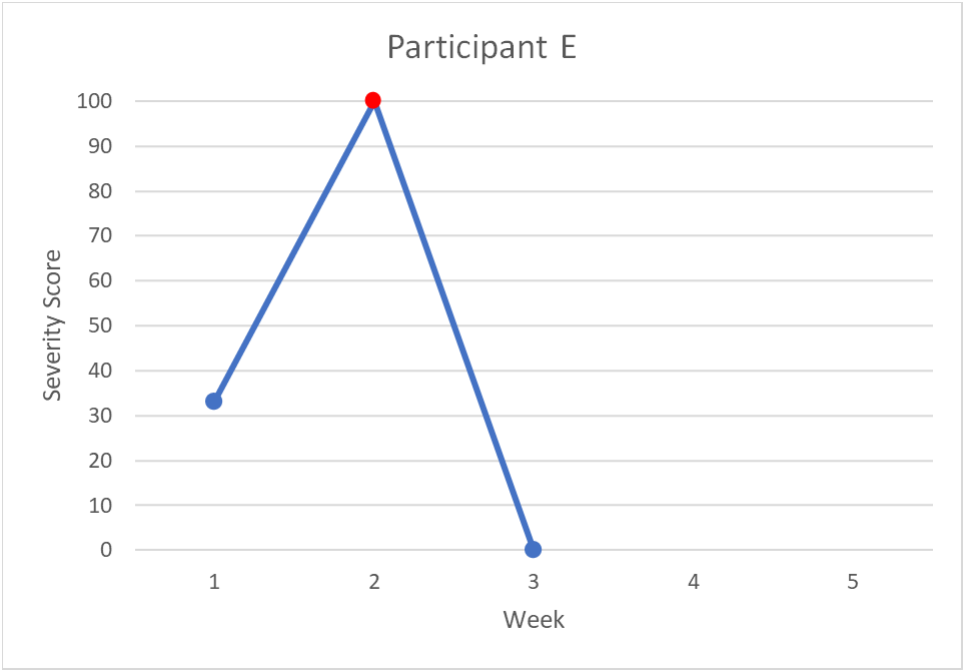
20
10
0
Severity Score
1
2
3
4
5
Week


Participant E
Severity Score
100
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20
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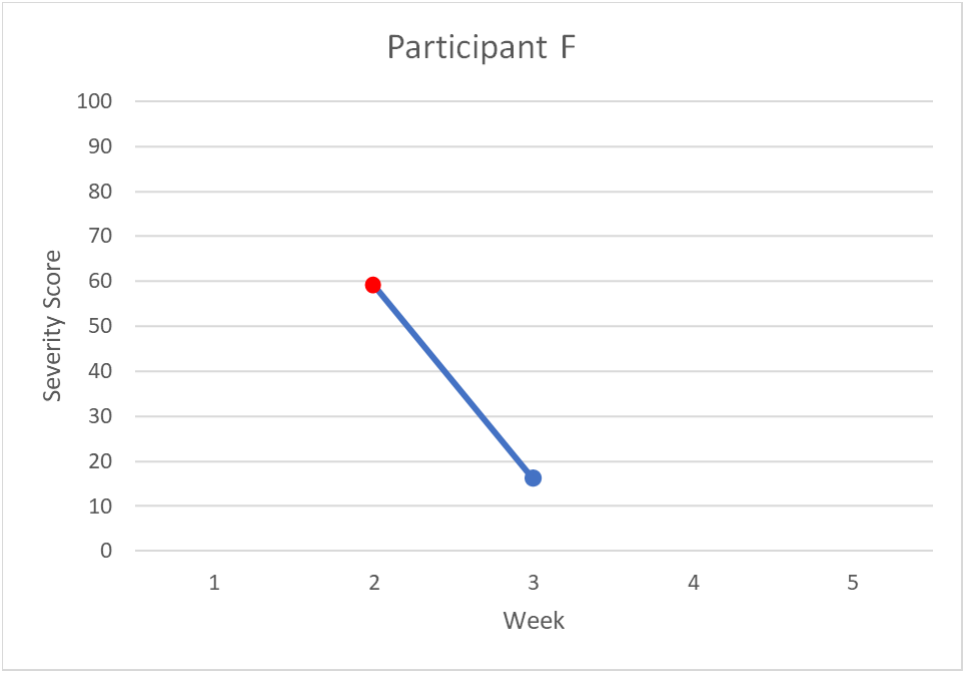
Week


Participant F
Severity Score
100
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80
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50
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10
0
1
2
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Week