Pre-season Screening and Injury Surveillance of Pre-Professional Dancers: A Longitudinal Study

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Pre-season Screening and Injury Surveillance of Pre-Professional Dancers: A Longitudinal Study

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
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Abstract

Few dance epidemiology studies have utilized evidence-based pre-season screening measures, prospective injury surveillance, and biostatistical modelling to investigate potential risk factors for dance-related injury across multiple years. Post-injury there is currently no return-to-dance protocol to guide injury rehabilitation. A dance-specific jump test to detect lower-limb asymmetries and normative values for common pre-season screening assessments may prove useful for onsite clinicians who are responsible for dancer populations. Therefore, the aims of this doctoral research were to assess the prevalence, incidence, and risk factors for dance-related injury in pre-professional ballet dancers, to evaluate the test-retest reliability of a dance specific jump test using wearable technology, and to establish normative values for common pre-season screening assessments.

In Chapter three, it was found that injury prevalence, injury rate, severity, and location remain consistent across five years of training, further justifying the growing body of research that demonstrates pre-professional ballet dancers are at high risk for injury. In an examination of potential risk factors in Chapter four, a significant association between lumbopelvic control and dynamic balance, when adjusted for psychological coping skills and years of previous dance training, with side-to-side differences was found.

In Chapter five, findings demonstrated that using accelerometers during a dance-specific jump test did not produce reliable measures of lower limb landing asymmetries. However, test-retest reliability was demonstrated for performance measures (i.e., flight time and jump height). This means that inertial measurement units placed on the lower limb could be used to quantify jump loads and measure jump height performance during injury rehabilitation. Finally, in chapter six, normative values and percentiles were determined for ankle and hip range of motion,
lumbopelvic control, and dynamic balance for healthy, adolescent ballet dancers training at the pre-professional level.

In conclusion, the use of a comprehensive injury surveillance program across multiple years has established consistent risks and a risk profile for dance-related injury in pre-professional dancers. Baseline and normative values of jump performance and common pre-season screenings may be a more appropriate reference for injury than lower-limb asymmetry metrics.
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Dan, thank you for encouraging me to follow my passions and believing in me. From T-ball, to gymnastics, to a PhD, you have always been my biggest cheerleader. Rough ‘em up, rough ‘em up, BU sucks! Mom, you have been a pillar of support and reassurance. Thank you for always picking up the phone and listening. You’ve held me up on too many occasions to count, and this degree truly would not have been possible without you. To you all, your unconditional love and unwavering support have made all the difference throughout this experience.
Dedication

To the woman who taught me to be
anything I wanted to be when I grew up…

even a Dance Scientist.

My Mom.
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<td>Athletic Coping Skills Inventory-28</td>
</tr>
<tr>
<td>ASLR</td>
<td>Active Straight Leg Raise</td>
</tr>
<tr>
<td>BMI</td>
<td>Bone Mineral Density</td>
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<tr>
<td>bpm</td>
<td>Beats Per Minute</td>
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<tr>
<td>CI</td>
<td>Confidence Interval</td>
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<tr>
<td>cm</td>
<td>Centimeters</td>
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<tr>
<td>CMJ</td>
<td>Countermovement Jump test</td>
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<td>DSJ</td>
<td>Dance-Specific Jump test</td>
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<tr>
<td>g</td>
<td>Gravity</td>
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<td>GRF</td>
<td>Ground Reaction Force</td>
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<td>HDC</td>
<td>Healthy Dancer Canada</td>
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<td>hrs</td>
<td>hours</td>
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<td>Hz</td>
<td>Hertz</td>
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<tr>
<td>IADMS</td>
<td>International Association for Dance Medicine and Science</td>
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<tr>
<td>ICC</td>
<td>Intraclass Correlation Coefficient</td>
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<tr>
<td>IMU</td>
<td>Inertial Measurement Unit</td>
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<tr>
<td>IOC</td>
<td>International Olympic Committee</td>
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<tr>
<td>IQR</td>
<td>Inter-Quartile Range</td>
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<td>kg</td>
<td>Kilogram</td>
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<tr>
<td>LE</td>
<td>Lower Extremity</td>
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<td>LOA</td>
<td>Limits of Agreement</td>
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<td>LSI</td>
<td>Limb Symmetry Index</td>
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<td>m</td>
<td>Meter</td>
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<td>OLS</td>
<td>One Leg Standing</td>
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<td>OSTRC-Q</td>
<td>Oslo Sports Trauma Research Centre Questionnaire on Health Problems</td>
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<tr>
<td>p</td>
<td>p-value</td>
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<tr>
<td>PF</td>
<td>Plantar Flexion</td>
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<tr>
<td>PSIS</td>
<td>Posterior Superior Iliac Spine</td>
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<tr>
<td>REDCap</td>
<td>Research Electronic Data Capture</td>
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<tr>
<td>RED-S</td>
<td>Relative Energy Deficiency Syndrome</td>
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<tr>
<td>ROM</td>
<td>Range of Motion</td>
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<tr>
<td>SD</td>
<td>Standard Deviation</td>
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<tr>
<td>SH</td>
<td>Single-leg side hop test</td>
</tr>
<tr>
<td>STROBE</td>
<td>Strengthening the Reporting of Observational studies in Epidemiology</td>
</tr>
<tr>
<td>TAT</td>
<td>Total Active Turnout</td>
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<tr>
<td>TRIPP</td>
<td>Translating Research into Injury Practice framework</td>
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<tr>
<td>VJFT</td>
<td>Vertical Jump Force Test</td>
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<tr>
<td>YBT</td>
<td>Y-Balance Test</td>
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<td>yr</td>
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Chapter One. Introduction

1.1 Background

Dance is a popular activity worldwide. Across the globe, dance is reported to be in the top five most popular activities for adolescent girls. Dancers often begin participating at a young age in a private studio setting and specialize early. Dancers typically enroll first in a ballet class before exploring other dance genres. Ballet training is often characterised by increased volume and higher intensity in training. Specifically, those who choose a level of elite level training focused on technical and artistic skill acquisition for a professional career are regarded as “pre-professional”. During the pursuit of pre-professional training, there is an increase in physical demands placed on dancers’ bodies, which subsequently, puts them at higher risk for injury. In pre-professional ballet dancers, the injury incidence rate has been estimated to be between 1.4 - 4.7 injuries per 1000 hours of exposure. Of these injuries, most result from repetitive stress and involve the lower extremity including the foot, ankle, shin, knee, hip, and lower back.

Despite published recommendations for dance injury epidemiology studies, previous research has been plagued by different definitions of injury, exposure, and by different methodologies making comparison of injury rates and risk factors for injury between studies difficult. While several high-quality prospective studies have been performed in pre-professional ballet populations following published method recommendations, the majority have been limited to one training season or academic year. The use of consistent injury surveillance across multiple years or seasons may provide improved understanding of how the burden of injury among pre-professional ballet dancers changes over time.
Sport and dance injury risk is multifactorial and dynamic in nature. There are modifiable and non-modifiable factors that can alter a dancer’s risk for being injured. Furthermore, these risk factors may change over time due to different intrinsic and extrinsic factors that occur during a dancer’s career that may influence their susceptibility to injury. More appropriate biostatistical measures may be needed to investigate these relationships. Current traditional modeling techniques assume that repeated outcomes (e.g. multiple dance-related injuries throughout a training season) are independent, not taking into account the complex and interconnected nature of dance-related injury.

A consistently identified risk factor, for dance-related injury is history of previous injury. One of the mechanisms by which previous injury is a risk factor for future injury is due to inadequate rehabilitation from an initial injury. Currently there are no evidence-informed rehabilitation protocols for dance clinicians to utilize when ensuring that dancers are returning to training fully rehabilitated from a dance-related injury. In sport, following lower extremity injury, the contralateral limb is often used as a reference to guide rehabilitation of the injured limb. A limb symmetry index (LSI) is determined by the ratio between the injured and contralateral limb and an LSI >90% has been used to establish effective return-to-sport criterion in athletes. Previous literature has shown that LSIs can be detected using Inertial Measurement Units (IMUs) in both bilateral and single leg jumps. However, these jump testing protocols don’t incorporate the aesthetic and temporal demands of dance. The development and reliability of a dance-specific jump test that utilizes IMUs may prove more useful for onsite clinicians who are responsible for dancer populations.
The use of pre-season screening in dance is well documented.\textsuperscript{92, 109, 152} Assessments typically take place at the beginning of an academic year in vocational, pre-professional, and university settings. Screening components that are commonly included in dancer screening programs are: observation of alignment, range of motion (e.g., ankle and hip), muscle strength, and balance.\textsuperscript{92, 137, 152} Overarching aims of these programs are to provide dancers with information about their bodies, identify dancers at risk for injury, and establish normative data for specific cohorts.\textsuperscript{92} Currently, there is a paucity of normative data in dance populations, specifically amongst the adolescent age group for ballet dancers.\textsuperscript{109} Normative data can be useful for the both the clinician and dance educator to provide context to which their dancers’ screening measures can be appropriately compared during both pre-season and post-injury. Access to normative data for the clinician and educator may help guide effective subsequent training and rehabilitation from injury.

1.2 Research Rationale

Robust injury surveillance methods are needed to inform injury prevention strategies. Injury surveillance across multiple years will provide a picture of how the burden of injury changes in pre-professional dancers across multiple training seasons. A comprehensive evaluation of potentially modifiable and non-modifiable risk factors for dance-related injury will inform the development of effective training practices designed to minimize injury risk. It is well established that most dance injuries occur in the lower extremity, that previous injury is a risk factor for future injury in this population, and that dancers return to dance before they are appropriately recovered from injury.\textsuperscript{42, 74, 80} Establishing a reliable dance specific jump test will
provide a tool that could be used to assess the recovery of injured dancers to ensure they are returning to dance fully rehabilitated. Providing normative values for pre-season screening assessments can also provide valuable information about dancers who have existing problems that may result in injury during the training season.

1.3 Research Objectives

The primary aim of this research is to establish the extent, characteristics, and risk factors for dance-related injury among pre-professional adolescent ballet dancers across five academic training years. Secondary aims are to establish the test-retest reliability of a proposed dance specific jump test using wearable technology to capture limb asymmetry and to establish normative values for pre-season screening assessments conducted with pre-professional adolescent ballet dancers.

The specific objectives addressed in this doctoral research are:

1. To establish the extent (prevalence, injury rate) and characteristics (severity, location) of injuries in female and male pre-professional adolescent ballet dancers across five academic training years.
2. To examine modifiable and non-modifiable risk factors for dance-related injury in female and male pre-professional adolescent ballet dancers.
3. To determine test re-test reliability of a dance-specific jump test using wearable technology to capture limb asymmetry in pre-professional dancers.
4. To establish normative values from pre-season screening assessments for ankle and hip range of motion, lumbopelvic control, and dynamic balance among female and male pre-professional adolescent ballet dancers.

1.4 Covid-19 Considerations

Initial plans for data collection of this doctoral research were meant to begin in September 2020. Due to provincial guidelines surrounding Covid-19, in-person data collection could not be conducted in under-age participants off the University of Calgary campus. Therefore, objectives of this project shifted to data collected prior to the onset of the pandemic with the exception of Chapter five. The population of interest for Chapter five was shifted to adult university pre-professional dancers who were able to attend data collection on the University of Calgary campus.

1.5 Summary of Thesis Format

Chapter two of this thesis reviews the current published literature exploring injury surveillance of pre-professional dancers and potential risk factors for injuries. Chapters three through six represent four studies with manuscripts that are under review or will be submitted to reputable peer-reviewed journals for publication. Specifically, chapter three is a descriptive study of the extent (prevalence, injury rate) and characteristics (severity, location) of injuries in pre-professional adolescent ballet dancers across five academic years. The manuscript has been submitted to a peer-review journal and is currently under review [Physical Therapy in Sport (Impact Factor: 2.92)]. Chapter four is a study that identifies potential risk factors for self-reported dance-related musculoskeletal injuries in adolescent pre-professional ballet dancers across five academic years. Chapter five examines the test-retest reliability of a dance-specific
jump test using wearable technology to capture limb asymmetry in university dancers. The manuscript presented in chapter six establishes normative values for pre-season screening components for adolescent pre-professional ballet dancers. This manuscript has been submitted to the Journal of Dance Medicine and Science (Impact Factor: 0.783) and is currently under review. Finally, the closing chapter seven summarizes the outcomes from all original research and provides directions for future research.
Chapter Two. Literature Review

2.1 Participation and Injury Burden

Dance is a popular activity that is often among the top five most popular activities for adolescent females worldwide. There are many benefits to participation in dance, such as improved physical and mental health, however this comes with a high-risk for injury. In pre-professional ballet dancers, the injury incidence rate has been estimated to be between 1.4 - 4.7 injuries per 1000 hours of exposure. Of these injuries, up to 86% are categorized as overuse injuries that occur from repetitive stress and involve the lower extremity including the foot, ankle, shin, knee, hip, and lower back.

Previous injury epidemiology research on dance-related injuries has been limited by a number of factors including inconsistent methods of defining injury and dance exposure, as well differing strategies of reporting injury. For example, it has now been described that medical attention and time-loss definitions of injury capture acute injuries well. However, overuse injuries that are typically caused by repetitive movements like jumping, are more common in dancers, and may not result in time-loss or medical attention. This indicates that an all-complaints definition may more accurately capture the burden of injury in dance.

2.2 Frameworks for Sport Injury Prevention Research

The first published framework for injury prevention research in sport outlined a specific sequence of events. van Mechelen’s model titled ‘The ‘sequence of prevention’ of sports injuries’ consists of four steps: 1) establishing the extent of the sport injury problem through incidence and severity estimates, 2) establishing aetiology and mechanisms of injury, 3)
introducing preventative measures, and 4) assessment of effectiveness of step three through repetition of step one (see Figure 2.1). Step four is optimally achieved using randomized controlled trials and a validated injury surveillance program to examine the efficacy of the proposed injury prevention measure. Further iterations of this model have expanded the four steps to include the implementation context for injury prevention. The Translating Research into Injury Practice framework (TRIPP) model proposes two more steps to research implementation issues once prevention measures have demonstrated as effective (see Figure 2.2). This model takes into account the implementation context for injury prevention to better inform injury prevention strategy adoption by the stakeholders. The current research focuses on steps one and two of these models to establish the extent and aetiology of injury in pre-professional dancers.

Figure 2.1. The ‘sequence of prevention’ of sports injuries. Reproduced from [Incidence, Severity, Aetiology and Prevention of Sports Injuries. van Mechelen, W, Sports Medicine, 14(2), 82-99, 1992] with permission from the publisher.
Figure 2.2. The Translating Research into Injury Practice (TRIPP) framework. Reproduced from [A new framework for research leading to sports injury prevention, Finch C, Journal of Science and Medicine in Sport, 2006;9:3-9.] with permission from the publisher.

2.3 Approaches for Better Understanding Etiology in Sport Injury

The first risk factor model for sport injuries was published in 1994 by Meeuwisse et al. A multifactorial approach was proposed to account for all the factors involved in injury along with the inciting event. These factors can be further categorized as intrinsic, extrinsic, modifiable, and non-modifiable factors. Intrinsic factors are those that are internal to the athlete, such as biomechanical alignment, fitness level, or maturational stage. Extrinsic factors are those
external to the athlete (e.g., equipment being used, environment of practice). Both intrinsic and extrinsic factors can be modifiable (subject to change via intervention) or non-modifiable (resistant to intervention).\textsuperscript{97, 140} This model was based on a risk for infectious diseases and had several limitations such as the assumption of a linear timeline from injury to recovery or prevention. The nature of sport injury does not always allow for a finite end point to measure. In 2005, Bahr and Krosshaug modified the previous 1994 model by Meeuwisse and colleagues, to develop a more comprehensive approach to understating injury causation or the inciting event (Figure 2.3). This model highlighted the importance of understanding injury mechanisms and provided guidelines for injury mechanism research.\textsuperscript{9}

![Comprehensive model for injury causation from Bahr and Krosshaug.\textsuperscript{9}](image)

Meeuwisse and colleagues published another iteration of the original 1994 model incorporating the dynamic and recursive nature of sport injury. Recovery, re-entry, and no injury can all result in adaptations that may alter an athlete’s status of injury susceptibility. This recursive model looks beyond the initial set of intrinsic and extrinsic risk factors and incorporates how these risk factors may change through preceding cycles of activity participation (see Figure 2.4). The most important message of this model is that each athlete has their own set of risk factors and these risk factors are dynamic in nature.

**Figure 2.4.** Dynamic, recursive model of etiology in sport injury. Reproduced from [A Dynamic Model of Etiology in Sport Injury: The Recursive Nature of Risk and Causation, Meeuwisse W, Tyreman H, Hagel B, Emery CA, Clinical Journal of Sport Medicine, 17(3), 215-219, 2007] with permission from the publisher.

In 2012, a consensus statement on injury surveillance was presented by the International Association for Dance Medicine and Science (IADMS). The goal was to establish standard measures of injury surveillance and reporting within the dance community similar to other
sports. The original multifactorial model for causation of sport injury was modified to be more dance-specific outlining intrinsic and extrinsic risk factors specific to the dance context (see Figure 2.5).

**Figure 2.5.** Dance modified dynamic, recursive model of etiology in sport injury.  


Finally, a complex system model for sport-related injuries was proposed by Bittencourt and colleagues in 2016. The implementation of complex system thinking allows researchers to better address sport injuries that are produced by an interaction of factors, or a web of determinants, which may produce a regularity, or risk profile for injury. This approach considers the interconnected nature of all risk factors, whose identification is integral to injury
prevention research (see Figure 2.6). A shift from risk factors to risk pattern recognition may be key to future preventative interventions for sport injury.

**Figure 2.6.** Complex model for sport injury. The group of variables at the bottom makes up the web of determinants with different weights. Dark circles lines represent variables with more interactions that variables encircled with lighter lines and exert a greater influence on the outcome. Dotted lines represent weak interactions while solid lines represent strong interaction. Arrows indicate the relationship between the observable regularities, capturing a risk/protective profile for injury.


### 2.4 Guidelines for Injury Surveillance

Injury surveillance systems are used to identify patterns, severity, and frequency of injuries within a given sport and to assess the risk of sustaining those injuries. The International Olympic Committee (IOC) has issued a consensus statement highlighting standardized methods for
recording and reporting epidemiological data for injury and illness in sport. Specific to dance, IADMS has also published consensus on dance-related injury surveillance, recommending that surveillance be mandatory, utilize licensed healthcare professionals trained in diagnosis, and standardized protocols for capturing injury per exposure for all dancers within a specified group be employed.

2.4.1 Injury definition

A review of current injury surveillance literature showed that injury surveillance programs generally employ one of three injury definitions (i.e., medical attention injuries, time-loss injuries, or an all-complaints definition). Each definition has advantages and disadvantages and it is up to the researcher to choose the definition(s) that is most appropriate to measure the outcome of interest in the population of interest. Injury is often defined as tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy. Bahr et al. recommend this broad definition to be inclusive of an array of injury-related health problems that affect an athlete. Specific sport injury surveillance programs can narrow this definition to be more operational for a specific objective. For dance, the recommended definition of injury is any anatomic tissue-level impairment diagnosed by licensed healthcare professionals that results in full time loss of activity for one or more days. If an injury falls short of this definition it is recommended to be categorised as a musculoskeletal complaint. Other research has shown that this definition may not be appropriate for dancers as the prevalence and full burden of injury may be underestimated.
2.4.1.1 Onset and mechanism of injury.

Injury has often been classified as either sudden onset (acute injury) or gradual onset (overuse injury). Acute injuries are considered to be those that result from a specific identifiable event while overuse injuries are those that develop gradually. In injury surveillance programs, an overuse injury is characterized by a gradual onset mechanism and an underlying pathogenesis of repetitive microtrauma. Overuse injuries can also be described as injuries without a specific, identifiable event responsible for their occurrence. The mechanism of an injury has often been classified by the inclusion of contact or non-contact with another person or object. Overuse injuries, which are most common in dance, are categorized as non-contact injuries. Current recommendations indicate that additional injury characteristics be recorded such as, anatomical region, injury type (pathology), and diagnosis.

2.4.1.2 Recurrent and subsequent injury.

Injury surveillance systems encounter difficulty in the recording and analysis of recurrent or subsequent injuries. Injuries are classified as recurrent when the same injury occurs to the same area and subsequent when either a new injury occurs at a different location, or the same location with a different diagnosis. A recurrent injury has also been defined as “an injury of the same type and at the same site as an index injury (initial injury) and which occurs after a player’s return to full participation from the index injury”. Finch et al. and Fortington et al. defined subsequent injury as any injury that occurs at any stage following an initial injury.

The IOC recommended framework for categorisation of subsequent injuries was proposed by Hamilton and colleagues. Hamilton et al.’s framework provides a standard for classifying and
categorising new, subsequent, recurring, and healed injuries. Developed using a dataset of injury patterns and injury reports of circus performers, Hamilton et al. found that the majority of subsequent injuries were new injuries to a new location. Seasonal incidence rates that only use the first recorded injury of an athlete may be underestimated due to lack of data representing subsequent injuries.

**2.4.1.3 Injury severity**

Injury severity has been reported in various ways across sport injury epidemiology literature, including time lost from activity and training, consequences of injury, financial implications, and clinical extent of an injury. Time lost in days from activity is most often reported and has been the recommended definition of severity in past consensus statements. However, this measure comes with a significant limitation for dancers, in that dancers often return to modified training before they are completely recovered from injury or continue to dance through injury. In response to this, the Oslo Sports Trauma Research Centre Questionnaire on Health Problems (OSTRC-H) has been used in dance injury surveillance systems and has been shown to capture the burden of injury more accurately in pre-professional dancers. Mean OSTRC severity scores have also been proposed, and used in pre-professional populations, as a function to demonstrate the severity of overuse and chronic injuries more accurately instead of average time lost.

**2.4.2 Athletic exposure**

Another key aspect of injury surveillance is recording athlete exposure to appropriately calculate injury incidence and risk. Exposure is often recorded as the number of athletic participations that
can be broken down further into subcategories, such as training or competition. The IOC recommends that both training and competition exposures be recorded and reported separately because injury risk is different between these two activities. Considerations for defining exposure in dancers are addressed in the 2012 IADMS Standard Measures Consensus Initiative. Conversely to the IOC, the recommended definition of one dance exposure does not distinguish between different aspects of participation but includes “any participation in class, rehearsal, or performance in which the dancer was exposed to the possibility of injury”.

2.4.3 Injury prevalence and incidence

Injury prevalence and incidence are metrics used to express injury risk in a specific population. Injury prevalence is the proportion of existing cases, or injuries, divided by the total population at risk at a given point in time. Commonly calculated in injury surveillance research is period prevalence; is the proportion of the study population that has an injury during a time period of interest (e.g., season or academic year). Incidence, or an injury rate, refers to the number of new injuries that occur during a defined period of time. Injury rates can be expressed in varying units. They are most often expressed as the number of new injuries per 100 or 1000 hours of exposure, number of new injuries per 1000 athlete exposures, or number of new injuries per 100 or 1000 athlete-years.

2.4.4 Injury burden

Injury burden describes the overall impact of a health problem in a specific population. Typically, burden is calculated for all injuries, both acute and overuse. Burden is expressed in differing outcomes, such as financial cost, mortality, morbidity, and in the case of injury, a
combination of frequency and consequences.\textsuperscript{8} As frequency and consequences of injury can be expressed in many ways, Bahr et al. recommended that results should be presented as number of days of time loss per 365 athlete-days to better compare the burden of injury across different sports in future research.\textsuperscript{8} As discussed earlier, this is a problem for dance injury surveillance systems as the most common type of injury is overuse injury to the lower extremity and utilization of a time-loss injury definition often underestimates the burden of overuse injuries.\textsuperscript{24, 42}

\subsection*{2.4.5 Limitations to current injury surveillance methods}

The recommended injury surveillance programs by the IOC and IADMS are costly, in both time and resources, and dance schools and companies may not have the means to implement them. In a review of methods and data quality of sport injury surveillance systems several limitations were discussed that may have implications for the use of surveillance systems in dance. Most surveillance systems operated within professional, male leagues and those that operated outside of professional leagues operated in university or high school settings with paid athletic trainers to record injury data.\textsuperscript{41} Injury surveillance methods have been employed in the dance setting, but similarly to sport, they have been limited to pre-professional schools and professional ballet and modern companies.\textsuperscript{3, 25, 82} Due to the costly nature, prospective injury surveillance methods have often been limited to one year or training season in pre-professional schools,\textsuperscript{81, 94} leaving the extent to which injury estimates vary across multiple training years unclear.
2.5 Injury Rates in Dance

Epidemiological research on dance injuries suffers from differing methodologies, creating a range in injury estimates and comparison across studies difficult. Injury prevalence in pre-professional dancers has been estimated to be as high as 82%. Depending on injury definition and registration, the injury incidence rate has been estimated to be between 0.8-4.7 injuries per 1000 hours of exposure. In an epidemiological review of injuries in this population, injuries recorded by a physiotherapist ranged from 1.09-3.52 injuries per 1000/dance exposures and 0.8-2.9 injuries per 1000 hours of exposure using both time-loss and medical-attention definitions of injury. Self-reported injury rates were higher at 4.7 injuries per 1000 hours of exposure. Across these studies, there was no standard methodology for capturing dance exposure. Exposure was estimated from weekly timetables and attendance records, limiting the ability to account for individual dance exposure or dance exposure outside of a dancers schooling. While subject to potential recall bias, self-reported dance hours allow for individual dancers to report additional dance training or rehearsals.

2.6 Potential Risk Factors for Injury in Pre-Professional Dancers

Investigation of risk factors for dance injury has been difficult due to different injury surveillance methodologies, including inconsistent injury and exposure definitions, and risk factor measurement during pre-season screening. To date Level 2 evidence, suggests that insufficient coping skills, low body mass index, increase in training hours, and history of previous injury are significantly associated with increased risk of dance-related injury. Similarly to descriptive injury epidemiology research, these studies differ in injury definition and methodology. Utilisation of clinically sound pre-screening measures is critical for assessment of
potential risk factors. Additionally, a more inclusive injury definition, such as self-reported all-complaints injury, may provide a more accurate measure of dance injury patterns. Furthermore, more appropriate biostatistical measures may be needed to investigate these relationships. Current traditional modeling techniques assume that repeated outcomes (e.g. multiple dance-related injuries throughout a training season) are independent, not taking into account the complex and interconnected nature of dance-related injury.

While consensus is lacking on some potential risk factors, a history of previous injury is consistently found to be associated with increased risk of dance-related injury. A possible mechanism by which previous injury is a risk factor for future injury is by inadequate rehabilitation from the initial injury. It has also been shown that dancers continue to train and perform while they are injured, potentially prolonging their recovery. Many dancers fear the consequences of injury. This culture of “fear and avoidance” that is often reported in dance, combined with a history of previous injury may lead dancers to not fully recovering from injury. Over 50% of dancers indicated that they believed there was a stigma associated with injuries in dance. Vassallo and colleagues defined stigma as “refers to a loss of status, discrimination, or labeled differences between individuals based heavily on social or cultural contexts”. Fifty-seven percent of full-time professional dancers and 72.3% of part-time dancers surveyed in Vassallo’s study indicated they had a fear of the repercussions of injury. Finally, over 50% of these dancers indicated that they would delay reporting of an injury. The fear and delay of reporting injury could lead to an underestimation of the prevalence and incidence of injury in dance populations in studies that rely solely on a third party registration of injury (i.e. physiotherapist or athletic trainer).
2.7 Dance Injury Rehabilitation

There is evidence to suggest that dancers are dancing through injuries or returning to dance from under-recovered injuries.74, 77 The “fear and avoidance” culture often reported in dance leads dancers to be over-eager to return to training after injury and results in incomplete rehabilitation, increasing risk for re-injury.1, 146 As such, researchers have attempted to establish a dance-specific, progressive rehabilitation schedule for dancers.1 However, this schedule has not been validated against other guidelines or schedules as there is a lack of dance-specific rehabilitation guidelines.

2.7.1 Bilateral asymmetry assessment

In sport injury rehabilitation, a limb symmetry index (LSI) is determined by the ratio between the injured and contralateral limb and an LSI greater than 85-90% (asymmetry < 10-15%) is used as a guideline for return-to-sport in injured athletes.71, 111, 155 However, symmetry is sometimes achieved post-injury due to decreased performance of the non-injured limb.120, 134 Additionally, asymmetry values less than the cut-off value are demonstrated in healthy, uninjured, adolescent athletes.29, 130 There are multiple methods to quantify a LSI via different limb symmetry calculations.17 Many calculations follow a similar equation to the following: (index limb – opposite limb)/(larger value of the two limbs) x 100.65 Depending on the research question, either the dominant/non-dominant, left/right, or injured/non-injured is chosen as the index limb. The magnitude of asymmetries has been shown to vary depending on the method of calculation and the test and index limb selected.16, 17
Assessment of bilateral strength asymmetry using a vertical jump force test (VJFT), referred to as a countermovement jump test, has been established to be both valid and reliable when compared to other strength measures, such as the isokinetic leg extension test and the isometric leg press. However, dancers regularly perform variations of repeated single-leg jumps and very rarely perform a maximal vertical jump for height. Maulder and Cronin concluded that repeated unilateral vertical jumps have been found to also detect LSIs just as well as a countermovement jump test. In a comparison of performance between unilateral jump assessments of 15 male adult athletes, it was found that a unilateral single-leg jump test was reliable (dominant limb ICC: 0.71 (0.007); non-dominant ICC: 0.81 (0.001)). LSIs calculated from the unilateral jump tests were similar to those previously published for healthy adult male subjects with no history of lower extremity injury. A repeated vertical single-leg hop test may be a more appropriate task to determine LSI values in dancers as it mimics the movement that is most often rehearsed and performed in this population. There is currently no dance-specific vertical jump test that encompasses the tempo component required by staying on beat to the music.

2.7.2 Assessment of bilateral asymmetry by inertial measurement units

The current gold standard method for detecting limb asymmetry among athlete populations involves the use of dual force plates. Dual force plates are typically only available in lab settings and are expensive. Inertial measurement units (IMUs), or wearable devices, are small and unobtrusive, meaning they can be worn in the studio, during technique class, and rehearsal. IMUs have been validated to detect jumping movements and jump height among college volleyball athletes. For example, in a validation against visual count from recorded video, wearable devices captured jump count with 97% sensitivity and 100% specificity. Other studies
have validated different wearable devices and found an average of only 0.7 cm difference between a Myotest acceleration system and the wearable device in countermovement jumps.\textsuperscript{107} A validation of two accelerometers in children found that IMUs have the potential to measure and quantify impact loading of bone and can determine ground reaction force (GRF) applied to the skeleton.\textsuperscript{105} Accelerometers were found to estimate and monitor landing forces in 15 ballet dancers performing continuous jumps until self-determined exhaustion.\textsuperscript{4} An LSI can be calculated by placing two IMUs on each tibia because IMUs are able to detect similar metrics to force plates and determine GRF applied to the skeleton. Accurate and reliable placement of the IMUs is necessary to account for the attenuation of force by the foot and ankle during jumping. IMUs have not been used to determine LSIs in an adolescent ballet population and their reliability needs to be established.

### 2.8 Pre-season Screening for Normative Data

The use of pre-season screening in dance is a popular and common practice in injury surveillance programs.\textsuperscript{92, 109, 152} Pre-season screening assessments have been used to provide dancers with information about their bodies, identify dancers at risk for injury, and establish baseline data for research purposes.\textsuperscript{92} Assessments typically take place at the beginning of an academic year in vocational, pre-professional, and university settings. Typical screening components include observation of alignment, range of motion (e.g., ankle and hip), muscle strength, and balance.\textsuperscript{92, 137, 152} Once a sufficient number of dancers have been assessed, it is possible to establish normative data for a specific cohorts of dancers.\textsuperscript{92} Normative data consists of performance standards and baseline distribution of results that can be used to evaluate a specific population.\textsuperscript{121} Norms for upper-body strength, endurance, and power in collegiate dancers have been
published. Currently, there is a lack of normative data in pre-professional ballet populations for other pre-season screening measures, specifically amongst the adolescent age group.\textsuperscript{109} Normative data can be useful for the both the clinician and dance educator to provide context to which their dancers’ screening measures can be appropriately compared.

### 2.9 Summary

Pre-professional dancers are at risk for dance-related injury. In order to understand the burden of injury in this population, strong injury surveillance methodology, utilizing consistent injury and exposure definitions, across multiple training years will provide insight into how injury estimates vary from year to year. Differing methodology has made comparison of injury burden, risk, and risk factors difficult in the previous literature. A consistently identified risk factor for injury is a history of previous injury possibly due to inadequate recovering of the previous injury. Rehabilitation from injury in sport has often been informed by the measurement of LSIs. Utilization of a reliable dance specific jump test to measure LSIs in pre-professional dancers could aide practitioners to appropriately rehabilitate dancers from injury and potentially decrease their risk for further injury. There are other potential risk factors for dance injuries, such as ankle and hip range of motion\textsuperscript{62,151}, poor lumbopelvic control\textsuperscript{129}, and decreased dynamic balance.\textsuperscript{99} Therefore, many dance schools conduct pre-season assessments to identify those dancers who have existing weaknesses in these areas. There is a lack of normative values for these common pre-season assessments leaving dance educators and clinicians with little context for dancers’ performance during pre-season screening.
Chapter Three. Injury Epidemiology in Pre-Professional Ballet Dancers: a 5-year Prospective Cohort Study

3.1 Abstract

**Introduction:** Pre-professional ballet dancers are at high-risk for injury, with injury rates ranging from 1.4 - 4.7 injuries/1000 dance-hours. In dance injury epidemiology, most published research has been limited to one training season. Thus, the extent to which injury estimates range from year to year in a pre-professional ballet program is currently unknown.

**Objective:** The aim of this study was to establish the extent and characteristics of injuries in pre-professional adolescent ballet dancers across five academic training years.

**Methods:** 452 female and male pre-professional ballet dancers (median age, 15 years; range, 11-20 years) participated across five academic years at a vocational ballet school. Participants completed an online weekly injury questionnaire (OSTRC-Q) and self-reported dance hours questionnaire.

**Results:** Questionnaire response was 91.4%. Depending on the definition of injury, seasonal injury prevalence ranged from 32.1% (145/452; time-loss) to 67.4% (305/452; all-complaints) across the 5 years. Seasonal injury rates ranged from 0.76 (95%CI: 0.66, 0.86; time-loss) to 2.54 (95%CI: 2.37, 2.73; all-complaints) per 1000 dance-hours. The ankle was the most reported injury location (range: 16-33%).

**Conclusions:** Injury prevalence and injury rate estimates remained high across five academic years in a pre-professional ballet population. Injury estimates were highest when an all-complaints definition was employed.
3.2 Introduction

Dance is a demanding activity that is practiced by many worldwide. In Canada and across the
globe, dance is reported to be in the top five most popular activities for adolescent girls.19, 38
Many dancers who choose to pursue pre-professional training, understand that there will be an
increase in the physical demands placed on their bodies, which subsequently, puts them at higher
risk for injury.82 In pre-professional ballet, injury prevalence has been estimated to be as high as
86%40 with injury rates reported up to 4.7 injuries per 1000 dance hours.40, 82 The most common
sites of these injuries sustained by adolescent, pre-professional ballet dancers involve the lower
extremity, mainly the foot, ankle, lower leg, knee, and hip.81, 82, 145 Most of these injuries are
characterized as overuse and result from repetitive stress.28 A key risk factor for these types of
dance-related injuries is dance exposure, with increased hours of dance training (i.e., volume of
training) being associated with an increase in injury incidence.78, 138

Studies describing dance-related injury incidence across multiple years are limited and findings
are inconsistent. In a systematic review and retrospective cohort study, it was found that first
year pre-professional ballet students had a decreased rate of injury compared with the higher year
levels.42, 51, 52 Conversely, in a prospective cohort study of pre-professional contemporary and
ballet dancers, there was an increased rate of injury in first-year students compared to more
senior students.90

Consensus statements focused on injury surveillance to capture sport and dance-related injuries
have recommended the prospective cohort as the study design of choice for this area of
research.8, 49, 93 Recommended definitions of dance-related injury have been stated in the 2012
International Association of Dance Medicine and Science (IADMS) Standard Measures Consensus Initiative.\textsuperscript{93} Specifically, it is suggested that ‘injury surveillance programs should be mandatory, encompass a diagnosis from a licensed healthcare professional, and employ a standardized protocol for capturing injury-per-exposure data’. \textsuperscript{93} However, employing an injury definition that requires medical attention, has been shown to underestimate injury burden among dancing populations.\textsuperscript{81} This underestimation may be related to the culture of “fear and avoidance” that is often reported in dance, in which dancers may be afraid to disclose an injury for fear of being told they have to stop dancing, and might subsequently lose a contract or performance role.\textsuperscript{146} Outcomes of Bolling and colleagues’ qualitative research found that dance injury is described as a spectrum by artistic staff and dancers in professional ballet, which depend on the dancer’s ability to perform to the best of their ability, pain level, and modification of participation.\textsuperscript{20} In order to capture the true burden of dance-related injury, the use of inclusive injury definitions in surveillance programs is now encouraged.\textsuperscript{8}

While several high-quality prospective studies have been performed in pre-professional ballet populations following the IADMS guidelines, the majority have been limited to one year.\textsuperscript{42, 90, 145} The use of consistent injury surveillance across multiple years or seasons could provide improved understanding of how the burden of injury among pre-professional ballet dancers changes over time. Therefore, the aim of this study was to establish the extent (prevalence, injury rate) and characteristics (severity, location) of injuries in pre-professional adolescent ballet dancers across five academic training years.
3.3 Methods

3.3.1 Study design and participants
This study followed the STROBE guidelines for reporting prospective cohort designs. Participants included a convenience sample of pre-professional adolescent ballet dancers from a vocational dance school in Calgary, Canada. Recruitment occurred at the beginning of each school term (September of each year) for five academic years (2015-2020). To be included, participants had to be registered as full-time students and provide informed consent, or assent and parent/guardian consent if under 18 years of age. Ethical approval for the study was granted by the Conjoint Health Research Ethics Board (Ethics ID: REB14-0897).

3.3.2 Procedures
At the beginning of each academic school year (August/September), height (m) and weight (kg) were measured, and participants completed a baseline questionnaire containing items relating to age, sex, years of previous training, as well as general medical and injury history.

3.3.3 Injury surveillance
The Research Electronic Data Capture tool (REDCap, Version 6.12.0; Vanderbilt University, Nashville, TN) was utilized to e-mail participants a weekly online questionnaire. Approximately 40 weeks were represented in each year except for year 5 in which 27 weeks were recorded due to the onset of the global Covid-19 pandemic. The weekly online questionnaire was the Oslo Sport Trauma Research Centre Questionnaire on Health Problems (OSTRC-Q) that had been modified for dance and used in previously published research (Appendix A). The OSTRC-Q consists of four key questions about the consequences of
health problems on participation, training volume, and performance along with symptoms/complaints experienced in the previous week. Participants were required to complete all questions prior to submission. Reminder emails were sent to non-responders every two days, up to three occasions. If participants reported an injury in one of the key questions, they were prompted to answer further questions pertaining to the injury. Participants sustaining multiple injuries in one week were instructed to reflect on their worst injury first and then the rest in decreasing severity for up to four injuries.

### 3.3.4 Injury definitions

Three definitions for injury were utilized as part of the weekly injury surveillance:

1. **All-complaints injury**: any physical complaint leading to difficulties participating in normal dance class, rehearsal, or performance, irrespective of the need for medical attention or time lost from dance activities.\(^ {49, 93} \)

2. **Medical-attention injury**: an anatomic tissue-level impairment that resulted in a dancer seeking care from a medical practitioner.\(^ {49, 93} \)

3. **Time-loss injury**: an anatomic tissue-level impairment that resulted in a dancer not able to complete a class, rehearsal, or performance or a subsequent class, rehearsal, or performance 1 or more days beyond the day of onset.\(^ {49, 93} \)

### 3.3.5 Injury severity

The severity of injury was categorized by the number of days lost from class, rehearsal, or performance due to the reported injury. Additionally, weekly injury severity scores were calculated for each participant based on their responses to the four key OSTRC-Q questions.
Following Clarsen et al (2014), scores were summed to estimate an overall severity between 0 (no problem) and 100 (cannot participate). 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.33

3.3.6 Dance exposure

Dance exposure was operationalized as, ‘any participation in class, rehearsal, or performance in which the dancer was exposed to the possibility of a dance injury’.93 The self-reported number of hours of dance exposure were collected online via questionnaire following the Dance OSTRC-Q.

3.3.7 Statistical analysis

All statistical procedures were performed using Stata Version 15.1 (StataCorp LLC, College Station, TX). Participant characteristics were summarized with means and standard deviations, medians and ranges, or frequencies and proportions. For each injury definition, injury prevalence, injury rates, and severity were examined. Any weeks missing from the Dance OSTRC-Q and dance-exposure questionnaire were excluded from analysis. Seasonal injury prevalence (proportions) was estimated by dividing the number of participants reporting at least one injury by the total number of participants at risk. Weekly injury prevalence (proportions) was estimated as the number of participants reporting an injury that week over the total number of participants who responded to the questionnaire that week. Injury rates (95% CI) were estimated as the number of new injuries per 1000 hours of dance exposure.
3.4 Results

A total of 452 female (n=399) and male (n=53) dancers (median age, 15 years; range, 11-20 years) participated across the five academic years (Year 1: n=85; Year 2: n=104; Year 3: n=78; Year 4: n= 102; Year 5: n=83) representing 965 dancer seasons. Participant characteristics and frequency are presented in Tables 3.1 and 3.2. In total, 17529 questionnaires were sent to participants and 15773 were completed, resulting in a response rate of 91.4% over the five years. Across the five years, 67.5% (305/452) participants reported at least one all-complaint injury, with 69.1% (276/399) of females and 54.7% (29/53) of males reporting an injury.

Table 3.1. Descriptive characteristics of participants by year.

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>85</td>
<td>104</td>
<td>78</td>
<td>102</td>
<td>83</td>
<td>452</td>
</tr>
<tr>
<td>Age, years*</td>
<td>14.9 (11-19)</td>
<td>15.1 (11-19)</td>
<td>15.1 (11-21)</td>
<td>14.9 (1-20)</td>
<td>14.8 (11-21)</td>
<td>15 (11-20)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>77 (90.5)</td>
<td>91 (87.5)</td>
<td>65 (83.3)</td>
<td>93 (91.2)</td>
<td>73 (87.9)</td>
<td>399 (88.3)</td>
</tr>
<tr>
<td>Male</td>
<td>8 (9.4)</td>
<td>13 (12.5)</td>
<td>13 (16.7)</td>
<td>9 (8.8)</td>
<td>10 (12.1)</td>
<td>53 (11.7)</td>
</tr>
<tr>
<td>Previous training ≥ 3 times per week, years*</td>
<td>8 (1-14)</td>
<td>8 (2-15)</td>
<td>8 (2-17)</td>
<td>8 (1.5-17)</td>
<td>7 (2-14)</td>
<td>8 (2-15)</td>
</tr>
<tr>
<td>Previous injury in last year, % ‡</td>
<td>49.4 (38.4, 60.5)</td>
<td>45.2 (34.5, 55.3)</td>
<td>50.0 (38.5, 61.5)</td>
<td>44.1 (34.3, 54.3)</td>
<td>36.6 (26.2, 47.9)</td>
<td>45.1 (40.4, 49.7)</td>
</tr>
</tbody>
</table>

*Values are median (range)
† Values are proportion (exact 95% confidence interval)
‡ Previous injury was operationally defined as any dance-related physical complaint that required medical attention and/or time-loss (i.e., caused the dancer to miss more than one day of class, rehearsal or performance) in the previous one-year49,93

Table 3.2. Frequency of participants across five academic years.
<table>
<thead>
<tr>
<th>Number of years participated</th>
<th>Number of participants</th>
<th>Dancer-seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>164</td>
<td>164</td>
</tr>
<tr>
<td>2</td>
<td>131</td>
<td>262</td>
</tr>
<tr>
<td>3</td>
<td>99</td>
<td>297</td>
</tr>
<tr>
<td>4</td>
<td>48</td>
<td>192</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>452</strong></td>
<td><strong>965</strong></td>
</tr>
</tbody>
</table>

### 3.4.1 Injury prevalence and injury rates

Depending on the definition of injury, seasonal injury prevalence ranged from 32.1% (145/452; time-loss) to 67.4% (305/452; all complaints) across the five years. A total of 791 new unique injuries were reported by 305 participants. A total of 279 injuries were categorized as substantial, with 35.6% (161/452) of participants reporting a substantial injury that resulted in a moderate to severe reduction of their ability to train, perform or participate in dance. Seasonal injury rates ranged from 0.76 (95% CI: 0.66, 0.86; time-loss) to 2.54 (95% CI: 2.37, 2.73; all-complaints) per 1000 dance-hours. Detailed descriptive characteristics of injury prevalence and injury rates are presented in Table 3.3.
Table 3.3. Injury prevalence (proportions), dance exposure, and injury rates (95% confidence interval) of all-complaints, medical attention, time-loss, and substantial injuries for Years 1-5.

<table>
<thead>
<tr>
<th>Year</th>
<th>Participants (n)</th>
<th>New injuries (n)</th>
<th>Injured dancers (n)</th>
<th>Proportion (%)</th>
<th>Exposure (hrs)</th>
<th>Injury rate (per 1000 dance hours)</th>
<th>95% CI</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 1</td>
<td>85</td>
<td>167</td>
<td>68</td>
<td>80.0</td>
<td>6490.98</td>
<td>2.57</td>
<td>2.19 - 2.99</td>
</tr>
<tr>
<td>All complaints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical attention</td>
<td>67</td>
<td>37</td>
<td>43.5</td>
<td>1.03</td>
<td></td>
<td>0.80 – 1.31</td>
<td></td>
</tr>
<tr>
<td>Time-loss</td>
<td>42</td>
<td>27</td>
<td>31.7</td>
<td>0.65</td>
<td></td>
<td>0.46 – 0.87</td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>48</td>
<td>34</td>
<td>40.0</td>
<td>0.75</td>
<td></td>
<td>0.55 – 0.98</td>
<td></td>
</tr>
<tr>
<td>Year 2</td>
<td>104</td>
<td>198</td>
<td>73</td>
<td>70.2</td>
<td>76331.26</td>
<td>2.59</td>
<td>2.24 – 2.98</td>
</tr>
<tr>
<td>All complaints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical attention</td>
<td>91</td>
<td>44</td>
<td>42.3</td>
<td>1.19</td>
<td></td>
<td>0.96 – 1.46</td>
<td></td>
</tr>
<tr>
<td>Time-loss</td>
<td>62</td>
<td>37</td>
<td>35.5</td>
<td>0.81</td>
<td></td>
<td>0.62 – 1.04</td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>70</td>
<td>38</td>
<td>36.5</td>
<td>0.92</td>
<td></td>
<td>0.71 – 1.16</td>
<td></td>
</tr>
<tr>
<td>Year 3</td>
<td>78</td>
<td>138</td>
<td>55</td>
<td>70.5</td>
<td>53466.49</td>
<td>2.58</td>
<td>2.17 – 3.05</td>
</tr>
<tr>
<td>All complaints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical attention</td>
<td>77</td>
<td>39</td>
<td>50.0</td>
<td>1.44</td>
<td></td>
<td>1.13 – 1.79</td>
<td></td>
</tr>
<tr>
<td>Time-loss</td>
<td>43</td>
<td>30</td>
<td>38.5</td>
<td>0.80</td>
<td></td>
<td>0.58 – 1.08</td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>46</td>
<td>34</td>
<td>43.5</td>
<td>0.86</td>
<td></td>
<td>0.63 – 1.15</td>
<td></td>
</tr>
<tr>
<td>Year 4</td>
<td>102</td>
<td>201</td>
<td>68</td>
<td>66.6</td>
<td>68464.84</td>
<td>2.94</td>
<td>2.54 – 3.37</td>
</tr>
<tr>
<td>All complaints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical attention</td>
<td>78</td>
<td>39</td>
<td>38.2</td>
<td>1.14</td>
<td></td>
<td>0.90 – 1.42</td>
<td></td>
</tr>
<tr>
<td>Time-loss</td>
<td>65</td>
<td>36</td>
<td>35.2</td>
<td>0.95</td>
<td></td>
<td>0.73 – 1.21</td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>77</td>
<td>36</td>
<td>35.2</td>
<td>1.12</td>
<td></td>
<td>0.88 – 1.41</td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>83</td>
<td>87</td>
<td>41</td>
<td>49.3</td>
<td>47372.85</td>
<td>1.83</td>
<td>1.47 – 2.27</td>
</tr>
<tr>
<td>All complaints</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Medical attention</td>
<td>35</td>
<td>21</td>
<td>25.3</td>
<td>0.74</td>
<td></td>
<td>0.52 – 1.03</td>
<td></td>
</tr>
<tr>
<td>Time-loss</td>
<td>24</td>
<td>15</td>
<td>17.9</td>
<td>0.51</td>
<td></td>
<td>0.32 – 0.75</td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>38</td>
<td>19</td>
<td>22.6</td>
<td>0.80</td>
<td></td>
<td>0.56 – 1.10</td>
<td></td>
</tr>
<tr>
<td>All years</td>
<td>452</td>
<td>791</td>
<td>305</td>
<td>67.4</td>
<td>310537.42</td>
<td>2.54</td>
<td>2.37 – 2.73</td>
</tr>
<tr>
<td>All complaints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical attention</td>
<td>348</td>
<td>180</td>
<td>39.8</td>
<td>1.12</td>
<td></td>
<td>1.01 – 1.24</td>
<td></td>
</tr>
<tr>
<td>Time-loss</td>
<td>236</td>
<td>145</td>
<td>32.1</td>
<td>0.76</td>
<td></td>
<td>0.66 – 0.86</td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>279</td>
<td>161</td>
<td>35.6</td>
<td>0.89</td>
<td></td>
<td>0.79 – 1.01</td>
<td></td>
</tr>
</tbody>
</table>
3.4.2 Weekly prevalence

The distribution of weekly prevalence of self-reported all-complaint injuries across all five academic years is illustrated in Figure 3.1. A similar pattern of peaks and troughs occurs across all years, with peaks corresponding with performances and troughs representing school holidays. The mean OSTRC-Q severity score for all unique injuries was 32.3 (SD=20.0) and for substantial injuries was 51.8 (SD=18.7). The mean days missed for all self-reported unique injuries was 0.79 (SD=1.88) days and for time-loss injuries was 3.01 (SD=2.37) days. For all dancers, most injuries occurred in the ankle (26.9%), hip & groin (14.8%) and knee (14.3%) (Table 3.4). For male dancers, the knee was the most common site of injury (27.5%), followed by the lower leg (17.5%) and lumbar spine (17.0%). In female dancers, the ankle was the most injured site (27.7%), followed by the hip/groin (15.5%) and the foot/toes (14.1%).
Figure 3.1. Weekly prevalence of self-reported all-complaints injuries over each academic year. Participants trained 40 weeks in Year 1 (dark blue), 41 weeks in Year 2 (orange), 40 weeks in Year 3 (red), 41 weeks in Year 4 (light blue), and 27 weeks in Year 5 (green).
Table 3.4. Mean severity score, days missed, and location of all self-reported unique injuries for Years 1-5.

<table>
<thead>
<tr>
<th></th>
<th>Severity score (SD)</th>
<th>Mean days missed (all injuries) (SD)</th>
<th>Mean days missed (time-loss) (days, SD)</th>
<th>Location (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>19.7 (22.5)</td>
<td>0.49 (1.5)</td>
<td>0.89 (1.9)</td>
<td>Ankle (30.7%), Knee (21.1%), Lower leg (13.5%)</td>
</tr>
<tr>
<td>Year 2</td>
<td>17.2 (22.5)</td>
<td>0.44 (1.4)</td>
<td>0.76 (1.4)</td>
<td>Ankle (29.7%), Hip/groin (20.7%), Lower leg (12.3%)</td>
</tr>
<tr>
<td>Year 3</td>
<td>20.2 (22.7)</td>
<td>0.51 (1.6)</td>
<td>1.01 (1.9)</td>
<td>Ankle (32.6%), Foot/toes (19.6%), Hip/groin (13.8%)</td>
</tr>
<tr>
<td>Year 4</td>
<td>19.2 (22.9)</td>
<td>0.49 (1.5)</td>
<td>0.87 (1.9)</td>
<td>Foot/toes (17.8%), Ankle (16.4%), Hip/Groin (15.8%)</td>
</tr>
<tr>
<td>Year 5</td>
<td>22.8 (22.6)</td>
<td>0.57 (1.6)</td>
<td>1.27 (2.1)</td>
<td>Foot/toes (20.6%), Ankle (19.6%), Hip/Groin (12.8%)</td>
</tr>
<tr>
<td>All years</td>
<td>19.8 (20.0)</td>
<td>0.79 (1.9)</td>
<td>3.01 (2.4)</td>
<td>Ankle (26.9%), Hip &amp; groin (14.8%), Knee (14.3%)</td>
</tr>
</tbody>
</table>

3.5 Discussion

The purpose of this study was to establish the extent (prevalence, injury rate) and characteristics (severity, location) of injuries in pre-professional adolescent ballet dancers across five academic training years. Results indicate variability in self-reported injury prevalence and injury rates among pre-professional ballet dancers is dependent on the injury definition utilized. When an all-complaints definition of injury was employed, injury prevalence was highest at 67.4% and an injury rate of 2.54/1000 dance hours (95% CI: 2.37 – 2.73). Injury prevalence based on a time-loss definition was lowest with 32.1% of participants reporting at least one injury and an injury rate of 0.76/1000 dance-hours (95% CI: 0.66 – 0.86). This study adds to the evidence that the
utilization of one injury definition in prospective cohort study designs may underestimate the true burden of injury if a medical attention or time-loss definition of injury are used.\textsuperscript{81}

The finding that injury rates are highest using an all-complaints definition, followed by medical attention and time-loss, respectively is consistent with previous research, as some dancers are averse to reporting or seeking help when they are injured, despite their participation in a physically demanding activity.\textsuperscript{2,146} In many adolescent team sports, most athletic injuries result in less than one game missed and therefore no time-loss.\textsuperscript{67} Similarly, in dance, participants experience overuse injuries that they most often continue to dance through by modifying movement or utilizing taping or wrapping techniques, resulting in no time-loss.\textsuperscript{26} This result supports the recommendation that an injury surveillance program encompassing multiple definitions of injury may better capture the true burden of injury.\textsuperscript{81}

The injury prevalence of 67.4\% from this five-year study is comparable to injury prevalence from one-year studies. For example, a systematic review indicated that injury prevalence ranges from 37\% to 85\% in pre-professional ballet and contemporary dancers across the training season or academic year.\textsuperscript{82} The injury rate from this 5-year study also compares with previously published injury rates in similar populations as previously reported to be between 0.77-4.7 injuries per 1000 dance-hours.\textsuperscript{82} The most common injury locations in this study were the ankle (26.7\%), hip & groin (14.8\%), and knee (14.3\%) for all dancers. These results are also in line with previous studies examining pre-professional populations.\textsuperscript{42,55,90} When collated across all five years, injury severity was comparable to severity scores from other pre-professional contemporary dancers as well.\textsuperscript{145}
3.5.1 Strengths and Limitations

The strengths of this study include the use of multiple definitions of injury to describe injury patterns in a 5-year prospective injury surveillance system with a high response rate (91.4%). The high response rate minimizes the likelihood of selection bias that often can impact internal validity of a study. It is recognized that the retrospective nature of data collection via questionnaire may be susceptible to recall bias. Specifically, students were given the opportunity to complete up to four of their previously missed weekly questionnaires in one sitting, enabling them to reflect on injuries and hours of dancing for up to four weeks prior. It is assumed that potential recall bias was minimal however, as the majority of participants kept up weekly questionnaires, reflecting on the previous seven days of training.

The main limitation of this study is the self-report nature of the questionnaire used. Because data was self-reported, medical diagnoses of reported injuries were not collected. Given the young age and lack of medical knowledge, it is possible that injury definitions could have been misinterpreted by some participants. However, this was mitigated at the start of the study by providing a detailed explanation of injury to each student. Dance exposure hours were also self-reported and there were no questions included in the questionnaire surrounding the intensity of dance training.

3.5.2 Future directions

Findings from this study indicate that injury prevalence, injury rate, and location remain consistent across five years of training. This contributes to the growing body of research that
demonstrates pre-professional ballet dancers are at high risk for injury. Following van Mechelen’s injury prevention model, future research should consider the potential modifiable and nonmodifiable risk factors for these injuries to inform future injury prevention strategies. In this population, weekly prevalence across the academic year follows a similar pattern with peaks occurring near performance time and lower prevalence surrounding holidays, suggesting a need to incorporate load management or periodization as part of these prevention programs. Fluctuations in training load have been found to be associated with high rates of injury in athletic populations. Training load monitoring, including measurement of training volume and intensity, is an effective strategy for prevention of sport-related injury. Increased dance hours, along with a history of injury, are also associated with greater odds of future injuries in this population. Future research should include measurement of the intensity of dance training as a means for primary prevention of dance-related injury.

### 3.6 Conclusions

The prevalence, injury rate, and severity of injuries of pre-professional ballet dancers depends on definition of injury used during injury surveillance. The use of an all-complaints injury definition illustrates the highest burden of injury for this dance context and culture. Injury prevalence and rates remained consistent across five years of study utilizing a comprehensive injury surveillance system. Dancers are at high risk for injury and future research into the modifiable and nonmodifiable risk factors for these injuries is needed.
3.7 Bridge to Chapter Four

The purpose of Chapter three was to establish the extent (prevalence, injury rate) and characteristics (severity, location) of injuries in pre-professional adolescent ballet dancers across five academic training years. When an all-complaints definition of injury was employed, injury prevalence was highest at 67.4% and an injury rate of 2.54/1000 dance hours (95% CI: 2.37 – 2.73). Injury prevalence, rate, severity, and location remained consistent across five years of study.

Findings from Chapter three are consistent with previous literature, adding to the evidence for high risk of dance-related injury in pre-professional ballet dancers. Along with injury prevalence and rate, prospective injury surveillance programs are often used to identify potential risk factors. Systematic and epidemiological reviews have attempted to summarize risk factors for dance-related injury with little success. Investigation of risk factors for dance-related injury has been difficult due to different injury surveillance methodologies, including inconsistent injury and exposure definitions, and risk factor measurement during pre-season screening. In addition, studies examining risk factors for dance-related injury have been limited to one training year or season. Finally, more appropriate biostatistical measures may be needed to investigate the relationship between potential risk factors and dance-related injury. Current traditional modeling techniques assume that repeated outcomes (e.g. multiple dance-related injuries throughout a training season) are independent, not taking into account the complex and interconnected nature of dance-related injury. Therefore, the aim of the following Chapter four, was to examine modifiable and non-modifiable risk factors for dance-related injury in adolescent female and male pre-professional ballet dancers across five years.
Chapter Four. Risk Factors for Dance-Related Injury in Pre-Professional Ballet Dancers

4.1 Abstract

Introduction: Pre-professional ballet dancers are at high risk for injury. Few dance epidemiology studies have utilized evidence-based pre-season screening measures, prospective injury surveillance, and biostatistical modelling to investigate potential risk factors for injury across multiple years. The aim of this study was to examine modifiable and non-modifiable risk factors for dance-related injury in adolescent female and male pre-professional ballet dancers across five years.

Methods: 452 pre-professional ballet dancers (399 female, 53 male; median age 15 years; range 11-20 years) participated across five academic years at a vocational ballet school. Participants completed baseline screening, and online weekly injury questionnaires (OSTRC-Q) including dance exposures (hours/week). Zero-inflated Poisson regression models were used to examine associations between potential risk factors measured at baseline and self-reported dance-related injury.

Results: In count model coefficients, left one leg standing score [log coefficient estimate: -0.249 (95%CI: -0.478, -0.02); p=0.033] and right unipedal dynamic balance time [log coefficient estimate: -0.0294 (95%CI: -0.048, -0.01); p>0.001] carried a protective effect with increased years of training. A significant association was also found for left unipedal dynamic balance time and dance-related injury [log coefficient estimate: 0.013 (95%CI: 0.000, 0.026); p=0.045]. No significant association was estimated for ankle and hip range of motion, active straight leg raise, or Y-balance test measures and dance-related injury.

Conclusion: When adjusted for psychological coping skills and years of previous dance training, findings from this study show a significant association between limb specific lumbopelvic
control and dynamic balance tasks with self-reported dance-related injury among female and male pre-professional ballet dancers.
4.2 Introduction

At a young age, pre-professional ballet dancers enter a highly demanding environment with a high risk for injury. Training at the pre-professional level is characterized by an increase in volume and intensity of training, progressing from more recreational participation levels. During the pursuit at this elite level, there is also an increase in physical and mental demands on the dancer, which can subsequently, put them at increased risk for injury. Pre-season screening assessments are routinely performed in pre-professional dance programs with the aim of understanding dancers’ risk of dance-related injuries before full-time training begins. Prospective injury surveillance programs are often used to investigate the prevalence, incidence, and potential risk factors for dance-related injury.

To date, Level 2 evidence suggests that insufficient coping skills, low body mass index, increased training hours, and history of previous injury are significantly associated with increased risk of dance-related injury. Additionally, the association between common pre-season screening measures (e.g., ankle and hip range of motion, lumbopelvic control, and dynamic balance), and dance-related injury have been investigated. However, results from these studies have been inconclusive (i.e., equal reports of significant and non-significant associations).

Many reviews have attempted to summarize risk factors for dance-related injury with little success. Investigation of risk factors for dance injury has been difficult due to different injury surveillance methodologies, inconsistent definitions of dance injury and dance exposure, and varying risk factor measurements taken during pre-season screening. Studies examining risk...
factors for dance-related injury have also been limited to one training year or season.\textsuperscript{42, 78, 145} Lastly, current biostatistical analyses employed in these studies assume that repeated outcomes (e.g., multiple dance-related injuries throughout a training season) are independent, and as such do not consider the complex, dynamic and interconnected nature of dance-related injury.\textsuperscript{18, 121} Thus, it has been suggested that more appropriate and comprehensive biostatistical modeling techniques are needed to better investigate the relationship between potential risk factors and dance-related injury. Therefore, the aim of this study was to examine modifiable and non-modifiable risk factors for dance-related injury in adolescent female and male pre-professional ballet dancers across five years.

**4.3 Methods**

**4.3.1 Study design and participants**

This study followed the STROBE guidelines for reporting prospective cohort designs.\textsuperscript{8} Participants included a convenience sample of pre-professional adolescent ballet dancers from a vocational dance school in Calgary, Canada. Recruitment occurred at the beginning of each school term (September) for five academic years (2015-2020). To be included, participants had to be registered as full-time students and provide informed consent, or assent and parent/guardian consent if under 18 years of age. Ethical approval for the study was granted by the Conjoint Health Research Ethics Board at the University of Calgary, Calgary, Canada (Ethics ID: REB14-0897).
4.3.2 Pre-season screening

Participants completed a baseline questionnaire containing items relating to age, sex, years of previous training, as well as general medical and injury history. Participants also completed an Athletic Coping Skills Inventory (ACSI-28) modified for dance. Following the completion of forms a series of physical assessments that demonstrate the highest level of evidence for measuring previously identified risk factors for dance-related injury in pre-professional ballet dancers were conducted (Table 4.1) (Appendix B). The typical time to complete pre-season screening for each dancer was 60-75 minutes. All raters were familiarized with testing procedures during a 3hr training session, one week prior to data collection. Between day reliability of all testing procedures were established prior to data collection.

Table 4.1. Components of Pre-Season Screening Program.

<table>
<thead>
<tr>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion Range of Motion (degrees)</td>
</tr>
<tr>
<td>Ankle Plantarflexion Range of Motion (degrees)</td>
</tr>
<tr>
<td>Active Hip External Rotation (degrees)</td>
</tr>
<tr>
<td>Active Straight Leg Raise (ASLR; with/without restriction)</td>
</tr>
<tr>
<td>One Leg Standing (OLS; negative/positive score)</td>
</tr>
<tr>
<td>Unipedal Dynamic Balance (UPDB; seconds)</td>
</tr>
<tr>
<td>Y-Balance Test (YBT; normalized composite reach (cm))</td>
</tr>
</tbody>
</table>

4.3.3 Injury surveillance

The Research Electronic Data Capture tool (REDCap, Version 6.12.0; Vanderbilt University, Nashville, TN) was utilized to e-mail participants a weekly online questionnaire: the Oslo Sports Trauma Research Centre Questionnaire on Health Problems (OSTRC-Q), which has been modified for dance and used in previously published research. The OSTRC-Q consists of four key questions about the consequences of health problems on dancers’ participation, training
volume, and performance along with other symptoms or complaints experienced in the previous one week. Participants were required to complete all questions prior to submission. Reminder emails were sent to non-responders every two days, for up to three occasions. If participants reported an injury in one of the key questions, they were prompted to answer further questions providing more detail about the injury. Participants sustaining multiple injuries in one week were instructed to reflect on their worst injury first and then the rest in decreasing severity for up to four injuries. Self-reported number of hours of dance exposure (i.e., time spent in class, rehearsal, and performance) were collected online via questions following the OSTRC-Q.

4.3.4 Outcome

The outcome of interest was the total number of weekly new self-reported dance injuries. An inclusive operational definition of injury was utilized: “any physical complaint leading to difficulties participating in normal dance class, rehearsal, or performance, irrespective of the need for medical attention or time lost from dance activities.”

4.3.5 Statistical analysis

All statistical analyses were performed in R using the lme4 package. Descriptive characteristics were calculated as means (standard deviation), medians (interquartile range (IQR)), or proportions (95%CI). A forward selection technique was used to build zero-inflated Poisson regression models. Following evidence from previous literature, BMI, ACSI score, and years of previous training were entered as predictors. Then potential risk factors (measures from Table 4.1) were entered into the regression models with new self-reported injuries as the outcome, adjusted for ACSI score and years training, with offset log hours of dance exposure. In
total, there were seven models (each containing ACSI and years training, offset by dance exposure hours), one for each pre-season screening assessment pairing bilaterally, including ankle dorsiflexion, ankle plantar flexion, active standing hip turnout, active straight leg raise, one leg standing, unipedal dynamic balance, and Y-balance test composite score. Zero-inflated model coefficients (binomial, logit linked) were calculated for each pre-season screening assessment. The significance level was set at $\alpha=0.05$.

4.4 Results

A total of 452 adolescent pre-professional ballet dancers (399 female, 53 male; median age 15 years, range 11-20 years) participated across the five academic years (Year 1: n=85; Year 2: n=104; Year 3: n=78; Year 4: n=102; Year 5: n=83) representing a total of 1,083 dancer-seasons. Participant characteristics are presented in Table 4.2. In total, 17,529 questionnaires were sent to participants and 15,773 were completed, resulting in a response rate of 91.4%. Across the five years, 67.5% (305/452) participants reported at least one all-complaint injury, with 69.1% (276/399) of females and 54.7% (29/53) of males reporting an injury. A total of 3,225 unique injuries were reported.
Table 4.2. Descriptive characteristics of participants by year. Values are mean (SD) unless otherwise indicated.

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{N} )</td>
<td>85</td>
<td>104</td>
<td>78</td>
<td>102</td>
<td>83</td>
<td>452</td>
</tr>
<tr>
<td>( \text{Age, years*} )</td>
<td>14.9 (11-19)</td>
<td>15.1 (11-19)</td>
<td>15.1 (11-21)</td>
<td>14.9 (11-20)</td>
<td>14.8 (11-21)</td>
<td>15 (11-20)</td>
</tr>
<tr>
<td>( \text{Sex, n (%)} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>77 (90.5)</td>
<td>91 (87.5)</td>
<td>65 (83.3)</td>
<td>93 (91.2)</td>
<td>73 (87.9)</td>
<td>399 (88.3)</td>
</tr>
<tr>
<td>Male</td>
<td>8 (9.4)</td>
<td>13 (12.5)</td>
<td>13 (16.7)</td>
<td>9 (8.8)</td>
<td>10 (12.1)</td>
<td>53 (11.7)</td>
</tr>
<tr>
<td>( \text{Body Mass Index (BMI; kg/m}^2 )</td>
<td>18.7 (2.3)</td>
<td>19.7 (2.1)</td>
<td>19.0 (2.3)</td>
<td>19.1 (2.2)</td>
<td>18.5 (1.9)</td>
<td>19.0 (3.5)</td>
</tr>
<tr>
<td>( \text{Previous training} \geq 3 \text{ times per week, years*} )</td>
<td>8 (1-14)</td>
<td>8 (2-15)</td>
<td>8 (2-17)</td>
<td>8 (1.5-17)</td>
<td>7 (2-14)</td>
<td>8 (2-15)</td>
</tr>
<tr>
<td>( \text{Previous injury in last year, %}^{\dagger \ddagger} )</td>
<td>49.4 (38.4, 60.5)</td>
<td>45.2 (34.5, 55.3)</td>
<td>50.0 (38.5, 61.5)</td>
<td>44.1 (34.3, 54.3)</td>
<td>36.6 (26.2, 47.9)</td>
<td>45.1 (40.4, 49.7)</td>
</tr>
<tr>
<td>( \text{Athletic Coping Skills Inventory (ACSI) score*} )</td>
<td>54 (49-63)</td>
<td>47 (42-54)</td>
<td>50 (44-57)</td>
<td>49 (43-56)</td>
<td>50 (42-58)</td>
<td>50 (43-57)</td>
</tr>
</tbody>
</table>

*Values are median (IQR)

\( \dagger \) Values are proportion (exact 95% confidence interval)

\( \ddagger \) Previous injury was operationally defined as any dance-related physical complaint that required medical attention and/or time loss (i.e., caused the dancer to miss more than one day of class, rehearsal, or performance) in the previous one-year.

For risk factor analyses, three participants were removed due to incomplete and missing data. All models were statistically significant for both intercept and individual, indicating that a zero-inflated Poisson regression modelling technique was appropriate for each model in question. ACSI score and years training were found to contribute to all models indicating an association with dance-related injury. BMI did not contribute to any of the models and was removed from analyses. In count model coefficients, left one leg standing score [log coefficient estimate: -0.249 (95%CI: -0.478, -0.02); \( p=0.033 \)] and right unipedal dynamic balance time [log coefficient estimate: -0.0294 (95%CI: -0.048, -0.01); \( p>0.001 \)] carried a protective effect for self-reported
dance-related injury with increased years of training (Table 4.3). A significant association was also found for left unipedal dynamic balance time and self-reported dance-related injury [log coefficient estimate: 0.013 (95% CI: 0.000, 0.026); p=0.045] (Table 3).

Table 4.3. Log coefficients, 95% Confidence Intervals, standard error, and p-value for years of previous dance training for each of the seven models including pre-season screening measures.

| Side                        | Coefficient | 95% CI          | SE  | Pr(>|z|) |
|-----------------------------|-------------|-----------------|-----|---------|
| Ankle Dorsiflexion          |             |                 |     |         |
| Left                        | 0.013       | (-0.037, 0.010) | 0.01| 0.267   |
| Right                       | 0.005       | (-0.019, 0.029) | 0.01| 0.674   |
| Ankle Plantar Flexion       |             |                 |     |         |
| Left                        | -0.026      | (-0.053, 0.000) | 0.01| 0.058   |
| Right                       | 0.016       | (-0.009, 0.042) | 0.01| 0.217   |
| Active Standing Turnout     |             |                 |     |         |
|                            | 0.003       | (-0.002, 0.008) | <0.01| 0.317  |
| Active Straight Leg Raise   |             |                 |     |         |
| Left                        | -0.039      | (-0.179, 0.101) | 0.07| 0.585   |
| Right                       | 0.042       | (-0.107, 0.191) | 0.08| 0.578   |
| One Leg Standing            |             |                 |     |         |
| Left                        | -0.249      | (-0.478, -0.021)| 0.12| 0.033*  |
| Right                       | -0.041      | (-0.231, -0.021)| 0.10| 0.677   |
| Unipedal Dynamic Balance    |             |                 |     |         |
| Left                        | 0.013       | (0.000, 0.026)  | <0.01| 0.045*  |
| Right                       | -0.029      | (-0.048, -0.011)| <0.01| <0.001*|
| Y-Balance Test              |             |                 |     |         |
| Left                        | 1.123e-02   | (-0.011, 0.000) | <0.01| 0.312   |
| Right                       | -1.550e-02  | (-0.037, 0.000) | <0.01| 0.150   |

*Indicates a significant finding

Statistical output suggests that for every positive score (hip ‘hiking’ or lifting) achieved during the one leg standing test on the left side, the estimated number of future injuries significantly decreases by a factor of \( e^{-0.249} \) or 0.78. During the timed dynamic balance assessment, when standing on the right side, for every one second increase in balance time, the estimated number of future injuries significantly decreased by a factor of \( e^{-0.029} \) or 0.97. And when standing on the left, for every one second increase in balance time, the estimated injury count significantly increased by a factor of \( e^{0.013} \) or 1.01.
When measures of ankle dorsiflexion, active standing hip turnout, active straight leg raise, Y-balance composite score were considered in the statistical models, no statistical significance with dance-related injury was found, though years training demonstrated a potentially minor protective effect [ankle dorsiflexion: log coefficient estimate, -0.023 (95%CI: -0.047, 0.001; p=0.063); active standing turnout: log coefficient estimate, 0.026 (95%CI: -0.046, 0.002; p=0.072); active straight leg raise: log coefficient estimate, -0.021 (95% CI -0.046, 0.003; p=0.087); Y-balance: log coefficient estimate, 0.024 (95% CI: -0.048, 0.000; p=0.05)] (Table 4.4).

Table 4.4. Log coefficients, 95% Confidence Intervals, standard error, and p-value for years of previous dance training for each of the seven models including pre-season screening measures.

| Model                          | Coefficient | 95% CI       | SE  | Pr(>|z|) |
|-------------------------------|-------------|--------------|-----|---------|
| Ankle Dorsiflexion            | -0.023      | (-0.047, 0.001) | 0.01 | 0.063   |
| Ankle Plantar Flexion         | -0.021      | (-0.045, -0.067) | 0.01 | 0.093   |
| Active Standing Turnout       | -0.022      | (-0.046, 0.002) | 0.01 | 0.073   |
| Active Straight Leg Raise     | -0.021      | (-0.046, 0.003) | 0.01 | 0.087   |
| One Leg Standing              | -0.022      | (-0.046, 0.002) | 0.01 | 0.074   |
| Unipedal Dynamic Balance      | -0.025      | (-0.049, -0.00) | 0.01 | 0.039   |
| Y-Balance Test                | -2.439e-02  | (-0.049, 0.000) | <0.01 | 0.050   |

*Indicates a significant finding

4.5 Discussion

The aim of this study was to examine modifiable and non-modifiable risk factors for dance-related injury in adolescent female and male pre-professional ballet dancers. Following comprehensive biostatistical modelling, results from this study show a significant association between lumbopelvic control and unipedal dynamic balance, with side-to-side differences, and self-reported dance injury, when adjusted for psychological coping skills’ score and years of previous dance training.
Across all significant models, previous training was shown to have a protective effect, indicating that the longer a participant had danced, their risk of dance-related injury decreased. Lee et al. found a similar finding, observing the highest injury rates in the first year of study in pre-professional ballet and contemporary dancers. Similar to youth football players, it is possible that emerging adolescent dancers may have a lower threshold for injury compared to advanced dancers that continue training through injury. It is hypothesized that as dancers progress throughout a program they may be better conditioned to meet the demands of their training.

Participants’ psychological coping skills were found to have a variable influence on dance-related injury. Specifically, in some models, higher ACSI scores, indicative of better psychological coping skills, led to a decreased risk of dance-related injury, while in others, they did not. While the results in this study are inconclusive surrounding psychological coping skills, other previous research has found a significant association with limited coping skills and increased risk of injury in pre-professional contemporary dancers. Additionally, ballet dancers who received coping skills training were found to spend less time injured. Future research should consider changes in athletic coping skills across a training season, and explore the possible moderating effect on self-reported dance-related injury.

For the one leg standing test (left side), it was found that the positive scores led to an estimated 0.78 reduction in the number of future dance-related injury. The finding comes as a surprise, because when a physiotherapist rated the dancer with a positive score during this test, it meant that they were ‘hiking’ (lifting) their gesture hip when transferring weight from two feet to one,
which is indicative of poor lumbopelvic control. However, in all models, years of dance training was shown to also have an influence on the association between potential risk factors and dance-related injury count. In the present study, the modeling techniques used indicate that years of dance training and one leg standing score are co-predictive, and years of dance training is conferring a protective effect upon the one leg standing score. Previous literature has shown that ballet dancers have demonstrated poor lumbopelvic control and develop movement strategies to compensate for that deficit. It is therefore possible that for the dancers in this cohort, as they trained longer, they may have attained a compensatory lumbopelvic movement strategy that is decreasing their risk for injury.

Measures from the timed unipedal dynamic balance test resulted in a significant association between balance time and self-reported dance-related injury. For most dancers, the dominant limb is the right and they have a tendency to initiate movement to the right side. It is common for elite-level dancers to develop a large lateral bias, in which dancers prefer one limb over the other for learning and performing skills. It is also suggested that dance training contributes to laterality, or asymmetry, in dancers, potentially explaining the protective effect seen in the right side.

BMI was not found to contribute to any model, indicating no evidence for an association between BMI and self-reported injury in this population. In the present study, there was limited variability in BMI estimates, consistent with other pre-professional cohorts, potentially explaining the lack of contribution to the model. Previous literature concerning the association between BMI and dance-related injury has been inconclusive, calling its utility during pre-season

53
screening into question. Ballet dancers have listed weight and diet as their chief concerns, or stressors, and have been shown to have significant energy deficits during a typical training day.\textsuperscript{39, 64} As an at-risk group for disordered eating and Relative Energy Deficiency Syndrome (RED-S), measurement of BMI may add more pressure surrounding weight and diet and not be beneficial to the adolescent ballet dancer.\textsuperscript{7}

Many pre-season screening tests were not found to be associated with self-reported dance-related injury in the present study. There are a number of reasons to participate in pre-season screening in addition to identifying dancers who may be at increased risk for injury.\textsuperscript{92} It is common practice to provide one-on-one feedback to individual dancers, sharing valuable information with them about their bodies; establishing baseline data at the start of the training year is helpful for clinical purposes if injuries are sustained throughout the season; and it gives opportunity to cultivate relationships between dancer and healthcare professional, which can aid in the early disclosure of pain or injury.\textsuperscript{83, 92, 118} Future research should consider normative and baseline values of common pre-season screening assessments to inform training and potential utility for injury rehabilitation.

\subsection*{4.5.1 Strengths and Limitations}

Strengths of this study include the use of evidence-informed pre-season screening measures and a 5-year prospective injury surveillance system with a high response rate (91.4\%). The high response rate minimizes the likelihood of selection bias that can impact internal validity of a study. The current study answers the call for more rigorous analysis in the identification for sport and dance injury.\textsuperscript{18, 93} To our knowledge, this study is among the first in the field of dance...
science to use a zero-inflated Poisson regression. This method allows for the modelling of count data that has an excess of zero counts (non-injured dancers captured weekly) that often occurs in longitudinal injury surveillance. The use of a dichotomous outcome measure of self-reported dance-related injury (yes/no) captures a more complete picture of dance injury burden. It is acknowledged that limiting the outcome of interest to one injury estimate per week does not fully acknowledge the dynamic nature of dance injury.

The main limitation of this study is the self-report nature of the questionnaire used. Because data was self-reported, medical diagnoses of reported injuries were not collected. It is possible that injury definition could have been misinterpreted by some participants (i.e., reporting muscle soreness as an injury) leading to an overestimation of injury occurrence. However, this was mitigated at the start of the study by providing a detailed explanation of injury to each participant. Additionally, lack of medical diagnoses limited the ability to examine risk factors for specific injury types. Another limitation was the small sample size of participants who participated across all five years of data collection (n=10). This limited the ability to examine year-to-year differences in our modeling. Finally, a small male sample size (n=53), didn’t allow for an examination of sex differences in this cohort.

4.6 Conclusions
To our knowledge, this is one of the first studies to utilize evidence-informed pre-season screening assessments, prospective injury surveillance, and rigorous biostatistical modeling to determine risk factors for dance-related injury across multiple years. Years of dance training
demonstrated a protective effect for count of self-reported dance-related injuries. Athletic coping skills had a variable effect upon the relationship between pre-season screening measures and self-reported dance-related injury. Findings from this study show a significant association between one leg standing score and unipedal dynamic balance adjusted for athletic coping skills and years of previous dance training. It is therefore important that dance educators and clinicians consider the interconnected nature of dance injury risk as it relates to the presence of bilateral differences, psychological coping skills among adolescent pre-professional ballet dancers.
4.7 Bridge to Chapter Five

The aim of Chapter four was to examine modifiable and non-modifiable risk factors for dance-related injury in adolescent female and male pre-professional ballet dancers across five years. Findings from this study show a significant association between one leg standing score and unipedal dynamic balance, with side-to-side differences, and adjusted for ACSI score and years of previous dance training.

Side-to-side differences in potential modifiable risk factors for injury indicates the need for a tool to measure performance of each limb separately. Research from Kimmerle indicates that adolescent dancers may demonstrate limb asymmetry when they are healthy and uninjured.84 Dancers demonstrate a strong lateral bias during training and performance leading to functional asymmetry.44, 84 Screening programs often compare left and right parameters in static and dynamic balance skills, range of motion skills, but there is a lack of asymmetry assessment and strength assessment in baseline screening.84 A reliable and valid method for tracking asymmetry and performance of both limbs during training and rehabilitation is needed.
Chapter Five. Test-Retest Reliability of a Dance-Specific Jump Test Using Wearable Technology with University Dance Majors

5.1 Abstract

Introduction: Following lower extremity injury, the contralateral limb is often used as a reference to guide rehabilitation of the injured limb. A limb symmetry index (LSI) is determined by the ratio between the injured and contralateral limb and an LSI >90% has been used to establish effective return-to-sport criterion in athletes. Previous literature has shown that LSIs can be detected using Inertial Measurement Units (IMUs) in both bilateral and single leg jumps. However, these jump testing protocols don’t incorporate the aesthetic and temporal demands of dance. A dance-specific jump test utilizing IMUs may prove more useful for onsite clinicians who are responsible for dancer populations. The reliability of this dance-specific jump testing using IMUs in the detection of LSI is currently unknown.

Purpose: To determine test re-test reliability of a dance-specific jump test using wearable technology to capture limb asymmetry in pre-professional dancers.

Methods: Nineteen female undergraduate dance majors participated in two jump testing sessions one week apart. Height (cm), weight (kg), and lower limb length (cm) were recorded at the initial testing session. Lower limb length was measured from the anterior superior iliac spine to the medial malleolus. Two inertial measurement units (IMUs) (Vicon Motion Systems, UK) were attached to the distal anteromedial aspect of each tibia, and one was attached at the low back at the L5/S1 joint. Participants performed a countermovement jump test (CMJ), a side-to-side hop test (SH), and a dance-specific jump test (DSJ).

Results: Test-retest reliability for the CMJ test was poor, [ICC 0.36 (95% CI -0.08 – 0.77)]. Results for the SH test indicated moderate reliability [ICC 0.66 (95% CI 0.35 – 0.88)] and good
reliability for the DSJ test [ICC 0.82 (95% CI 0.49-0.94)]. Wide 95% LOA was demonstrated for all asymmetry measures for all jumps.

**Discussion:** Test-retest reliability was established for performance measures for countermovement jump, side-hop, and dance-specific jump tests. Lack of agreement was found for asymmetry measures between baseline and follow-up for all jump tests.
5.2 Introduction

It has been suggested that dancers demonstrate a strong lateral bias and findings indicate that the dominant or preferred leg is at higher risk for injury than the non-dominant leg in female pre-professional ballet dancers. Prior research suggests a history of previous injury is significantly associated with increased risk of injury in pre-professional dancers. One of the mechanisms by which previous injury is a risk factor for future injury is by inadequate rehabilitation from the initial injury. Currently, return-to-sport criteria for strength after an injury relies on an limb symmetry index (LSI) greater than 85-90% (or asymmetry <10-15%) being the indicator for return to play.

Recent studies have shown that after injury performance of the uninjured limb decreases, making it an unsuitable reference standard for rehabilitation. A reduction in asymmetry during injury rehabilitation may be due to declined performance of the uninjured limb. Comparison of LSI values across rehabilitation to baseline asymmetry measures may help establish a better rehabilitation criterion for medical professionals who are treating dancers. A reliable and valid method for tracking asymmetry and performance of both limbs during training and rehabilitation is needed.

The current gold standard method for detecting limb asymmetry involves the use of dual force plates. Dual force plates are typically only available in lab settings, and expensive, limiting their use in longitudinal study. Inertial measurement devices (IMUs) or wearable devices are small and unobtrusive, meaning they can be worn in the studio, during technique class, and rehearsal. A validation of two accelerometers in children found that IMUs have the potential to measure
and quantify impact loading of bone and can determine ground reaction force (GRF) applied to the skeleton. Additionally, IMUs have been validated to detect jumping movements and jump height among college volleyball athletes. Accurate and reliable placement of the IMUs is necessary to account for the attenuation of force by the foot and ankle during jumping. IMUs have not been used to determine LSIs in pre-professional dance populations and their reliability is yet to be established.

Dancers regularly perform variations of repeated single-leg jumps. Accelerometers were found to estimate and monitor landing forces in ballet dancers performing continuous jumps until self-determined exhaustion. Maulder and Cronin concluded that repeated unilateral vertical jumps have been found to also detect LSIs just as well as a countermovement jump test. LSIs calculated from the unilateral jump tests were similar to those previously published for healthy adult male subjects with no history of lower extremity injury. A repeated vertical single-leg hop test may be a more appropriate task to determine LSI values in dancers as it mimics the movement that is most often rehearsed and performed in this population. There is currently no dance-specific vertical jump test that encompasses the tempo component required by staying on beat to the music.

A dance specific single-leg hop test, versus a bilateral countermovement jump test, may be a more appropriate task to determine LSI values in dancers as it mimics the movement that is most often rehearsed and performed in this population. There is currently no dance-specific vertical jump test that encompasses the tempo component required by staying on beat to the music. The study will aim to establish a reliable dance-specific jump test to capture limb asymmetry using
wearable technology. It was hypothesized that a dance-specific jump test would be a reliable method to detect lower limb asymmetry in university contemporary dancers.

5.3 Methods

Twenty-two female university contemporary dancers were recruited to participate in two jump testing sessions one week apart. Nineteen dancers completed both testing sessions. Height (cm), weight (kg), and lower limb length (cm) were recorded at the initial testing session. Lower limb length was measured from the anterior superior iliac spine to the medial malleolus. Two inertial measurement units (IMUs) (Vicon Motion Systems, UK) were attached to the distal anteromedial aspect of each tibia, and one was attached at the low back at the L5/S1 joint. IMUs were placed by the same researcher (MC) each day. Participants performed a countermovement jump test (CMJ), a side-to-side hop test (SH), and a dance-specific jump test (DSJ). Dancers wore their typical class attire and were barefoot during testing. This study was approved by the Conjoint Health Research Ethics Board (REB20-1210).

5.2.1 Countermovement jump test (CMJ)

Participants started with feet shoulder-width apart. Participants flexed at the hip, knee, and ankle to lower the body and then jump as high as possible while swinging their arms. The depth of the countermovement was not controlled as the goal of the jump was to maximize vertical height. Participants were given a minimum of one practice trial, followed by three recorded trials with a minimum of 30 seconds rest between each maximal jump to reduce the effects of fatigue. 71
5.2.2 Single-leg side hop test (SH)

Following the protocol of Caffrey et al., participants were instructed to hop on one limb laterally across a 30 cm distance for 10 repetitions. One repetition was counted when the participant hopped 30 cm to the side and back to the starting point without the contralateral limb touching down to the ground. Participants were instructed to complete the repetitions as quickly as possible and the time it took the participant to complete the task was recorded. Participants were given a minimum of one practice trial, followed by two recorded trials on each limb, with a minimum of 30 seconds rest between trials.

5.2.3 Dance-specific jump test (DSJ)

Participants performed 10 repetitions of a ballet specific movement called a temps levé in which the participant performed a small hop on one foot with the other foot raised off the floor. Participants were instructed to perform 10 temp levés on each limb to the beat of a metronome (95 bpm). One repetition was counted when the participant hopped in the air as high as they could while staying on tempo with the metronome (i.e. landing on the beat) and landed without the contralateral limb touching down to the ground. Participants were given a minimum of one practice trial, followed by two recorded trials on each limb, with a minimum of 30 seconds rest between trials.

5.2.4 Data processing

All data processing and analysis steps were conducted using built-in functions and custom MATLAB software (9.6.0.1335978 (R2019a) Update 8, Mathworks, Inc., Natick, MA, USA).
Tibial acceleration data from the IMUs were sampled at 200 Hz and filtered using a fourth order, zero lag Butterworth filter with a cut-off frequency of 15 Hz. The peak impact accelerations were identified for each take-off and landing (g). For CMJ, the peak impact acceleration during landing was identified in the signals. For repeated jumps (SH and DSJ), an algorithm was created to set a minimum distance and prominence between peaks in the acceleration signal to detect negative (take-off) and positive (landing) peaks. Plots of the time series were visually inspected to ensure that the relevant peaks in the acceleration signal were identified and that the number of jumps was correct. For each dancer, the number of impact accelerations identified was consistent with the number of landings expected from each task.

5.2.5 Outcome measures

For peak impact tibial accelerations, the mean impact acceleration across all landings within a signal was calculated. Asymmetry was calculated as the difference between the left and right peak tibial impact accelerations divided by the maximum peak and expressed as a percentage. A positive value indicated a greater left limb peak, a negative value indicated a greater right limb peak, and 0% indicated perfect symmetry. Mean asymmetry was calculated across all trials for each participant. Asymmetry was calculated as \((\text{left limb} – \text{right limb})/(\text{larger value of the 2 sides})\).17

For performance of the SH test, time from first peak to last peak was calculated. Mean time to complete the task was averaged across both trials. For the CMJ and DSJ tests, flight time was calculated as well as jump height. Flight time was calculated as the change in time between take-off and landing for each jump in the signal in seconds. Jump height was calculated using the
formula discussed in Moir et al., where $t_{\text{flight}}$ is flight time and $g$ is the gravitational acceleration.

$$\text{jump height} = g \times \frac{t_{\text{flight}}^2}{8}$$

Flight time and jump height were calculated for each jump in the signal, averaged across all jumps and across both trials.

### 5.2.6 Statistical analysis

All statistical procedures were performed using Stata Version 15.1 (StataCorp LLC, College Station, TX). Participant characteristics were summarized with means (95% CI), medians (IQR), or proportions. Intraclass correlation coefficient (ICC$_{(3,k)}$) were calculated to examine the extent of relative agreement between asymmetry calculations, peak impact tibial acceleration, and performance measures from the IMUs during baseline and follow-up testing sessions. ICC values above 0.90 indicated excellent reliability, between 0.75-0.90 indicated good reliability, between 0.50-0.75 indicated moderate reliability, and below 0.50 indicated poor reliability. Bland Altman methods of agreement and 95% limits of agreement (LOA) were used to estimate absolute reliability between measures from each testing session.

### 5.4 Results

In total, 19 participants completed both testing sessions. Descriptive characteristics of included participants are described in Table 5.1.
Table 5.1. Descriptive characteristics of all included participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N=19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>20.12 (1.58)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.83 (7.67)</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>63.84 (7.07)</td>
</tr>
<tr>
<td>Previous training ≥ 3 times/week (years)</td>
<td>13.05 (7-19)</td>
</tr>
</tbody>
</table>
Table 5.2. Means (95% Confidence Interval) of flight time, jump height, peak tibial impact acceleration, and asymmetry measures for all jump tests.

<table>
<thead>
<tr>
<th></th>
<th>Side</th>
<th>Baseline (95% CI)</th>
<th>Follow-up (95% CI)</th>
<th>ICC (95% CI)</th>
<th>Mean Difference (95% LOA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CMJ</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight time (sec)</td>
<td></td>
<td>0.51 (0.48, 0.53)</td>
<td>0.50 (0.48, 0.53)</td>
<td>0.85 (0.56, 0.95)</td>
<td>0.002 (-0.061, 0.066)</td>
</tr>
<tr>
<td>Jump height (cm)</td>
<td></td>
<td>31.6 (29.2, 34.0)</td>
<td>31.4 (28.1, 34.6)</td>
<td>0.86 (0.60, 0.95)</td>
<td>0.002 (-0.072, 0.077)</td>
</tr>
<tr>
<td>Peak impact acceleration (g)</td>
<td>Left</td>
<td>6.08 (5.71, 6.46)</td>
<td>6.07 (5.75, 6.01)</td>
<td>0.78 (0.33, 0.94)</td>
<td>-0.031 (-2.052, 1.983)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>6.31 (5.94, 6.68)</td>
<td>6.34 (6.01, 6.68)</td>
<td>0.82 (0.41, 0.95)</td>
<td>-0.084 (-1.655, 1.496)</td>
</tr>
<tr>
<td>Asymmetry (%)</td>
<td></td>
<td>-3.35 (-8.13, 1.42)</td>
<td>-3.99 (-8.43, 0.44)</td>
<td>0.36 (-0.08, 0.77)</td>
<td>1.165 (-29.601, 31.221)</td>
</tr>
<tr>
<td><strong>SH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (sec)</td>
<td>Left</td>
<td>10.12 (9.49, 10.75)</td>
<td>9.39 (8.74, 10.04)</td>
<td>0.75 (0.14, 0.92)</td>
<td>0.739 (-1.061, 2.539)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>9.96 (9.19, 10.73)</td>
<td>9.43 (8.51, 10.36)</td>
<td>0.86 (0.59, 0.95)</td>
<td>0.523 (-1.505, 2.553)</td>
</tr>
<tr>
<td>Peak impact acceleration (g)</td>
<td>Left</td>
<td>5.92 (5.23, 6.61)</td>
<td>6.05 (5.27, 6.83)</td>
<td>0.82 (0.49, 0.94)</td>
<td>-0.196 (-2.847, 2.446)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>5.98 (5.12, 6.85)</td>
<td>6.19 (5.37, 7.01)</td>
<td>0.86 (0.60, 0.95)</td>
<td>-0.218 (-2.539, 2.110)</td>
</tr>
<tr>
<td>Asymmetry (%)</td>
<td></td>
<td>0.03 (-4.79, 4.79)</td>
<td>-1.79 (-7.53, 3.94)</td>
<td>0.66 (0.04, 0.88)</td>
<td>1.799 (-17.844, 21.445)</td>
</tr>
<tr>
<td><strong>DSJ</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight time (sec)</td>
<td>Left</td>
<td>0.37 (0.35, 0.40)</td>
<td>0.35 (0.32, 0.38)</td>
<td>0.27 (-0.96, 0.74)</td>
<td>0.022 (-0.118, 0.161)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.35 (0.32, 0.37)</td>
<td>0.37 (0.33, 0.39)</td>
<td>0.24 (-0.27, 0.57)</td>
<td>-0.018 (-0.159, 0.137)</td>
</tr>
<tr>
<td>Jump height (cm)</td>
<td>Left</td>
<td>17.7 (15.7, 19.7)</td>
<td>16.2 (13.4, 18.9)</td>
<td>0.42 (-0.61, 0.79)</td>
<td>0.015 (-0.092, 0.122)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>16.5 (13.8, 19.2)</td>
<td>17.6 (14.5, 20.6)</td>
<td>0.26 (-0.22, 0.67)</td>
<td>-0.011 (-0.016, 0.137)</td>
</tr>
<tr>
<td>Peak impact acceleration (g)</td>
<td>Left</td>
<td>4.63 (4.12, 5.13)</td>
<td>4.68 (4.29, 5.07)</td>
<td>0.19 (-1.56, 0.73)</td>
<td>0.251 (-2.121, 2.171)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>4.74 (4.14, 5.33)</td>
<td>4.64 (4.19, 5.08)</td>
<td>0.69 (0.11, 0.89)</td>
<td>0.142 (-1.593, 1.874)</td>
</tr>
<tr>
<td>Asymmetry (%)</td>
<td></td>
<td>-1.53 (-9.18, 6.12)</td>
<td>1.22 (-4.05, 6.49)</td>
<td>0.82 (0.49, 0.93)</td>
<td>-2.74 (-21.56, 16.06)</td>
</tr>
</tbody>
</table>
5.4.1 Asymmetry measures

For asymmetry measures, relative reliability for the CMJ test was poor, \((\text{ICC}_{(3,k)} = 0.36, 95\% \text{ CI: } -0.08 \text{ to } 0.77)\) (Table 5.2). The mean difference was 1.16% with 95% LOA: -29.60% to 31.22% (Table 5.2 & Figure 5.1). Results for the SH test indicated moderate relative reliability \([\text{ICC}_{(3,k)} = 0.66 (95\% \text{ CI } 0.35 \text{ – } 0.88)]\) and the mean difference was 1.78% with 95% LOA; -17.84% to 21.44% (Table 5.2 & Figure 5.2). For the DSJ test, good reliability was found for the DSJ test \([\text{ICC}_{(3,k)} = 0.82 (95\% \text{ CI } 0.49 \text{ - } 0.94)]\) for asymmetry measures between baseline and follow-up (Table 5.2). For limb asymmetry measures, the mean difference between baseline and follow-up testing was -2.74% with 95% LOA; -21.56% to 16.06% (Figure 5.3).

**Figure 5.1.** Bland-Altman distribution plot of the differences in mean limb asymmetry between baseline and 1-week follow-up against the mean difference for the CMJ test.
**Figure 5.2.** Bland-Altman distribution plot of the differences in mean limb asymmetry between baseline and 1-week follow-up against the mean difference for the SH test.
5.4.2 Peak tibial impact acceleration

Good relative reliability [ICC\(_{(3, k)} = 0.78 (0.33, 0.94)\) (left); 0.82 (0.41, 0.95) (right)] was demonstrated for peak tibial impact acceleration on both the right and left limbs in the CMJ test. The mean difference between peak axial tibial acceleration from baseline to follow-up was -0.03 g with 95% LOA; -2.05 g to 1.98 g and -0.08 g with 95% LOA; -1.65 g to 1.49 g for the left and right limbs respectively (Table 5.2).

For SH, ICC\(_{(3, k)}\) values were 0.82 (0.49, 0.94) on the left and 0.86 (0.60, 0.95) on the right indicating good reliability for peak tibial impact acceleration between baseline and follow-up. The mean difference between peak tibial impact acceleration from baseline to follow-up was -
0.19 g with 95% LOA; -2.84 g to 2.44 g and -0.21 g with 95% LOA; -2.53 g to 2.11 g for the left and right limbs respectively (Table 5.2).

In the DSJ test, relative reliability for peak tibial impact acceleration was poor [ICC(3,k) = 0.19 (-1.56, 0.73)] for the left, and moderate [ICC(3,k) = 0.69 (0.11, 0.89)] for the right. The mean difference between peak tibial impact acceleration from baseline to follow-up was 0.25 g with 95% LOA; -2.12 g to 2.17 g and 0.14 g with 95% LOA; -1.59 g to 1.87 g for the left and right limbs respectively (Table 5.2).

5.4.3 Performance measures

For the CMJ test, good relative reliability was demonstrated between baseline and follow up session for flight time and jump height [ICC(3,k) = 0.85 (0.56, 0.95); ICC: 0.86 (0.60, 0.95)] (Table 5.2). The mean difference between baseline and follow-up testing sessions for flight time was 0.002 seconds (95% LOA: -0.061 to 0.066). The mean difference between testing sessions for jump height was 0.002 cm with 95% LOA (0.072 to 0.077).

Good relative reliability [ICC(3,k) = 0.75 (0.14, 0.92)(left); 0.86 (0.59, 0.95)(right)] was demonstrated on both left and right limbs for time to complete the SH test. For the left limb, the mean difference was 0.739 seconds (95% LOA -1.061 to 2.539), while the mean difference was 0.523 seconds (95% LOA -1.505 to 2.553) on the right limb (Table 5.2).

For the DSJ test, ICC(3,k) values ranged from 0.24 – 0.42 indicative of poor relative reliability for both limbs for flight time and jump height (Table 5.2). For flight time, the mean difference
between testing sessions was 0.022 sec (95% LOA -0.118 to 0.161) on the left limb, and -0.018 sec (-0.159 to 0.137) on the right limb. On the left limb, mean difference in jump height from baseline to follow-up testing was 0.015 cm with 95% LOA -0.092 to 0.122. Mean difference from baseline to follow-up for jump height on the right limb was -0.011 (95% LOA -0.016 to 0.137).

5.5. Discussion

The aim of this study was to determine test re-test reliability of a dance-specific jump test using wearable technology to capture limb asymmetry in university contemporary dancers. Relative reliability ranged from poor to good across the three jump tests performed in this study. Wide limits of agreement were demonstrated by all jump tests for landing asymmetry measures. ICCs are a measure of relative reliability and correlation; high correlation does not always mean the agreement between the two methods is good. \(^{57,121}\) While good relative reliability was demonstrated by the DSJ test for asymmetry measurement, wide LOA indicates that this test is not a solution for monitoring of asymmetries during training or rehabilitation. These findings are similar to research comparing force-plate and accelerometer metrics, acceptable agreement was found for impact acceleration measurement but not for the monitoring of asymmetries. \(^{127}\)

There is a lack of longitudinal and normative data to establish if dance training increases symmetry or the reverse. Kimmerle suggests that dancers demonstrate a strong lateral bias in common pre-season screening measures, training, and performance. \(^{84}\) Conversely, dancers have shown to be symmetrical in jump measures such as jump height, GRF, and balance ability during landing. \(^{58,104}\) Dancers in the current study demonstrated symmetry, as the absolute value of mean
asymmetries ranged from 0.03% to 3.99%. While the previous studies discussed did not focus on the impact acceleration during landing of the jump, these findings are consistent with findings from other jump metrics.58, 104

With every human movement some movement variability between repetitions is to be expected.123 Fanning in Figure 5.1 demonstrates that as participants demonstrated larger asymmetries in the CMJ, the differences between baseline and follow-up also became larger. Participants who demonstrated a large asymmetry at baseline testing tended to decrease their asymmetry at the follow-up testing session. This created a larger difference between baseline and follow-up testing sessions, decreasing the test-retest reliability. In healthy children and adults, intra-subject variation has been demonstrated for joint moments, power, and lower-limb coordination during a CMJ.125, 126 It has been argued that movement variability could be functional and potentially reduce injury risk.10 More study is needed to determine if decreased reliability in asymmetry measures may be due to movement variability and be indicative of functional asymmetry in this population. Future research should consider longitudinal and normative data on functional asymmetries to provide more clarity.

In this study, there appeared to be greater asymmetry in CMJ than SH and DSJ tests. In the CMJ test, participants were instructed to jump as high as they could without any instruction on the landing. For the single leg tests (SH & DSJ), there was a temporal component that required participants to control their landings and limit their jump height to meet the demands of the task. As the tibial impact acceleration is directly related to jump height, participants experienced more impact acceleration at the shin level during the CMJ test, where they jumped higher, compared to
the DSJ. Differences in the task demands may have contributed to the discrepancies in asymmetry measures between jumps.

The Bland-Altman analysis has been previously used to determine that a range between 2-3 g is acceptable agreement between ground reaction force and accelerometer-based impacts during landing.\textsuperscript{122} Narrow LOA across all tests for peak tibial impact acceleration, indicate that this method may be used to quantify jump loads during training or rehabilitation. High loading, including elevated peak tibial acceleration, has been associated with lower-extremity overuse injuries, specifically tibial stress fractures in runners.\textsuperscript{68, 106} For flight time and jump height, relative reliability of the DSJ was poor. However, narrow LOA from the Bland-Altman analysis demonstrate that this test could be used to reliably measure flight time and jump height. This method may also be used to monitor the performance of jumps. Future research is needed to determine normative or baseline values for jumping performance in this population for comparison.

\textbf{5.5.1 Limitations}

This study has several limitations that should be considered when interpreting results. A small sample size of female, healthy participants, free from injury in the past 6 months, limits the generalizability of this study. Placement of the IMUs on the tibia doesn’t account for any accelerations proximal to the shin during landing. In addition, no analysis was performed on the propulsion phase of the jumps, which is relevant during lower-extremity injury rehabilitation. This study was limited to two testing sessions. Other research has shown that four to five testing sessions may be needed to produce reliable estimates of individual movement patterns in
runners.\textsuperscript{14} More testing sessions could have potentially increased the reliability of this protocol. Lastly, a lack of previous literature describing the acceptable limits of agreement for acceleration during landing and inter-limb asymmetries meant that acceptable limits of agreement were not outlined \textit{a priori}.

\textbf{5.6 Conclusions}

Findings of this study show that the dance-specific jump test using accelerometers is not a reliable measure of lower limb landing asymmetries. Test-retest reliability was demonstrated for performance measures for all jump tests. Accelerometers placed on the lower limb could be used to quantify jump loads and measure jump height performance. Future research should consider longitudinal measurement and normative values of functional asymmetry using traditional methods, jump load, and performance measures in this population.
5.7 Bridge to Chapter Six

In Chapter six, we sought to establish the test-retest reliability of a dance-specific jump test using wearable technology in university dancers. Findings from this study show that the dance-specific jump test using accelerometers is not a reliable measure of lower limb landing asymmetries. However, test-retest reliability was established for performance measures for countermovement jump, side-hop, and dance-specific jump tests.

Findings from Chapter five illustrated that accelerometers could not be used to track and monitor lower-limb asymmetries during training or injury rehabilitation. Future work should focus on determining normative values for lower-limb asymmetries during landing tasks. Normative data consists of performance standards and baseline distribution of results that can be used to evaluate a specific population. Currently, there is a lack of normative data in dance populations, specifically amongst the adolescent age group for ballet dancers. Normative data can be useful for both the clinician and dance educator because it provides context to which their dancers’ screening measures can be appropriately compared.
Chapter Six. Pre-Season Screening Assessments: Normative Data for Pre-Professional Ballet Dancers

6.1 Abstract

Introduction: Pre-professional dance is high-risk, with injury incidence up to 4.7 injuries/1000 dance hours. Pre-season screening measures have been utilized to assess risk factors for dance-related injury, however normative values haven’t been established for a pre-professional ballet population.

Purpose: To establish normative values of ankle and hip joint range of motion (ROM), lumbopelvic control, and dynamic balance pre-season screening measures for pre-professional ballet dancers.

Methods: 498 adolescent pre-professional ballet dancers [n=219 junior division (194 female, 25 male; mean age: 12.9±0.9 yrs); n=281 senior division (238 female, 41 male; mean age: 16.8±1.5 yrs)] participated in baseline screening tests across five seasons (2015-2019). Baseline measures took place at the beginning of each academic year: ankle ROM [dorsiflexion (deg); plantarflexion (PF) (deg)], total active turnout (TAT) (deg), lumbopelvic control [active straight leg raise (ASLR) (score); one leg standing test (OLS) (score)], and dynamic balance [unipedal balance (sec); Y-Balance Test (cm)].

Results: Percentiles for ankle dorsiflexion ranged from 28.2 degrees (male senior division, 10th percentile) to 63.3 degrees (female junior division, 100th percentile). For PF, percentiles ranged from 77.5-111.8 degrees (male junior division, 10th percentile; male senior division, 100th percentile). Percentiles for TAT for all participants ranged between 121.1-131.0 degrees. For the ASLR, the proportion of participants moving with compensation (pelvis shifting) was between 64.0% and 82.2%. For OLS, 19.7% to 56.1% of dancers had a positive score (hip hiking).
Percentiles for dynamic balance ranged from 3.5-17.1 seconds (unipedal dynamic balance) and 75.8-103.3 cm (YBT composite reach score) across all groups.

**Conclusion:** The establishment of normative values of pre-season screening measures among a pre-professional ballet population can be used to determine areas to target during training, recognize individuals with possible injury risk, and inform return to dance protocols following injury. Comparison with other dancer/athletic populations will also provide insight into the performance of dancers and identify areas in need of improvement.
6.2 Introduction

Dance as an activity combines artistic as well as physical demands including flexibility, muscular strength, balance, and neuromuscular coordination. Elite level dance has been categorized as high-risk for injury with injury incidence rates as high as 4.7/1000 dance hours and seasonal prevalence of up to 81% in pre-professional ballet dancers. Pre-season screening programs have been used to potentially identify dancers who may be at risk for these injuries.

The use of pre-season screening in dance is well documented. In addition, to identifying dancers at risk for injury, overarching aims of these programs also include providing dancers with information about their bodies, and establishing baseline data for research purposes. Assessments typically take place at the beginning of an academic year in vocational, pre-professional, and university settings. Typical screening components include observation of alignment, joint range of motion (e.g., ankle and hip), muscular strength, and balance. As such, it is best for screening measures to focus on the assessment of modifiable factors and the dancer’s functional capacity relative to the unique training requirements of the specific dance style. It has been recommended that screening be used to gain important information about a dancer that can be used to support and promote their ongoing health and well-being.

Various organizations, such as the International Associations for Dance Medicine and Science (IADMS), the Dance/USA Taskforce, and Healthy Dancer Canada (HDC), have published screening guidelines for health professionals and dance educators. Despite having access to these evidence-informed methodologies for pre-season screening assessments, components and...
protocols of the pre-season screening have not been published or validated and vary between programs.\textsuperscript{109, 152} Due to these differences, it is of upmost importance that the specific components of pre-season screening are valid and reliable. The validity and reliability of common dancer screening assessments of ankle and hip joint range of motion, lumbopelvic control, and dynamic balance have been established.\textsuperscript{79}

Once validity and reliability of screening tests have been determined, and a sufficient number of dancers have been assessed, it is possible to establish normative data for a particular group.\textsuperscript{92} Normative data consists of performance standards and baseline distribution of results that can be used to evaluate a specific population.\textsuperscript{121} Currently, there is a lack of normative data in dance populations, specifically amongst the adolescent age group for ballet dancers.\textsuperscript{109} Normative data can be useful for both the clinician and dance educator because it provides context to which their dancers’ screening measures can be appropriately compared. Therefore, the purpose of this study was to establish normative values for ankle and hip joint range of motion, lumbopelvic control, and dynamic balance screening test measures among adolescent pre-professional ballet dancers.

6.3 Methods

6.3.1 Study design and participants

498 adolescent pre-professional ballet dancers [$n=219$ junior division (194 female, 25 male; mean age: 12.9±0.9 yrs); $n=281$ senior division (238 female, 41 male; mean age: 16.8±1.5 yrs)] participated in pre-season screening across five seasons (2015-2019) representing a total of 1,083 dancer-seasons. Descriptive characteristics for all participants are presented in Table 6.2. Results from participants’ pre-season screening measures are presented in Table 6.3.
The present study was part of a larger prospective cohort study that followed the STROBE reporting guidelines.\textsuperscript{147} Participants included a convenience sample of adolescent pre-professional ballet dancers from a vocational dance school in Calgary, Canada. Recruitment occurred at the beginning of each school year (September) from 2015-2019. Exclusion criteria from pre-season screening were a self-reported current injury resulting in the inability to participate fully in dance training, a current vestibular dysfunction or other medical condition associated with balance impairment at the time of screening, and/or a concussion within the previous 3 months. All participants were registered as full-time students, provided informed consent/assent, or parent/guardian consent if under 18 years of age. Ethical approval was granted by the University of Calgary (Canada) Conjoint Health Research Ethics Board (Ethics ID: REB14-0897).

### 6.3.2 Procedures

All participants underwent a standardized 60–75-minute pre-participation screening at the beginning of each academic year. Following systematic review of the literature, this evaluation consisted of psychometric and clinical tests that demonstrated the highest level of evidence for measuring previously identified risk factors for musculoskeletal injury in pre-professional ballet dancers (Table 6.1)(Appendix B).\textsuperscript{82} Pre-season screening assessments took place onsite in a dance studio during class time. To minimize measurement bias, all raters were familiarized with testing procedures during an extensive three-hour training session, one week prior to data collection. Standardized protocols were followed for daily calibration of all testing equipment. Between-day reliability of all testing procedures were established prior to analyses.\textsuperscript{79}
6.3.2.1 Ankle range of motion

Ankle dorsiflexion was measured barefoot, while weight bearing (standing lunge), and followed protocols from Bennell et al.\textsuperscript{11} To be considered a valid trial, the knee of the participant must have been touching the wall, while the heel maintained contact with the floor, and the knee aligned with the foot. The standing lunge measure included the distance from the big toe to the wall (cm) and the angle of the Achilles tendon to the vertical using an inclinometer (deg) placed along the tibia one third of the distance from the medial malleolus to the lateral epicondyle.

Non weight bearing active plantar flexion (PF) was assessed with an inclinometer as per Russell et al.\textsuperscript{131} Two measures were recorded: one along the anterior border of the distal tibia and the second along the dorsal foot across the distal talus and navicular. The difference between values indicated participants’ degree of PF. A difference of 0 deg described a 180 deg angle between tibia and foot (corresponding to 90 deg PF), a positive difference indicated greater than 180 deg (PF>90 deg) and a negative difference indicated less than 180 deg (PF<90 deg).\textsuperscript{131}

6.3.2.2 Hip range of motion

Total active external hip rotation was assessed using Functional Footprints\textsuperscript{®} (Balanced Body, Sacramento, CA, USA). Functional Footprints\textsuperscript{®} produce minimal friction, requiring the participant to utilize their external rotator muscles as opposed to ‘forcing turnout’. Participants stood barefoot with the heel and second toe aligned with pre-determined markers on the Functional Footprints\textsuperscript{®}. With instruction to keep the spine and pelvis neutral, the participant
externally rotated from the hips. The corresponding angle from each leg was recorded from the Functional Footprints® and added together to determine total active standing turnout.75

6.3.2.3 Lumbopelvic control

The integrity of the function to transfer loads between the lumbosacral spine and legs was assessed by the Active Straight Leg Raise (ASLR). Utilizing protocol described by Mens et al 103, dancers lay supine with extended legs. Participants were asked to raise one leg at a time, five cm in the air. A physiotherapist scored presence of compensation on a 4-point Likert scale (0=no restriction; 1=limited compensation, mild impairment; 2=increased compensation, moderate impairment; 3=inability to raise the leg). Each participant completed three repetitions on each side.

The ability to stabilize intrapelvic motion was assessed by the Stork test, hereafter referred to as One Leg Standing (OLS). Following Hungerford et al 69, participants were instructed to stand in parallel with equal weight distributed through each leg. A physiotherapist palpated the posterior superior iliac spine (PSIS) and the sacrum. Participants raised the contralateral leg to 90 deg hip flexion and 90 deg knee flexion three times, returning to neutral stance in between each movement. A positive score resulted if the PSIS on the supportive leg side moved upward relative to the sacrum (hip hiking), a negative score indicated the PSIS stayed neutral or moved downward relative to the sacrum (hip dropping).

6.3.2.4 Dynamic balance
Non-functional dynamic balance included a barefoot, timed, one leg balance on a foam pad with eyes closed. Protocol followed Emery et al. where the longest time on balance was recorded following three trials. Participants stood with bilateral feet in the center of the balance pad with eyes closed, hands on hips. Participants closed their eyes prior to elevation of the non-weight bearing foot from the pad. The non-weight bearing foot hovered at approximately shin level, with the sole of the foot facing posteriorly, not contacting the weight-bearing leg. The longest balance time (to the nearest tenth of a second) of three trials (15 seconds rest between trials) was recorded using a stopwatch for each leg. Time was stopped with loss of balance (i.e., removal of one hand from the hip, eyes opening, touching the balance pad, weight bearing leg or floor with the non-weight bearing foot, movement of the weight-bearing foot or balance from its original position).

Functional dynamic balance utilized the Y-Balance Test. Lower limb length (anterior superior iliac spine to lateral malleolus in cm) was measured in order to normalize distance reached. Three trials were measured, and the farthest distance (cm) reached in each of three directions (anterior, posteromedial, posterolateral) was recorded. Participants were instructed to hold their foot for approximately two seconds at the end of each maximal reach. The gesture leg returned to center and was allowed to touch down momentarily before reaching in the next direction. A trial was discarded and repeated with loss of balance (i.e., lifting or moving the standing foot from the grid, fully touching down with the gesture foot, failing to return the gesture foot to center between each direction, removal of one hand from the hip).
6.3.3 Statistical Analyses

All statistical procedures were performed in Stata Version 15.1 (StataCorp LLC, College Station, TX). Participant characteristics were summarized with means (95% confidence intervals (CI)), medians (interquartile range (IQR)), or proportions (95% CI). Percentiles were estimated for all screening measures. Results were stratified by age and level at the ballet school: junior division students were enrolled in grade 7-9 in school (age range: 10-14 years) and senior division students were in grade 9-12 or training at the post-graduate level (age range: 15-21 years).

Table 6.1. Components of Pre-Season Screening Program

<table>
<thead>
<tr>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion Range of Motion (degrees)</td>
</tr>
<tr>
<td>Ankle Plantarflexion Range of Motion (degrees)</td>
</tr>
<tr>
<td>Active Hip External Rotation (degrees)</td>
</tr>
<tr>
<td>Active Straight Leg Raise (ASLR; with/without restriction)</td>
</tr>
<tr>
<td>One Leg Standing (OLS; negative/positive score)</td>
</tr>
<tr>
<td>Unipedal Dynamic Balance (UPDB; seconds)</td>
</tr>
<tr>
<td>Y-Balance Test (YBT; normalized composite reach (cm))</td>
</tr>
</tbody>
</table>

6.4 Results

No significant differences were found between groups for ankle dorsiflexion or PF. For hip range of motion, based on non-overlapping 95% CI, there were significant differences between male senior division participants and both junior and senior division female participants in active standing turnout (Table 6.3). Male senior division participants had the least active standing turnout [121.1 degrees (95% CI: 116.9, 125.4)] when compared to female participants [female junior: 131.0 degrees (95% CI: 128.9, 133.1); female senior: 130.2 degrees (95% CI: 128.3, 132.2)]. For lumbopelvic control measures, no differences were found for the ASLR. Side to side differences were observed in the OLS test for all groups. Specifically, all groups demonstrated a higher proportion of positive OLS scores on the right side compared to the left. Significant
differences were also found between male and female participants for the OLS test, with male participants demonstrating a higher proportion of positive OLS scores (Table 6.3). Finally, no significant differences were found between groups for dynamic balance measures.

Table 6.2. Descriptive characteristics of participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Females (n=432)</th>
<th>Males (n=66)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>Junior</td>
<td>Senior</td>
</tr>
<tr>
<td></td>
<td>194 (88.6)</td>
<td>238 (85.3)</td>
</tr>
<tr>
<td>Age (years)*</td>
<td>12.9 (0.9)</td>
<td>16.8 (1.5)</td>
</tr>
<tr>
<td>Previous training ≥ 3 times/week (years)</td>
<td>6.8 (6.5, 7.2)</td>
<td>9.5 (9.1, 9.9)</td>
</tr>
<tr>
<td>Previous injury† in the last year‡</td>
<td>43.8%</td>
<td>49.5%</td>
</tr>
<tr>
<td></td>
<td>(85/194)</td>
<td>(118/238)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>17.9 (17.4, 18.4)</td>
<td>19.7 (19.2, 20.2)</td>
</tr>
<tr>
<td>Athletic Coping Skills Inventory-28 score</td>
<td>50.4 (48.9, 51.9)</td>
<td>49.7 (48.6, 50.9)</td>
</tr>
</tbody>
</table>

Values are means (95% confidence intervals) unless otherwise indicated.

*Values are mean (SD)
†Values are proportion (%)
‡Previous injury was operationally defined as any dance-related physical complaint that required medical attention and/or time-loss (i.e., caused the dancer to miss more than one day of class, rehearsal or performance) in the previous one-year.⁴⁹, ⁹³
§Previous injury data was missing for one participant.
Table 6.3. Characteristics of pre-season screening assessments for junior and senior division ballet students.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Side</th>
<th>Females (n=432)</th>
<th>Males (n=66)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Junior (n=194)</td>
<td>Senior (n=238)</td>
</tr>
<tr>
<td>Ankle Dorsiflexion (degrees)</td>
<td>Left</td>
<td>43.3 (42.2, 44.5)</td>
<td>41.9 (40.8, 43.1)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>43.2 (42.0, 44.3)</td>
<td>42.0 (40.9, 43.1)</td>
</tr>
<tr>
<td>Ankle Plantar Flexion (degrees)</td>
<td>Left</td>
<td>91.3 (90.3, 92.4)</td>
<td>91.4 (90.5, 92.4)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>91.5 (90.4, 92.7)</td>
<td>91.4 (90.4, 92.4)</td>
</tr>
<tr>
<td>Active Standing Turnout (degrees)</td>
<td>Both</td>
<td>131.0 (128.9, 133.1)</td>
<td>130.2 (128.3, 132.2)</td>
</tr>
<tr>
<td>Active Straight Leg Raise (% with restrictions, CI, n)†</td>
<td>Left</td>
<td>73.1% (66.5, 78.9) (142/194)</td>
<td>73.3% (67.2, 78.6) (173/236)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>80.9% (74.7, 85.9) (157/194)</td>
<td>82.2% (76.8, 86.6) (194/236)</td>
</tr>
<tr>
<td>One Leg Standing (% positive score, CI, n)†</td>
<td>Left</td>
<td>19.7% (14.6, 25.9) (38/193)</td>
<td>25.3% (20.1, 31.3) (7/25) (60/237)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>33.7% (27.4, 40.7) (65/193)</td>
<td>32.1% (26.4, 38.3) (76/237)</td>
</tr>
<tr>
<td>Unipedal Dynamic Balance (seconds)*</td>
<td>Left</td>
<td>6.0 (4.0 -8.0)</td>
<td>5.3 (4.0 - 8.0)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>5.2 (4.0 - 8.3)</td>
<td>5.6 (4.0 – 8.0)</td>
</tr>
<tr>
<td>Y-Balance Test – normalized composite reach (cm)</td>
<td>Left</td>
<td>87.0 (85.7, 88.4)</td>
<td>85.5 (84.2, 86.9)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>86.8 (85.5, 88.2)</td>
<td>86.8 (83.8, 89.8)</td>
</tr>
<tr>
<td>Y-Balance Test – anterior reach (cm)</td>
<td>Left</td>
<td>64.8 (63.7, 65.8)</td>
<td>63.3 (62.3, 64.3)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>64.3 (63.3, 65.4)</td>
<td>62.9 (61.8, 63.9)</td>
</tr>
</tbody>
</table>

Values are means (95% CI) unless otherwise indicated.  
*Values are median (IQR)  
† Values are proportion (exact 95% confidence interval)
Percentiles for ankle dorsiflexion, ankle plantar flexion, active standing turnout, unipedal dynamic balance, and Y-Balance test (YBT) composite reach scores are presented in Tables 6.4 - 6.7.

**Table 6.4.** Percentiles for ankle range of motion, active standing turnout, and dynamic balance measures for female junior division ballet students (N=194; age range 10-14 years).

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Ankle Dorsiflexion (degrees)</th>
<th>Ankle Plantarflexion (degrees)</th>
<th>Active Standing Turnout (degrees)</th>
<th>Unipedal Dynamic Balance (sec)</th>
<th>Y-Balance Test – normalized composite reach (cm)</th>
<th>Y-Balance Test – anterior reach (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>63.3</td>
<td>108.3</td>
<td>163.3</td>
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<td>70</td>
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<td>66.9</td>
</tr>
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<td>45.7</td>
<td>94.0</td>
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<td>6.5</td>
<td>89.2</td>
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<tr>
<td>50</td>
<td>44.3</td>
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</tr>
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<td>39.7</td>
<td>86.0</td>
<td>123.3</td>
<td>4.5</td>
<td>83.4</td>
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<tr>
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<td>117.3</td>
<td>4</td>
<td>81.3</td>
<td>60.9</td>
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<tr>
<td>10</td>
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<td>81.5</td>
<td>112.0</td>
<td>3.5</td>
<td>79.3</td>
<td>58.4</td>
</tr>
</tbody>
</table>

**Table 6.5.** Percentiles for ankle range of motion, active standing turnout, and dynamic balance measures for female senior division ballet students (N=238; age range 15-21 years).

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Ankle Dorsiflexion (degrees)</th>
<th>Ankle Plantarflexion (degrees)</th>
<th>Active Standing Turnout (degrees)</th>
<th>Unipedal Dynamic Balance (sec)</th>
<th>Y-Balance Test – normalized composite reach (cm)</th>
<th>Y-Balance Test – anterior reach (cm)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>65.9</td>
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<tr>
<td>60</td>
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<td>126.7</td>
<td>5.2</td>
<td>84.3</td>
<td>62.1</td>
</tr>
<tr>
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<td>123.7</td>
<td>4.5</td>
<td>81.5</td>
<td>61.2</td>
</tr>
</tbody>
</table>
Table 6.6. Percentiles for ankle range of motion, active standing turnout, and dynamic balance measures for male junior division participants (N=25, age range 11-14 years).

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Ankle Dorsiflexion (degrees)</th>
<th>Ankle Plantarflexion (degrees)</th>
<th>Active Standing Turnout (degrees)</th>
<th>Unipedal Dynamic Balance (sec)</th>
<th>Y-Balance Test – normalized composite reach (cm)</th>
<th>Y-Balance Test-anterior reach (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>56.3</td>
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<td>10.78</td>
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</tr>
<tr>
<td>90</td>
<td>52.7</td>
<td>106.3</td>
<td>140.7</td>
<td>10.0</td>
<td>92.5</td>
<td>67.9</td>
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<tr>
<td>80</td>
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<td>100.8</td>
<td>137.3</td>
<td>9.0</td>
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</tr>
<tr>
<td>70</td>
<td>47.2</td>
<td>90.5</td>
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<td>50</td>
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<td>83.2</td>
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<td>6.0</td>
<td>85.4</td>
<td>63.1</td>
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<tr>
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<td>35.5</td>
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<td>111.8</td>
<td>3.9</td>
<td>79.9</td>
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<td>77.5</td>
<td>105.0</td>
<td>3.5</td>
<td>75.8</td>
<td>56.6</td>
</tr>
</tbody>
</table>

Table 6.7. Percentiles for ankle range of motion, active standing turnout, and dynamic balance measures for male senior division participants (N=41, age range 15-21 years).

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Ankle Dorsiflexion (degrees)</th>
<th>Ankle Plantarflexion (degrees)</th>
<th>Active Standing Turnout (degrees)</th>
<th>Unipedal Dynamic Balance (sec)</th>
<th>Y-Balance Test – normalized composite reach (cm)</th>
<th>Y-Balance Test-anterior reach (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>54.5</td>
<td>111.8</td>
<td>155.3</td>
<td>16.5</td>
<td>103.4</td>
<td>75.1</td>
</tr>
<tr>
<td>90</td>
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<td>105.8</td>
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<td>14.5</td>
<td>94.7</td>
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</tr>
<tr>
<td>80</td>
<td>49.5</td>
<td>94.2</td>
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<td>10.5</td>
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<tr>
<td>70</td>
<td>48.5</td>
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<td>125.0</td>
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<td>8.0</td>
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<td>50</td>
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<td>121.7</td>
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<td>40</td>
<td>43.5</td>
<td>83.0</td>
<td>120.7</td>
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<td>30</td>
<td>39.5</td>
<td>80.5</td>
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<tr>
<td>20</td>
<td>37.8</td>
<td>78.3</td>
<td>109.0</td>
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<tr>
<td>10</td>
<td>34.2</td>
<td>75.3</td>
<td>103.3</td>
<td>4.4</td>
<td>81.7</td>
<td>58.8</td>
</tr>
</tbody>
</table>
For female participants in the junior division, percentiles for ankle dorsiflexion and plantar flexion ranged from 32.0-63.3 and 81.5-108.3 degrees (10th and 100th percentiles), respectively. Active standing turnout ranged from 112.0-163.3 degrees (10th and 100th percentiles). Percentiles for dynamic balance ranged from 3.5-17.1 seconds (unipedal dynamic balance), 79.3-103.6 cm (YBT composite reach score), and 58.4 -78.7 cm (YBT anterior reaching direction). In senior division female participants, percentiles for ankle dorsiflexion and plantar flexion ranged from 32.2-61.3 and 81.8-105.5 degrees (10th and 100th percentiles), respectively. Active standing turnout ranged from 112.7-155.7 degrees (10th and 100th percentiles). Percentiles for dynamic balance ranged from 3.5-17.1 seconds (unipedal dynamic balance), 77.2-102.4 cm (YBT composite reach score), and 57.1-73.9 cm (YBT anterior reaching direction).

For male junior division participants, percentiles for ankle dorsiflexion and plantar flexion ranged from 28.2-56.3 degrees and 77.5-108.3 degrees (10th and 100th percentiles), respectively. Their active standing turnout ranged from 105.0-164.3 degrees (10th and 100th percentiles). Percentiles for dynamic balance ranged from 3.5-10.8 seconds (unipedal dynamic balance), 75.8-97.6 cm (YBT composite reach score), and 56.6. – 72.9 cm (YBT anterior reaching direction). In senior division male participants, percentiles ranged from percentiles for ankle dorsiflexion and plantar flexion ranged from 34.2-54.5 and 75.3-111.8 degrees (10th and 100th percentiles), respectively. Active standing turnout ranged from 103.3-155.3 degrees (10th and 100th percentiles). Percentiles for dynamic balance ranged from 4.4-16.8 seconds (unipedal dynamic balance), 81.7-103.4 cm (YBT composite reach score), and 58.8 – 75.1 cm (YBT anterior reaching direction).
6.5 Discussion

The aim of this study was to establish normative values for ankle and hip joint range of motion, lumbopelvic control, and dynamic balance screening test measures among adolescent pre-professional ballet dancers. The following sections will discuss how the results from this study compare to values in other populations and the implications of these normative values for clinicians and dance educators.

6.5.1 Ankle range of motion

Having a history of musculoskeletal injury in the leg, as well as incidence of new leg injuries, have been found to be correlated with reduced dorsiflexion range in pre-professional dancers, indicating that ankle range of motion tests may be used to potentially identify dancers at risk for injury.\(^{151}\) Percentiles for ankle dorsiflexion ranged from 28.2 degrees (male senior division, 10\(^{th}\) percentile) to 63.3 degrees (female junior division, 100\(^{th}\) percentile). Ballet dancers have been found to have greater ankle dorsiflexion than non-dancing controls.\(^{12}\) Ankle dorsiflexion values were found to be higher in this cohort than in other dancer populations.\(^{12, 37}\) For PF, percentiles ranged from 77.5-111.8 degrees (male junior division, 10\(^{th}\) percentile; male senior division, 100\(^{th}\) percentile). PF was found to be consistent with other published values within the range that is claimed to be the desired dancer range of motion (90-100 degrees).\(^{59, 62, 109}\)

6.5.2 Active standing turnout

As turnout is essential in classical ballet, it is important that dancers initiate their external rotation from the hip joint, rather than from the knee or ankle joints, to decrease their risk of
It has been suggested that 50-70% of turnout should come from the hip in order to reduce excessive tibial torsion stress on the knee.\textsuperscript{30, 70} Percentiles for active standing turnout for all participants ranged between 121.1-131.0 degrees across all groups. This is consistent with finding in other pre-professional ballet cohorts with an average active standing turnout of 123.4 degrees and a little less than professional classical ballet dancers (133.0 degrees).\textsuperscript{133, 148} The active standing turnout of this cohort is a little less than that of the average functional turnout measured in a professional cohort, indicating that training to improve external hip rotation may benefit those dancers aspiring for a professional performance career.\textsuperscript{62}

### 6.5.3 Lumbopelvic control

In this cohort, a large proportion of participants had indications of poor lumbopelvic control. For the ASLR, the proportion of participants demonstrating a leg lift while in supine with restriction (i.e., unable to lift the leg without pelvic compensation) was between 64.0% and 82.2%. For OLS, 19.7% to 56.1% of dancers had a positive score, which is also indicative of poor lumbopelvic control (i.e., the gesture hip lifts while transferring weight from two feet to one). Side to side differences were found with all groups demonstrating higher proportion of positive scores on the right compared to the left. It was also found that male participants had a higher proportion of positive scores than the female dancers. As such, this highlights one of the benefits of pre-season screening, that training to improve stability of the pelvis when transferring weight is an area for improvement in this cohort of dancer. In female athletes it has been shown that impaired core stability predicts the risk of knee injuries.\textsuperscript{154} Altered lumbopelvic control in dance movements may cause compensation in the lower limbs and potentially lead to musculoskeletal injuries.\textsuperscript{129}
6.5.4 Dynamic balance

Percentiles for dynamic balance ranged from 3.5-17.1 seconds (unipedal dynamic balance), 75.8-103.3 cm (YBT composite reach score), and 56.6-78.8 (YBT anterior reaching direction) across all groups. Previous research has shown that dancers demonstrate higher dynamic stability scores than non-dancers.\(^5\) When compared to athletic populations, findings are less consistent. Ambegaonkar and colleagues determined that dancers do not demonstrate better balance than athletic populations and found their balance performance to be comparable using multiple balance tests.\(^5\) However, findings from this study indicate adolescent pre-professional ballet dancers had greater reaching distances than a cohort of NCAA Division I athletes.\(^5\) Greater balance is associated with lower musculoskeletal injury rates in high school aged basketball players.\(^9\)

6.5.5 Practical applications

The values presented in this study provide percentiles and ranges for healthy, adolescent, pre-professional ballet dancers. It is anticipated that these normative data can be used as baseline benchmarks for similar cohorts. Specifically, these norms can be used to inform both health professionals and dance educators about the performance of their dancers on pre-season screening tests, and as such, can be used to determine areas to target during training, recognize individuals with possible injury risk, and inform return to dance protocols after injury. Additional presentation of pre-season screening norms from other injury surveillance programs is recommended for future research. Furthermore, future prospective work is recommended to assess whether pre-season norms are an appropriate target for rehabilitation post injury.
6.5.6 Limitations

Despite best efforts to standardize pre-season screening protocols and procedures, due to the longitudinal nature of this study different raters administered different screening tests from year to year introducing the possibility of some variability in the results. However, between-day reliability of all assessments was established in the first year of this study and all raters underwent the same comprehensive training each subsequent year to mitigate potential variability. Values presented in this study are specific to adolescent pre-professional ballet dancers, and so generalizability of findings should be limited to similar dancer populations. Lastly, there was a small sample size of male dancers in this study (n=66), contributing to the specificity of these results for this cohort of male adolescent pre-professional dancers.

6.6 Conclusions

Normative values of pre-season screening measures for ankle and hip joint range of motion, lumbopelvic control, and dynamic balance have been established in an adolescent pre-professional ballet dancer cohort. These values provide health professionals and dance educators with areas to target during training in hopes of mitigating future injury risk while enhancing performance potential. Practitioners working with these dancers can use normative values to determine their dancers’ performance of pre-season screening tests and plan training programs to prevent or rehabilitate dance-related injury.
Chapter Seven. Conclusion and Future Directions

The aims of this doctoral research were to assess the prevalence, incidence, and risk factors for dance-related injury in pre-professional ballet dancers, to evaluate the test-retest reliability of a dance specific jump test using wearable technology, and to establish normative values for common pre-season screening assessments. Each chapter in this dissertation is meant to contribute high quality evidence towards achieving these aims. To our knowledge, each individual investigation contributes to the understanding of prevention of dance-related injury.

7.1 Chapter Summaries

7.1.1 Chapter three

Objective: To establish the extent (prevalence, injury rate) and characteristics (severity, location) of injuries in adolescent female and male pre-professional ballet dancers across five academic training years.

Findings from this study indicate that injury prevalence, injury rate, severity, and location remain consistent across five years of training, further justifying the growing body of research that demonstrates pre-professional ballet dancers are at high risk for injury. The longitudinal nature of this study provides evidence that injury prevalence and rate estimates remain high across all years of training. Results from this study indicate that there is variability in self-reported injury prevalence and injury rates among pre-professional ballet dancers when different injury definitions are utilized. For example, the use of an all-complaints injury definition results in a higher burden of injury being reported by this population compared to when injuries are defined...
by medical-attention or time-loss. Following van Mechelen’s sequence of prevention model, future research should consider the potential modifiable and nonmodifiable risk factors for these injuries to inform future injury prevention strategies.\textsuperscript{143}

\subsection*{7.1.2 Chapter four}
\textbf{Objective: To examine modifiable and non-modifiable risk factors for dance-related injury in adolescent female and male pre-professional ballet dancers.}

To our knowledge, this is one of the first studies to utilize evidence-informed pre-season screening assessments, prospective injury surveillance, and comprehensive biostatistical modeling to determine potential risk factors for dance-related injury across multiple years. Years of dance training demonstrated a protective effect for count of self-reported dance-related injuries. Psychological coping skills conferred an effect upon the relationship between pre-season screening measures and self-reported dance-related injury. Though, the effect to which psychological coping skills conferred an effect was inconclusive. Findings from this study show a significant association between lumbopelvic control and dynamic balance, when adjusted for psychological coping skills and years of previous dance training, with side-to-side differences. As such, it is recommended that assessment of psychological coping skills, lumbopelvic control, and one-legged dynamic balance be prioritized in pre-season dancer screening programs when identifying injury risk is a priority. It is also suggested that dance educators, researchers and clinicians understand the interconnection of training, lateral bias, and coping skills when developing dance curriculum, planning pre-season screening, and strategizing rehabilitation for adolescent pre-professional populations.
7.1.3 Chapter five

Objective: To determine test re-test reliability of a dance-specific jump test using wearable technology to capture limb asymmetry in pre-professional dancers.

This reliability study focused on the evaluation of a novel method of measurement for lower-limb asymmetries among pre-professional dancers via a dance-specific jump test and wearable technology. Findings demonstrated that using accelerometers during a dance-specific jump test did not produce reliable measures of lower limb landing asymmetries. However, test-retest reliability was demonstrated for performance measures (i.e., flight time and jump height). This means that inertial measurement units placed on the lower limb could be used to quantify jump loads and measure jump height performance. Future research should consider longitudinal measurement and normative values of functional asymmetry using traditional methods, as well as jump load, and performance measures in pre-professional dance populations.

7.1.4 Chapter six

Objective: To establish normative values for ankle and hip range of motion, lumbopelvic control, and dynamic balance screening test measures among adolescent female and male pre-professional ballet dancers.

We believe this study is among the first to establish normative values and percentiles for pre-season screening measures in female and male pre-professional ballet dancers. Specifically,
normative values and percentiles have been determined for ankle and hip range of motion, lumbopelvic control, and dynamic balance for healthy, adolescent ballet dancers training at the pre-professional level. It is anticipated that these normative data can be used as baseline benchmarks for similar cohorts. Specifically, these norms can be used to inform both health professionals and dance educators about the fitness level of their dancers and as such, can be used to determine areas to target during training, recognize individuals with possible injury risk, and inform return to dance protocols after injury. Additional presentation of pre-season screening norms from other injury surveillance programs is recommended for future research. Furthermore, future prospective work is recommended to assess whether pre-season norms are an appropriate target for rehabilitation post injury.

7.2 Future Directions

7.2.1 Injury definition and surveillance systems

Because estimates for injury outcomes vary depending on the operational definition of injury employed, a comprehensive understanding of the strengths and limitations of each definition is critical to assess the outcome of interest in injury surveillance research programs. Thorough understanding of injury surveillance methodologies and injury definitions is critical to dance injury epidemiology research. Future injury surveillance programs should utilize an injury definition that is appropriate to the research aims and objectives. For example, injury surveillance programs with the aim of understanding the full impact of injury in a dance population should consider the use of a self-reported all-complaints definition. Additionally, the current research predominantly examined the physical traits of injury, future research should
consider inclusion of other factors that may contribute to dancer wellness (e.g., sleep, nutrition, social support, etc.).

### 7.2.2 Risk factor assessment

Employing a comprehensive injury surveillance program, including pre-season measurement of evidence-based potential risk factors is key to understanding risk for dance-related injury.\(^{72}\) Participation in dance training in the presence or absence of injury may cause adaptations that alter a dancer’s injury profile. Repeated measures of potential risk factors across an academic year or season will contribute to further understanding of dance-related injury.

While robust statistical measures were employed in the current study to identify potential modifiable risk factors for dance-related injury, further research needs to continue to address the complexity of dance-related injury risk. For example, non-linear analytic approaches that account for injury risk being dynamic and recursive, and that continued participation, adaptations from training, and previous injury may alter a dancer’s risk profile for future injury need to be considered in future dance epidemiology studies.

Future research may want to further examine recurrent injury in this population. As such, other analytic approaches may be more appropriate. Frailty models are a type of survival analysis that measures time to a given event of interest, such as an injury or recurrence of an injury.\(^{114}\) These models have yet to be fully adopted in sport and dance injury epidemiology research. Another approach for the examination of dance-related injury and recurrent injury is a complex system approach. This method goes beyond traditional linear analyses of injury that have focused on the
identification of isolated factors. Future epidemiological studies of dance-related injury may need to employ analytical strategies that incorporate interactions of multiple risk factors for the identification of risk pattern recognition.18

7.2.3 Injury prevention strategies

The current research has re-affirmed that pre-professional dancers are at high risk for dance-related injury, focusing mainly on steps 1 and 2 of the van Mechelen sequence of prevention.143 Findings indicate that there are modifiable risk factors for dance-related injury that may be the focus of targeted primary injury prevention programs. Specifically, preliminary evidence from this doctoral research suggests that the teaching psychological coping skills, focusing on improving lumbopelvic control and dynamic balance may be important components to minimize injury risk among adolescent, pre-professional ballet populations. Therefore, the development, implementation, and evaluation of such a program is needed to potentially decrease the burden of injury in this population.

7.2.4 Recommendations for pre-season screening

The current research suggested that side-to-side differences, lumbopelvic control measures, and dynamic balance should be prioritized during pre-season screening with the aim of detecting injury risk early. Other common pre-season screening measures, such as, ankle and hip range of motion and the Y-balance test were not associated with dance-related injury risk. As the purposes for pre-season screening vary, researchers and dance educators should consider their goals and objectives for pre-season screening when developing their protocols.92 Schools and studios that have the resources to perform a variety of measures, (i.e., range of motion, strength,
lumbopelvic control, dynamic balance) may provide their students and teachers with knowledge about their dancers’ bodies and use these measures to inform subsequent training. However, for those with the primary aim of early detection of injury risk, lumbopelvic control and dynamic balance measures should be prioritized. Additionally, other research suggests that future screening programs aimed at identification of injury risk should also consider measurement of aerobic fitness, the Beighton hypermobility test, lower extremity muscle flexibility, and dance technique motor control/alignment, as these measures have also been associated with dance-related injury.23

7.2.5 Injury rehabilitation
Findings from the current research indicate that accelerometers are not a reliable tool for measuring lower-limb asymmetries in healthy dancers, limiting their use for injured dancers. There has been much discussion surrounding the utility of lower-limb asymmetry measurement throughout injury rehabilitation in sport. For example, recent literature has shown that decreases in asymmetry during lower-limb asymmetry rehabilitation is likely due to decreased performance of the uninjured limb.120 Therefore, to move dance-related injury rehabilitation strategies forward, future studies should focus on the establishment of baseline and normative values of limb asymmetries and jump performance for a more appropriate reference post-injury.

7.3 Strengths and Limitations
The body of research in this dissertation has several strengths. A comprehensive injury surveillance program with evidence-based pre-season screening was employed in a pre-professional ballet cohort across five academic years. A high response rate (91.4%) across the
Five years minimizes the likelihood of selection bias in this research. The use of a consistent, evidence-based pre-season screening protocol across allowed for establishment of norms and rigorous examination of potential modifiable risk factors for dance-related injury.

For Chapters three and four, the main limitation of this study is the self-report nature of the questionnaire used. Because data was self-reported, medical diagnoses of reported injuries were not collected. Given the young age and lack of medical knowledge, it is possible that injury definitions could have been misinterpreted by some participants (i.e., muscle soreness reported as an injury). However, this was mitigated at the start of the study by providing a detailed explanation of injury to each student. In Chapter three, dance exposure hours were also self-reported and there were no questions included in the questionnaire surrounding the intensity of dance training. For Chapter four, another limitation was the small sample size of participants who participated across all five years of data collection (n=10). This limited the ability to examine year-to-year differences in our risk factor modeling.

Chapter five of this study evaluated the reliability of a dance-specific jump test using wearable devices for the detection of lower-limb asymmetry. Placement of the IMUs on the tibia doesn’t account for any accelerations proximal to the shin during landing. In addition, no analysis was performed on the propulsion phase of the jumps, which is relevant during lower-extremity injury rehabilitation. Additionally, this study was limited to two testing sessions, when previous research has found that four to five testing sessions may be necessary to produce reliable estimates of individuals movement patterns. Lastly, a lack of previous literature describing the acceptable limits of agreement for acceleration during landing and inter-limb asymmetries meant
that acceptable limits of agreement were not outlined \textit{a priori}. A small sample size of female, healthy, free from injury dancers limits the generalizability of the findings from Chapter five.

In Chapter six, different raters administered different screening tests from year to year introducing the possibility of some variability in the results, due to the longitudinal nature of the study. However, between-day reliability of all assessments was established in the first year of the study and all raters underwent the same comprehensive training each subsequent year to mitigate potential variability. Values presented in Chapter six are specific to adolescent pre-professional ballet dancers, and therefore generalizability of findings should be limited to similar dancer populations. Additionally, there is limitation to the use of normative values in an adolescent cohort who may be at different phases of maturation. Consideration of the individual’s growth and stage of development is important when comparing a dancer’s values to these norms.

Lastly, across this body of research, there was a small sample size of male dancers in this study (Chapters three and four: n=53; Chapter six: n=66), limiting the ability to examine risk factors of dance-related injury by sex. A small male sample size in Chapter six contributes to the specificity of the normative values and percentiles presented for that cohort of male adolescent pre-professional ballet dancers. Additionally, pre-professional dancers were the population of interest in all studies, limiting the generalizability of results to other dance genres or levels.

7.4 Conclusions

In conclusion, the research presented in this dissertation has made novel contributions to the current understanding of injury and potential risk factors among pre-professional level dancers.
The use of a comprehensive injury surveillance program across multiple years has established consistent risks for dance-related injury in pre-professional dancers. The interconnection of specific risk factors (i.e., years of previous dance training, psychological coping skills) for dance-related injury was determined. Baseline and normative values of jump performance and common pre-season screenings may be a more appropriate reference for injury than lower-limb asymmetry metrics. Knowledge from this research will further aid the development, implementation, and evaluation of targeted injury prevention programs to reduce the prevalence and incidence of injury in pre-professional dancers.
References


60. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports medicine.* 2014;44:139-147.


64. Harrison EC. Within-Day Energy Balance and the Relationship to Injury Rates in Pre-Professional Ballet Dancers. 2009;


APPENDIX A: DANCE-SPECIFIC QUESTIONNAIRE ON HEALTH PROBLEMS

The following questions will be completed online by each dancer, each week.

Please answer ALL questions, regardless of whether or not you have experienced health problems in the past week. If you have several illnesses or injury problems, please refer to the one that has been your worst problem this week. Reply with the number that corresponds to your best answer to each question.

Question 1. Have you had any difficulties participating in normal dance class, rehearsals, and/or performances due to injury, illness or other health problems during the past week?
   - Full participation without health problems
   - Full participation, but with injury/illness
   - Reduced participation due to injury/illness
   - Cannot participate due to injury/illness

Question 2. To what extent have you reduced the amount you dance due to injury, illness or other health problems during the past week?
   - No reduction
   - To a minor extent
   - To a moderate extent
   - To a major extent
   - Cannot participate at all

Question 3. To what extent has injury, illness or other health problem affected your dancing during the past week?
   - No effect
   - To a minor extent
   - To a moderate extent
   - To a major extent
   - Cannot participate at all

Question 4. To what extent have you experienced symptoms/health complaints during the past week?
   - No symptoms/health complaints
   - To a mild extent
   - To a moderate extent
   - To a severe extent

* If participant responds #1 to the first 4 questions, they will be asked Question 13.
* If participant responds any number except #1 to the first 4 questions, they will be asked Question 5.

Question 5. Is the health problem referred to in the first four questions an injury or an illness?
   - Injury
   - Illness

* If participant answers #1 to Question 5, they will be asked Question 6, 8 onwards.
* If participant answers #2 to Question 5, they will be asked Question 7, 8 onwards.

Question 6. What is the location of your injury? If the injury involves several locations, please select the main area.
- Head/face
- Neck
- Shoulder
  (including clavicle)
- Upper arm
- Elbow
- Forearm
- Wrist
- Hand/fingers
- Chest/ribs
- Abdomen
- Thoracic spine
- Lumbar spine
- Pelvis and buttock
- Hip and groin
- Thigh
- Knee
- Lower leg
- Ankle
- Foot/toes
- Other

**Question 7.** What major symptom have you experienced during the past 7 days? Select several symptoms if they are related.

- Fever
- Fatigue/exhaustion
- Swollen glands
- Sore throat
- Blocked
  nose/running
- nose/sneezing
- Cough
- Breathing
difficulty/tightness
- Headache
- Nausea
- Vomiting
- Diarrhea
- Constipation
- Fainting
- Rash/itchiness
- Irregular
  pulse/arrhythmia
- Chest pain/angina
- Abdominal pain
- Other pain
- Numbness/pins
  and needles
- Anxiety
- Depression/sadness
- Irritability
- Eye symptoms
- Ear symptoms
- Symptoms from
  urinary
  tract/genitalia
- Other
Question 8. Please state the number of days over the past 7-day period that you have had to completely miss dancing due to this problem?
   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7

Question 9. Is this the first time you have reported this problem through this monitoring system?
   - Yes, this is the first time.
   - No, I have reported the same problem in one of the previous four weeks.
   - No, I have reported the same problem previously, but it was more than four weeks ago.

Question 10. Have you sought medical attention for this problem?
   - Yes
   - No

*If participant responds #1 for Question 10, they will be asked Question 11.

Question 11. Please provide a diagnosis for this problem.

Question 12. Have you experienced any other injuries, illnesses or other health problems that have restricted you from full participation in class, rehearsal, and/or performances in the past week?
   - Yes
   - No

*If participant responds #1 for Question 12, they will be asked Question 13.

Question 13. Please provide detail on what this injury or illness was.

DANCE EXPOSURE

Question 1. State the total number of hours you spent in CLASS during the past 7 days.

Question 2. State the total number of hours you spent in REHEARSAL during the past 7 days.

Question 3. State the total number of hours you spent in PERFORMANCE during the past 7 days.

Question 4. State the total number of hours you spent in OTHER PHYSICAL ACTIVITY during the past 7 days.
APPENDIX B: PRE-SEASON SCREENING PROTOCOLS

Baseline Data Collection: Demographic Risk Factors
Following informed consent (see Appendix C & D), participants will complete two questionnaires prior to the start of the academic year:
1. Physical Activity Readiness Questionnaire (PAR-Q) (Appendix E). All participants with any positive response on the PAR-Q will be reviewed and where indicated, participants will be referred to a physician for completion of the Physical Activity Readiness Medical Examination (PARmed-X) (Appendix F), prior to participation in baseline data collection.

2. Health Screen for Dancers Form (Appendix G) as adapted from the Taskforce on Dancer Health, Dance/USA. Components include, age, general medical history, prior injury history, menstrual status, years dance training, and dance discipline.

Baseline Data Collection: Psychological Risk Factors
Athletic Coping Skills Inventory-28 (ACSI-28)(Appendix H). The ACSI is a measure of coping skills. The ACSI-28 contains 28 items representing seven sub-scales: coping with adversity, peaking under pressure, goal setting/mental preparation, concentration, freedom from worry, confidence and achievement motivation, and coachability. The response scale ranges from 0 (almost never) to 3 (almost always). To apply the ACSI-28 to dance, this questionnaire has been modified to refer to dance practice and performance.

Baseline Data Collection: Structural Risk Factors
Height (m) will be measured without shoes using a portable stadiometer to the nearest 0.1 cm. Weight (kg) will be measured using a portable medical weight scale to the nearest 0.1 kg. The weight scale will be calibrated prior to each testing day. Body mass index (BMI) will be calculated (kg/m²).

Baseline Data Collection: Range of Motion (ROM) Risk Factors

Ankle range of motion
Ankle dorsiflexion was measured barefoot, while weight bearing (standing lunge), and followed protocols from Bennell et al. To be considered a valid trial, the knee of the participant must have been touching the wall, while the heel maintained contact with the floor, and the knee aligned with the foot. The standing lunge measure included the distance from the big toe to the wall (cm) and the angle of the Achilles tendon to the vertical using an inclinometer (deg) placed along the tibia one third of the distance from the medial malleolus to the lateral epicondyle.

Non weight bearing active plantar flexion (PF) was assessed with an inclinometer as per Russell et al. Two measures were recorded: one along the anterior border of the distal tibia and the second along the dorsal foot across the distal talus and navicular. The difference between values indicated participants’ degree of PF. A difference of 0 deg described a 180 deg angle between
tibia and foot (corresponding to 90 deg PF), a positive difference indicated greater than 180 deg (PF>90 deg) and a negative difference indicated less than 180 deg (PF<90 deg).\textsuperscript{131}

\textit{Hip range of motion}

Total active external hip rotation was assessed using Functional Footprints\textsuperscript{®} (Balanced Body, Sacramento, CA, USA). Functional Footprints\textsuperscript{®} produce minimal friction, requiring the participant to utilize their external rotator muscles as opposed to ‘forcing turnout’. Participants stood barefoot with the heel and second toe aligned with pre-determined markers on the Functional Footprints\textsuperscript{®}. With instruction to keep the spine and pelvis neutral, the participant externally rotated from the hips. The corresponding angle from each leg was recorded from the Functional Footprints\textsuperscript{®} and added together to determine total active standing turnout.\textsuperscript{75}

\textbf{Baseline Data Collection: Functional Risk Factors}

\textit{Lumbopelvic control}

The integrity of the function to transfer loads between the lumbosacral spine and legs was assessed by the Active Straight Leg Raise (ASLR). Utilizing protocol described by Mens et al\textsuperscript{103}, dancers lay supine with extended legs. Participants were asked to raise one leg at a time, 5 cm in the air. A physiotherapist scored presence of compensation on a 4-point Likert scale (0=no restriction; 1=limited compensation, mild impairment; 2=increased compensation, moderate impairment; 3=inability to raise the leg). Each participant completed three repetitions on each side.

The ability to stabilize intrapelvic motion was assessed by the Stork test, hereafter referred to as One Leg Standing (OLS). Following Hungerford et al\textsuperscript{69}, participants were instructed to stand in parallel with equal weight distributed through each leg. A physiotherapist palpated the posterior superior iliac spine (PSIS) and the sacrum. Participants raised the contralateral leg to 90 deg hip flexion and 90 deg knee flexion three times, returning to neutral stance in between each movement. A positive score resulted if the PSIS on the supportive leg side moved upward relative to the sacrum (hip hiking), a negative score indicated the PSIS stayed neutral or moved downward relative to the sacrum (hip dropping).

\textit{Dynamic balance}

Non-functional dynamic balance included a barefoot, timed, one leg balance on a foam pad with eyes closed. Protocol followed Emery et al\textsuperscript{43} whereby the longest time on balance was recorded following three trials. Participants stood in the center of the balance pad with eyes closed, hands on hips. Participants closed their eyes prior to elevation of the non-weight bearing foot from the pad. The non-weight bearing foot hovered at approximately shin level, with the sole of the foot facing posteriorly, not contacting the weight-bearing leg. The longest balance time (to the nearest 0:01 seconds) of 3 trials (15 seconds rest between trials) was recorded using a stopwatch for each leg. Time was stopped with loss of balance (i.e., removal of one hand from the hip, eyes opening, touching the balance pad, weight bearing leg or floor with the non-weight bearing foot, movement of the weight-bearing foot or balance from its original position).
Functional dynamic balance utilized the Y-Balance Test. Lower limb length (anterior superior iliac spine to lateral malleolus in cm) was measured in order to normalize distance reached. Three trials were measured, and the farthest distance (cm) reached in each of three directions (anterior, posteromedial, posterolateral) was recorded. Participants were instructed to hold their foot for approximately 2 seconds at the end of each maximal reach. The gesture leg returned to center and was allowed to touch down momentarily before reaching in the next direction. A trial was discarded and repeated with loss of balance (i.e., lifting or moving the standing foot from the grid, fully touching down with the gesture foot, failing to return the gesture foot to center between each direction, removal of one hand from the hip).
APPENDIX C: CONSENT FORM FOR DANCERS (18 YEARS AND OVER)


SPONSOR: Sport Injury Prevention Research Centre, University of Calgary.

INVESTIGATORS: Principal Investigator: Dr. Carolyn Emery; Research Coordinator: Sarah Kenny, PhD Candidate

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information. You will receive a copy of this form.

BACKGROUND
In order to master their craft, dancers participate in rigorous training that incorporates both physical and artistic requirements. Research suggests that dance is a high-risk activity with high prevalence and incidence of musculoskeletal injuries. Attempts to understand potential causes of injuries in dance have focused on a variety of factors (e.g. age, previous injury, intensity of training), but only recently have efforts been put forward to understand dance-specific screening assessments to help develop effective means of preventing and reducing the risk of injury in the dance population.

Put simply, a dance injury will keep you from dancing and being active, which can change how healthy you are. Research is important to help understand how to keep these dance injuries from happening. It helps us understand how many injuries there are and what increases the chances of getting hurt. This research will also help us come up with ways to stop injuries from happening in the future.

WHAT IS THE PURPOSE OF THE STUDY?
The purpose of this study is to understand injury patterns and if there are certain measures that can help identify your chances of getting an injury before an injury actually happens.

WHAT WOULD I HAVE TO DO?
All testing will be done in a dance studio at your school. One test will be carried out in the Human Performance Lab at the University of Calgary.

Before training starts:
You will fill out forms that include a medical questionnaire, a dance history form, and a psychological skills form. After completing the forms, you will participate in physical assessments that will measure:
• how tall you are, how much you weigh, your foot position, how much range of motion is in your ankles and hips
• how well you plié, control your pelvis, land a jump and balance
• the density (strength) of your bones, and the size of your lower back muscles
You may be randomly selected to repeat these measures one week later. A certified physiotherapist and the research coordinator will conduct all of the assessments. It should take approximately 1.5hrs to complete all of these tests.

During the school year:
After testing, you will keep track of how many hours of dancing you participate in each week (including all classes, rehearsals, and performances). You may be randomly selected to record your sleep quality by wearing a monitor on your wrist for 5 consecutive nights at 3 points during the year. You will also keep track if get injured at any time during the academic year by completing a weekly online questionnaire. An injury means any physical or psychological complaint resulting from class, rehearsal or performance regardless of its consequences (e.g. having to miss class or see a medical practitioner). The physiotherapist will support you if you get injured, giving any treatment and rehabilitation you may need. If you have an injury that makes you miss more than one week of class, rehearsal or performance, you will have the chance to see a Sports Medicine Physician at the Sports Medicine Centre at the University of Calgary.

WHAT ARE THE RISKS?
We will do everything we can to ensure that you do not experience any discomfort during the physical assessments. It is possible that discomfort could arise during the tests but this is unlikely, because you will be moving within your normal ranges of movement and muscle strength. There is a very small chance of getting a sprain or strain while landing a jump. If this is the case, testing will cease immediately.

WILL I BENEFIT IF I TAKE PART?
If you agree to participate in this study there may or may not be a direct benefit to you. If you have been identified as having a dance injury, your condition may be improved during the study but there is no guarantee that this research will help you. The information we get from this study may help us to provide better treatments in the future for injured dancers.

DO I HAVE TO PARTICIPATE?
You do not have to be in the study and you can leave the study at any time by telling the research coordinator, Sarah Kenny (403220-8949 or kenny.s@ucalgary.ca). Your decision to take part or not will have no impact on course grades or other evaluations. You can ask questions at any time during the study, and if anything new about the study comes up while it is happening, you will be told.

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?
You will not get paid for being a part of this study. You will not have to pay for anything.

WILL MY RECORDS BE KEPT PRIVATE?
All of the information collected throughout the study period will have the names taken off and will remain private. The information collected about you will be kept safely locked. Only the researchers responsible for this study, the Dance
Physiotherapist who will be doing the baseline testing, and the Conjoint Health Research Ethics Board will have access to this information. Using only a study identification number in the database will protect your privacy. The reported results of the study will not identify you in any way.

IF I SUFFER A RESEARCH RELATED INJURY, WILL I BE COMPENSATED?
In the event that you suffer injury as a result of participating in this research, no compensation will be provided to you by the Sport Injury Prevention Research Centre, the University of Calgary, Alberta Health Services or the Researchers. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

SIGNATURES
Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardizing your health care. If you have further questions concerning matters related to this research, please contact: Sarah Kenny (Research Coordinator) 1-403-220-8949 Dr. Carolyn Emery (Principal Investigator) 1-403-220-4608

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary at 1-403-220-7990.

__________________________________________
Participant’s Name

Signature and Date

__________________________________________
Investigator/Delegate’s Name

Signature and Date

__________________________________________
Witness’ Name

Signature and Date

The University of Calgary Conjoint Health Research Ethics Board has approved this research study. A signed copy of this consent form has been given to you to keep for your records and reference.
APPENDIX D: ASSENT FORM FOR DANCERS (UNDER 18 YEARS)

**TITLE:** Does injury definition matter? The influence of different definitions on the pattern of injury and risk factors for injury in female ballet and contemporary student dancers.

**SPONSOR:** Sport Injury Prevention Research Centre, University of Calgary.

**INVESTIGATORS:** Principal Investigator: Dr. Carolyn Emery; Research Coordinator: Sarah Kenny, PhD Candidate

**WHAT IS A RESEARCH STUDY?**
A research study is a way to find out new information about something. Children do not need to be in a research study if they don’t want to.

**WHAT IS THIS RESEARCH STUDY ABOUT?**
In Calgary, a lot of children take dance classes and it is common to get injured in these dance classes. A dance injury will keep you from dancing and being active, which can change how healthy you are. Research is important to help understand how to keep these injuries in dance from happening. It helps us understand how many children dance, how many injuries there are, what makes the chances of getting injured higher and what people can do to lower the chances of getting hurt right now. This will help researchers come up with ways to stop injuries from happening in the future.

**WHY AM I BEING ASKED TO BE PART OF THIS RESEARCH STUDY?**
You are being asked to take part in this research study because we are trying to learn more about how we can prevent dance injuries from happening. We are asking you to be in the study because it will help us understand if there are certain measurements that can help identify your chances of getting an injury before an injury actually happens. About 100 dancers will be in this study.

**IF I JOIN THE STUDY WHAT WILL HAPPEN TO ME?**
We want to tell you about some things that will happen to you if you are in this study. You will be in the study for one academic year.

**Before dance training starts:**
You will fill out some more forms that include a medical questionnaire, a dance history form, and a form that tells us how well you manage being a dancer. After completing the forms, you will participate in physical assessments that will measure:
- how tall you are, how much you weigh, your foot position, how much range of motion is in your ankles and hips
- how well you plié, control your pelvis, land a jump and balance
the density (strength) of your bones, and the size of your lower back muscles
You may be asked to repeat these measures one week later. A certified physiotherapist and research coordinator will conduct all of the assessments. It should take approximately 1.5hrs to complete all of these tests.

During the school year:
After testing, you will keep track of how many hours of dancing you do each week (including classes, rehearsals, and performances). You may be selected to measure your sleep quality by wearing a monitor on your wrist for 5 consecutive nights at 3 points during the year. You will also keep track if get injured at any time during the school year by filling out a questionnaire online. An injury means any physical or psychological complaint resulting from class, rehearsal or performance regardless of its consequences (e.g. having to miss class or see a medical practitioner). The physiotherapist will support you if you get injured, giving any treatment and rehabilitation you may need. If you have an injury that makes you miss more than one week of class, rehearsal or performance, you will have the chance to see a Sports Medicine Physician at the Sport Medicine Centre at the University of Calgary.

WILL ANY PART OF THE STUDY HURT?
We will do everything we can to ensure that you do not experience any discomfort during the physical assessments. It is possible that discomfort could arise during the tests but this is unlikely, because you will be moving within your normal ranges of movement and muscle strength. There is a very small chance of getting a sprain or strain while jumping. If this is the case, testing will stop immediately.

WILL THE STUDY HELP ME?
If you agree to be in this study there may or may not be a direct medical advantage. You may have lower chance of injury during the study but there is no guarantee that this research will help you. If you have a dance injury during the study, the physiotherapist will assess you and give you advice about any treatment they think would help you.

WILL THE STUDY HELP OTHERS?
This study might find out things that will help other young dancers not get injured as much someday.

DO MY PARENTS/GUARDIANS KNOW ABOUT THIS STUDY?
We will talk to your parents/guardians about your participation in this study as well. You can talk this over with them before you decide.

WHO WILL SEE THE INFORMATION COLLECTED ABOUT ME?
The information collected about you during this study will be kept safely locked up. Nobody will know it except the people doing the research. The study information about you will not be given to your parents or teachers. The researchers will not tell your friends or anyone else.

WHAT DO I GET FOR BEING IN THE STUDY?
You will not get paid for being a part of this study. You will not have to pay for anything.

**DO I HAVE TO BE IN THE STUDY?**
You do not have to be in the study. No one will be upset if you don’t want to do this study. Your decision to be in the study or not will have no impact on course grades or other evaluations. If you don’t want to be in this study, you just have to tell us. It’s up to you. You can also take more time to think about being in the study.

**WHAT IF I HAVE ANY QUESTIONS?**
You can ask any questions that you may have about the study. If you have a question later that you didn’t think of now, either you can call or have your parents call the Research Coordinator, Sarah Kenny (403-220-8949 or kennys@ucalgary.ca). You can also take more time to think about being in the study and also talk some more with your parents about being in the study.

**WHAT CHOICES DO I HAVE IF I SAY NO TO THIS STUDY?**
This study is extra, so if you don’t want to do it nothing else will change.

**OTHER INFORMATION ABOUT THE STUDY**
If you decide to be in the study, please write your name below. You can change your mind and stop being part of it at any time. All you have to do is tell the person in charge. It’s okay. The researchers and your parents won’t be upset. You will be given a copy of this paper to keep.

**WOULD YOU LIKE TO TAKE PART IN THIS STUDY?**

_____ Yes, I will be in this research study.  
_____ No, I don’t want to do this.

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<tr>
<th>Child’s Name (Print)</th>
<th>Signature of the child</th>
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APPENDIX E: PAR-Q
PAR-Q & YOU
(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO
1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered
YES to one or more questions
Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.
• You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
• Find out which community programs are safe and helpful for you.

NO to all questions
If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
• start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
• take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:
• if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
• if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____________________________

SIGNATURE ____________________________ DATE __________

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) ____________________________ WITNESS ____________________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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Health Canada

Santé Canada

continued on other side...
...continued from other side

PAR-Q & YOU

Physical Activity Readiness Questionnaire - PAR-Q
(Revised 2012)

Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add up your activities in periods of at least 10 minutes each. Start slowly... and build up.

Time needed depends on effort

Start with a 10 minute walk – gradually increase this time. Find out about walking and cycling path nearby and use them.

Benefits of regular activity

Better health, improved fitness, better balance and co-ordination, weight control, stronger muscles and bone density, reduced stress, reduced risk of chronic disease, improved mood and reduced risk of coronary disease in later life.


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FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors’ use by contacting the Canadian Society for Exercise Physiology (address below):

- The Physical Activity Readiness Medical Examination (PARmed-X) – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

- The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy) – to be used by doctors with pregnant patients who wish to become more active.

References:


For more information, please contact the:

Canadian Society for Exercise Physiology
200-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

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Ethics ID: REB14-0897

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APPENDIX F: PAR-MEDX
The PARmed-X is a physical activity-specific checklist to be used by a physician with patients who have had positive responses to the Physical Activity Readiness Questionnaire (PAR-Q). In addition, the Conveyance/Referral Form in the PARmed-X can be used to convey clearance for physical activity participation, or to make a referral to a medically-supervised exercise program.

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. The PAR-Q by itself provides adequate screening for the majority of people. However, some individuals may require a medical evaluation and specific advice (exercise prescription) due to one or more positive responses to the PAR-Q.

Following the participant’s evaluation by a physician, a physical activity plan should be devised in consultation with a physical activity professional (CSEP-Professional Fitness & Lifestyle Consultant or CSEP-Exercise Therapist™). To assist in this, the following instructions are provided:

**PAGE 1:**
- Sections A, B, C, and D should be completed by the participant BEFORE the examination by the physician. The bottom section is to be completed by the examining physician.

**PAGES 2 & 3:**
- A checklist of medical conditions requiring special consideration and management.

**PAGE 4:**
- Physical Activity & Lifestyle Advice for people who do not require specific instructions or prescribed exercise.
- Physical Activity Readiness Conveyance/Referral Form - an optional tear-off tab for the physician to convey clearance for physical activity participation, or to make a referral to a medically-supervised exercise program.

**A PERSONAL INFORMATION:**
- NAME ____________________________
- ADDRESS ____________________________
- TELEPHONE ____________________________
- BIRTHDATE ___________ GENDER ______
- MEDICAL No. ____________________________

**RISK FACTORS FOR CARDIOVASCULAR DISEASE:**
- Check all that apply
- Less than 30 minutes of moderate physical activity most days of the week.
- Currently smoker (tobacco smoking 1 or more times per week).
- High blood pressure reported by physician after repeated measurements.
- High cholesterol level reported by physician.
- Excessive accumulation of fat around waist.
- Family history of heart disease.

**PAR-Q:** Please indicate the PAR-Q questions to which you answered YES
- Q 1 Heart condition
- Q 2 Chest pain during activity
- Q 3 Chest pain at rest
- Q 4 Loss of balance, dizziness
- Q 5 Bone or joint problem
- Q 6 Blood pressure or heart drugs
- Q 7 Other reason:

**PHYSICAL ACTIVITY INTENTIONS:**
- What physical activity do you intend to do?

**D PHYSICAL ACTIVITY INTENTIONS:**
- What physical activity do you intend to do?

**This section to be completed by the examining physician**

**Physical Exam:**
- Ht Wt BP (i) / BP (ii) /

**Conditions limiting physical activity:**
- Cardiovascular
- Respiratory
- Musculoskeletal
- Abdominal
- Other

**Tests required:**
- ECG
- Exercise Test
- X-Ray
- Blood
- Urinalysis
- Other

**Physical Activity Readiness Conveyance/Referral:**
- Based upon a current review of health status, I recommend:
- No physical activity
- Only a medically-supervised exercise program until further medical clearance

- Progressive physical activity:
  - with avoidance of:
  - with inclusion of:

- under the supervision of a CSEP-Professional Fitness & Lifestyle Consultant or CSEP-Exercise Therapist™
- Unrestricted physical activity—start slowly and build up gradually

**Supported by:**
- Health Canada
- Canadian Society for Exercise Physiology

**Ethics ID: REB14-0897**
### PARmed-X PHYSICAL ACTIVITY READINESS MEDICAL EXAMINATION

Following is a checklist of medical conditions for which a degree of precaution and/or special advice should be considered for those who answered "YES" to one or more questions on the PAR-Q and people over the age of 69. Conditions are grouped by system. Three categories of precautions are provided. Comments under Advice are general, since details and alternatives require clinical judgement in each individual instance.

<table>
<thead>
<tr>
<th>Absolute Contraindications</th>
<th>Relative Contraindications</th>
<th>Special Prescriptive Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent restriction or temporary restriction until condition is treated stable, and/or past acute phase.</td>
<td>Highly variable. Value of exercise testing and/or program may exceed risk. Activity may be restricted. Desirable to maximize control of condition. Direct or indirect medical supervision of exercise program may be desirable.</td>
<td>Individualized prescriptive advice generally appropriate: • Limitations imposed and/or • Special exercises prescribed. May require medical monitoring and/or initial supervision in exercise program.</td>
</tr>
</tbody>
</table>

#### Cardiovascular
- aortic aneurysm (dissecting)
- aortic stenosis (severe)
- congestive heart failure
- crescendo angina
- myocardial infarction (acute)
- myocarditis (active or recent)
- pulmonary or systemic embolism—acute
- thrombophlebitis
- ventricular tachycardia and other dangerous dysrhythmias (e.g., multi-focal ventricular activity)

#### Infections
- acute infectious disease (regardless of etiology)
- subacute/chronic/ recurrent infectious diseases (e.g., malaria, others)

#### Metabolic
- uncontrolled metabolic disorders (diabetes mellitus, thyrotoxicosis, myxedema)

#### Pregnancy
- complicated pregnancy (e.g., toxemia, hemorrhage, incompetent cervix, etc.)
- advanced pregnancy (late 3rd trimester)

#### Cardiac
- aortic (or pulmonary) stenosis—mild aortic stenosis and other manifestations of coronary insufficiency (e.g., post-acute infarct)
- cyanotic heart disease
- shunts (intermittent or fixed)
- conduction disturbances
- complete AV block
- left BBB
- Wolff-Parkinson-White syndrome
- dysrhythmias—corroded
- fixed rate pacemakers

#### Hypertension
- systolic 160-180; diastolic 105+
- progressive exercise; care with medications (serum electrolytes; post-exercise syncope; etc.)

#### Intermittent Claudication

#### Progressive exercise to tolerance

#### References:

The PAR-Q and PARmed-X were developed by the British Columbia Ministry of Health. They have been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

No changes permitted. You are encouraged to photocopy the PARmed-X, but only if you use the entire form.

Disponible en français sous le titre «Évaluation médicale de l’aptitude à l’activité physique (X-AAP)»

Continued on page 3...
### Special Prescriptive Conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td></td>
</tr>
<tr>
<td>❑ chronic pulmonary disorders</td>
<td>special relaxation and breathing exercises</td>
</tr>
<tr>
<td>❑ obstructive lung disease</td>
<td>breath control during endurance exercises to tolerance; avoid polluted air</td>
</tr>
<tr>
<td>❑ asthma</td>
<td></td>
</tr>
<tr>
<td>❑ exercise-induced bronchospasm</td>
<td>avoid hyperventilation during exercise; avoid extremely cold conditions; warm up adequately; utilize appropriate medication.</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td></td>
</tr>
<tr>
<td>❑ low back conditions (pathological, functional)</td>
<td>avoid or minimize exercise that precipitates or exacerbates e.g., forced extreme flexion, extension, and violent twisting; correct posture, proper back exercises</td>
</tr>
<tr>
<td>❑ arthritis—acute (infective, rheumatoid, gout)</td>
<td>treatment, plus judicious blend of rest, splinting and gentle movement</td>
</tr>
<tr>
<td>❑ arthritis—subacute</td>
<td>progressive increase of active exercise therapy</td>
</tr>
<tr>
<td>❑ arthritis—chronic (osteoarthritis and above conditions)</td>
<td>maintenance of mobility and strength; non-weight bearing exercises to minimize joint trauma e.g., cycling, aquatic activity, etc.</td>
</tr>
<tr>
<td>❑ orthopaedic</td>
<td>highly variable and individualized</td>
</tr>
<tr>
<td>❑ hemia</td>
<td>minimize straining and isometrics; strengthen abdominal muscles</td>
</tr>
<tr>
<td>❑ osteoporosis or low bone density</td>
<td>avoid exercise with high risk for fracture such as push-ups, curl-ups, vertical jump and trunk forward flexion; engage in low-impact weight-bearing activities and resistance training</td>
</tr>
<tr>
<td>CNS</td>
<td></td>
</tr>
<tr>
<td>❑ convulsive disorder not completely controlled by medication</td>
<td>minimize or avoid exercise in hazardous environments and/or exercising alone e.g., swimming, mountain climbing, etc.</td>
</tr>
<tr>
<td>❑ recent concussion</td>
<td>thorough examination if history of two concussions; review for discontinuation of contact sport if three concussions, depending on duration of unconsciousness, retrograde amnesia, persistent headaches, and other objective evidence of cerebral damage</td>
</tr>
<tr>
<td>Blood</td>
<td></td>
</tr>
<tr>
<td>❑ anemia—severe (&lt; 10 Gm/d)</td>
<td>control preferred; exercise as tolerated</td>
</tr>
<tr>
<td>❑ electrolyte disturbances</td>
<td></td>
</tr>
<tr>
<td>Medications</td>
<td></td>
</tr>
<tr>
<td>❑ antianginal</td>
<td></td>
</tr>
<tr>
<td>❑ antiarrhythmic</td>
<td></td>
</tr>
<tr>
<td>❑ antihypertensive</td>
<td></td>
</tr>
<tr>
<td>❑ anticonvulsant</td>
<td></td>
</tr>
<tr>
<td>❑ beta-blockers</td>
<td></td>
</tr>
<tr>
<td>❑ diuretics</td>
<td></td>
</tr>
<tr>
<td>❑ ganglionic blockers</td>
<td></td>
</tr>
<tr>
<td>❑ others</td>
<td></td>
</tr>
<tr>
<td>Foley</td>
<td></td>
</tr>
<tr>
<td>❑ antiarrhythmic</td>
<td></td>
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<tr>
<td>❑ antihypertensive</td>
<td></td>
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<tr>
<td>❑ anticonvulsant</td>
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<tr>
<td>❑ beta-blockers</td>
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<tr>
<td>❑ diuretics</td>
<td></td>
</tr>
<tr>
<td>❑ ganglionic blockers</td>
<td></td>
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<tr>
<td>❑ others</td>
<td></td>
</tr>
</tbody>
</table>

*Refer to special publications for elaboration as required*

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**The following companion forms are available online:** [http://www.csse.ca/forms.asp](http://www.csse.ca/forms.asp)

**The Physical Activity Readiness Questionnaire (PAR-Q)** - a questionnaire for people aged 15-69 to complete before becoming much more physically active.

**The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for PREGNANCY)** - to be used by physicians with pregnant patients who wish to become more physically active.

For more information, please contact the:

Canadian Society for Exercise Physiology  
205 - 185 Somerset St West  
Ottawa, ON K1P 0Z  
Tel. 1-877-651-3755 • FAX (613) 234-3565 • Online: www.csse.ca

---

**Note to physical activity professionals...**

It is a prudent practice to retain the completed Physical Activity Readiness Convenance/Referral Form in the participant's file.
PARmed-X Physical Activity Readiness Conveyance/Referral Form

Based upon a current review of the health status of ________________________________, I recommend:

- No physical activity
- Only a medically-supervised exercise program until further medical clearance
- Progressive physical activity
  - with avoidance of: ________________________________
  - with inclusion of: ________________________________
  - under the supervision of a CSEP-Professional Fitness & Lifestyle Consultant or CSEP-Exercise Therapist™
- Unrestricted physical activity — start slowly and build up gradually

Further Information:
- Attached
- To be forwarded
- Available on request

Physician/clinic stamp: ________________________________

NOTE: This physical activity clearance is valid for a maximum of six months from the date it is completed and becomes invalid if your medical condition becomes worse.

M.D. ___________________________________________ 2004

(date)
APPENDIX G: HEALTH SCREEN FOR DANCERS

Participant ID: ______________  Date: ____________

Name: ________________________________________________________________
Address: ______________________________________________________________
Home Phone: ____________________________________________________________
Cell Phone: ______________________________
E-mail address: _________________________________________________________

Date of birth: _______________________________________________________________________
Age: ______________________________________________________________________________
Sex: Male  Female

Background Information
Current year of study: _________________________________________________________
Predominant dance style/discipline: ______________________________________________
How many years have you been dance training prior to starting at this institution?
(at least 3 times per week): ______________________________________________________

Medical History
Check ‘yes’ or ‘no’. Explain YES answers below.
Circle questions you do not know the answers to.
If you need assistance with any of the questions below, please ask the health care team.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1. Has a doctor ever denied or restricted your participation in dance or sports for any reason?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Do you have an ongoing medical condition such as a thyroid disease, diabetes or asthma? Please specify:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Have you ever passed out or nearly passed out DURING exercise?</td>
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<td>4. Have you ever passed out or nearly passed out AFTER exercise?</td>
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<td>5. Have you ever had discomfort, pain or pressure in your chest during exercise?</td>
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<td></td>
<td>6. Does your heart race or skip beats during exercise?</td>
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<tr>
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<td></td>
<td>Has a doctor ever told you that you have: (check all that apply)</td>
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<tr>
<td></td>
<td></td>
<td>7. high blood pressure</td>
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<tr>
<td></td>
<td></td>
<td>8. heart murmur</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9. high cholesterol</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10. heart infection</td>
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<tr>
<td></td>
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<td>11. Has a doctor ever ordered a test for your heart? (For example: EKG, Echocardiogram)</td>
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<tr>
<td>Question</td>
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<td>-------------------------------------------------------------------------</td>
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<td>12. Has anyone in your family ever died for no apparent reason?</td>
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<tr>
<td>13. Does anyone in your family have a heart problem?</td>
<td></td>
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<tr>
<td>14. Has any family member or relative died of heart problems or sudden death before age 50?</td>
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<tr>
<td>15. Does anyone in your family have Marfan's syndrome?</td>
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<tr>
<td>16. Have you ever spent the night in the hospital?</td>
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<td>17. Have you ever had surgery?</td>
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<tr>
<td>18. Do you cough, wheeze, or have difficulty breathing during or after exercise?</td>
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<td>19. Have you ever used an inhaler or taken asthma medicine?</td>
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<tr>
<td>20. Do you have any rashes, pressure sores or other skin problems?</td>
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<tr>
<td>21. Have you had infectious mononucleosis (mono) in the past month?</td>
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<td>22. Have you ever had a head injury or concussion?</td>
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<td>23. Have you ever been hit in the head and been confused or lost your memory?</td>
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<tr>
<td>24. Have you ever had a seizure?</td>
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<tr>
<td>25. Do you have headaches with exercise?</td>
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<tr>
<td>26. When exercising in the heat, do you have severe muscle cramps or become ill?</td>
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<tr>
<td>27. Has a doctor told you that you or someone else in your family has sickle cell trait or sickle cell disease?</td>
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<tr>
<td>28. Have you had any problems with your eyes or vision?</td>
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<tr>
<td>29. Do you wear glasses or contacts?</td>
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<tr>
<td>30. Have you been vaccinated for chicken pox?</td>
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<td></td>
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<tr>
<td>31. Have you been vaccinated for mumps?</td>
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<td></td>
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<tr>
<td>32. Have you been vaccinated for measles?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33. Have you been vaccinated for rubella?</td>
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<tr>
<td>34. Are you up to date on your vaccines?</td>
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</tbody>
</table>

Please give dates and detailed explanations for any items marked ‘yes’ above:

Questions Number | Dates and Explanations
<table>
<thead>
<tr>
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<tbody>
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</table>

Please describe and explain any other medical issues not stated above:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
**Orthopedic History**
Check ‘yes’ or ‘no’. Explain YES answers below.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1. Have you ever had an injury, like a sprain, muscle or ligament tear or tendinitis that caused you to miss more than two days of class, rehearsal or performances? If yes, circle affected area below:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Have you ever had any broken or fractured bones or dislocated joints? If yes, circle below:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Have you had a bone or joint injury that required x-rays, MRI, CT, surgery, injections, physical therapy, a brace, a cast or crutches? If yes, circle and explain below:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neck</td>
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<td></td>
<td></td>
<td>Hip</td>
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<td>4. Have you ever had a stress fracture? Where?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Have you ever sprained your ankle? If yes: right? left?</td>
</tr>
</tbody>
</table>

Please give dates and detailed explanations for any items marked ‘yes’ above:
Indicate if injury is ongoing or resolved at this time.

<table>
<thead>
<tr>
<th>Dates and Explanations</th>
<th>Ongoing</th>
<th>Resolved</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

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### General Questions
Check ‘yes’ or ‘no’. Explain YES answers below.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>During the past month have you felt down, depressed or hopeless?</td>
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<td></td>
<td></td>
<td>During the past month have you lost interest or pleasure in doing things?</td>
</tr>
<tr>
<td></td>
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<td>Do you feel you suffer from bouts of fatigue or tiredness more than your fellow dancers?</td>
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<tr>
<td></td>
<td></td>
<td>Do you have trouble falling asleep or getting back to sleep if you wake in the night?</td>
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<td></td>
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<td>Do you consider yourself sleep deprived?</td>
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<tr>
<td></td>
<td></td>
<td>Do you often wake up more than twice during the night or have trouble going to sleep?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Never</td>
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<tr>
<td></td>
<td></td>
<td>Sometimes</td>
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<tr>
<td></td>
<td></td>
<td>Often</td>
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<tr>
<td></td>
<td></td>
<td>Very often</td>
</tr>
</tbody>
</table>

In the past year, have you had a loss of friend(s), or family, or partner/spouse, or pet through death, separation, change in relationship or relocation?

Do you have difficulty with substance abuse?

Are you interested in nutritional counseling?

Do you take calcium supplements? _________ mg/day

Do you take Vitamin D? _________ International Units/day

Are you a smoker?
If yes: How many years? _________ How many cigarettes per day? _________

Do you feel you would benefit from counseling for any of the above?

Other Concerns:

________________________________________

________________________________________

________________________________________

________________________________________

Females Only
Last gynecological visit: ___________________________________________________
Have you started to menstruate? ___________________________________________
At what age did your periods start? _________________________________________
Frequency of menstruation (# of times/year) ______
Approximately how many periods have you had in the last 12 months? (Please tick)
☐ 0-3  ☐ 3-6  ☐ 6-9  ☐ 9-12  ☐ 12+
Are your cycles: (circle) Regular  Irregular
If irregular, longest time between cycles: ______________________________________
Are you currently on any form of birth control?   Yes  No
Please list: _______________________________________________________________
APPENDIX H: ATHLETIC COPING SKILLS INVENTORY-28

Participant ID: ______________ Date: ____________

**Instructions**: The following are statements that dancers have used to describe their experiences. Please read each statement carefully, and then recall as accurately as possible how often you experience the same thing. There are no right or wrong answers. Do not spend too much time on any one statement.

Please circle how often you have these experiences when you are dancing.

<table>
<thead>
<tr>
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<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On a daily or weekly basis, I set very specific goals for myself that guide what I do.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>2</td>
<td>I get the most out of my talent and skill.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>3</td>
<td>When a teacher or director tells me how to correct a mistake I've made, I tend to take it personally and feel upset.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>4</td>
<td>When I'm dancing, I can focus my attention and block out distractions.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>5</td>
<td>I remain positive and enthusiastic during performance, no matter how badly things are going.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>6</td>
<td>I tend to perform better under pressure because I think more clearly.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>7</td>
<td>I worry quite a bit about what others think of my performance.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>8</td>
<td>I tend to do lots of planning about how to reach my goals.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>9</td>
<td>I feel confident that I will perform well.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>10</td>
<td>When a teacher or director criticizes me, I become upset rather than feel helped.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>11</td>
<td>It is easy for me to keep distracting thoughts from interfering with something I am watching or listening to.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td></td>
<td>I put a lot of pressure on myself by worrying about how I will perform.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
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</tr>
<tr>
<td>13</td>
<td>I set my own performance goals for each practice.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>14</td>
<td>I don't have to be pushed to practice or perform well; I give 100%.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>15</td>
<td>If a teacher criticizes or yells at me, I correct the mistake without getting upset about it.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>16</td>
<td>I handle unexpected situations in my performance very well.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>17</td>
<td>When things are going badly, I tell myself to keep calm, and this works for me.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>18</td>
<td>The more pressure there is during a performance, the more I enjoy it.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>19</td>
<td>While performing, I worry about making mistakes or failing to come through.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>20</td>
<td>I have my own performance plan worked out in my head long before the performance begins.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>21</td>
<td>When I feel myself getting too tense, I can quickly relax my body and calm myself.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>22</td>
<td>To me, pressure situations are challenges that I welcome.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>23</td>
<td>I think about and imagine what will happen if I fail or screw up.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>24</td>
<td>I maintain emotional control regardless of how things are going for me.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>25</td>
<td>It is easy for me to direct my attention and focus on a single object or person.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>26</td>
<td>When I fail to reach my goals, it makes me try even harder.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>27</td>
<td>I improve my skills by listening carefully to advice and instruction from teachers and directors.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>28</td>
<td>I make fewer mistakes when the pressure is on because I concentrate better.</td>
<td>Almost never</td>
<td>Sometimes</td>
<td>Often</td>
<td>Almost always</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------</td>
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APPENDIX I: CONSENT FORM FOR UNIVERSITY DANCE MAJORS

UNIVERSITY OF CALGARY
CONSENT TO PARTICIPATE IN RESEARCH

TITLE: Returning to Dance: Assessment of asymmetry during rehabilitation of elite adolescent ballet dancers

SPONSOR: Sport Injury Prevention Research Centre, University of Calgary

INVESTIGATORS: Principal Investigator: Dr. Kati Pasanen
Co-Investigators: Dr. Sarah Kenny, Dr. Reed Ferber, Dr. Lauren Benson, and Meghan Critchley, MSc

CONTACT INFORMATION: Phone: 307-287-1997
Email: meghan.critchley@ucalgary.ca

INTRODUCTION

Kati Pasanen and associates from the Faculty of Kinesiology at the University of Calgary are conducting a research study.

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information. You will receive a copy of this form for your records.

You were identified as a possible participant in this study because you are a full-time student at the University of Calgary in the Bachelor of Arts Dance program. Your participation in this research study is voluntary.

WHY IS THIS STUDY BEING DONE?

In order to master their craft, dancers participate in rigorous training that incorporates both physical and artistic requirements. Research suggests that dance is a high-risk activity with high prevalence and incidence of musculoskeletal injuries. Attempts to
understand potential causes of injuries in dance have focused on a variety of factors (e.g. age, previous injury, intensity of training), but only recently have efforts been put forward to understand dance-specific screening assessments to help develop effective means of preventing and reducing the risk of injury in the dance population.

Put simply, a dance injury will keep you from dancing and being active, which can change how healthy you are. Research is important to help understand how to keep these dance injuries from happening. It helps us understand how many injuries there are and what increases the chances of getting hurt. This research will also help us come up with ways to stop injuries from happening in the future.

The purpose of this research study is to understand injury patterns and if there are certain measures that can help identify your chances of getting an injury before an injury actually happens.

HOW MANY PEOPLE WILL TAKE PART IN THIS STUDY?

About 40 people will take part in this study at the University of Calgary.

WHAT WILL HAPPEN IF I TAKE PART IN THIS STUDY?

If you volunteer to participate in this study, the researcher will ask you to do the following:

Before training starts:
You will fill out forms that include a medical questionnaire, a dance history form, and a psychological skills form that may include sensitive questions (i.e. questions concerning psychological stress, sleep habits, or nutrition) that may be upsetting to some individuals. After completing the forms, you will participate in physical assessments that will measure:

- how tall you are, how much you weigh, your foot position, how much range of motion is in your ankles and hips
- the strength of your legs, how well you plié, control your pelvis, land a jump and balance

You will repeat these measures one week later. A certified physiotherapist and the research coordinator will conduct all of the assessments. It should take approximately 1 hr to complete all of these tests. You will be excused from class to participate in this testing session.

All testing will be done in a dance studio at your school.

HOW LONG WILL I BE IN THIS STUDY?
Participation will take a total of about 30 min during the baseline testing and another 30 minutes session a week later.

**ARE THERE ANY POTENTIAL RISKS OR DISCOMFORTS THAT I CAN EXPECT FROM THIS STUDY?**

We will do everything we can to ensure that you do not experience any discomfort during the physical assessments. It is possible that discomfort could arise during the tests, but this is unlikely, because you will be moving within your normal ranges of movement and muscle strength. There is a very small chance of getting a sprain or strain while landing a jump. If this is the case, testing will cease immediately.

**ARE THERE ANY POTENTIAL BENEFITS IF I PARTICIPATE?**

If you agree to participate in this study, there may or may not be a direct benefit to you. If you have been identified as having a dance injury, your condition may be improved during the study but there is no guarantee that this research will help you. The information we get from this study may help us to provide better treatments in the future for injured dancers.

**WHAT OTHER CHOICES DO I HAVE IF I CHOOSE NOT TO PARTICIPATE?**

You do not have to be in the study and you can leave the study at any time by telling the research coordinator, Meghan Critchley (307-287-1997 or meghan.critchley@ucalgary.ca). Your decision to take part or not will have no impact on course grades or other evaluations. You can ask questions at any time during the study, and if anything new about the study comes up while it is happening, you will be told.

**CAN I STOP BEING IN THE STUDY?**

Yes. You can decide to stop at any time. Tell the researchers if you are thinking about stopping or decide to stop.

**WHAT IF RESEARCHERS DISCOVER SOMETHING ABOUT ME?**

During the study, the researchers could learn something about you that they didn’t expect. For example, the researchers may find out that you have another medical condition. The researchers will consult with medical experts as needed to evaluate the findings and will then share these results with you. You will be helped with arranging appropriate follow up and care.
I consent for the researchers to share findings with me:

☐ YES
☐ NO

WITHDRAWAL OF STUDY DATA
You are free to withdraw from the study at any time. Should you wish to withdraw from this study, you can also request that your data be removed from the study. You will be able to withdraw your data from this study until data analysis begins up to 2 months after the end of the school year. At this point, you will no longer be able to request to have your data removed from the study.

WILL I BE PAID FOR PARTICIPATING?
You will not be paid for your participation in this research study.

DO I HAVE TO PAY FOR ANYTHING?
You will not have to pay for anything. There are no costs associated with this study as participation will take place at your school.

WILL INFORMATION ABOUT ME AND MY PARTICIPATION BE KEPT CONFIDENTIAL?
The researchers will do their best to make sure that your private information is kept confidential. Information about you will be handled as confidentially as possible, but participating in research may involve a loss of privacy and the potential for a breach in confidentiality. The research team will handle data according the Data Management Plan as outlined below:

Some identifiable information about you will be replaced with a code. A master list linking the code and your identifiable information will be kept separate from the research data. Only the investigators responsible for this study, the research staff, the University of Calgary, and the Conjoint Health Research Ethics Board will have access to this information. Confidentiality will be protected by using only study identification numbers in the database. Any results of the study, which are reported, will in no way identify study participants. Your de-identified data may be combined with data from other studies conducted by the research team. This study utilizes an online survey company (REDCap), which stores identifying data separately, securely, and is a double authentication password-protected secure database. This data will be stored securely on servers within Canada.

HOW LONG WILL INFORMATION FROM THE STUDY BE KEPT?
The researchers intend to keep and store the research data and records for approximately 5 years on a secure server. If you consent to the use of your research
data for use in future research it may be kept for a longer period. Any future use of this research data is required to undergo review by a Research Ethics Board.

USE OF DATA FOR FUTURE RESEARCH

My research data may be kept for use in future research to learn about, prevent or treat other health-related problems.

☐ YES
☐ NO

CONTACT FOR FUTURE RESEARCH

University of Calgary researchers may contact me in the future to ask me to take part in other research studies.

☐ YES
☐ NO

IF I SUFFER A RESEARCH-RELATED INJURY, WILL I BE COMPENSATED?

It is important that you tell the researchers if you believe that you have been injured because of taking part in this study.

In the event that you suffer injury as a result of participating in this research, no compensation will be provided to you by the Sport Injury Prevention Research Centre, the University of Calgary, Alberta Health Services or the Researchers. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

WHOM MAY I CONTACT IF I HAVE QUESTIONS ABOUT THIS STUDY?

The Research Team:
You may contact Meghan Critchley at meghan.critchley@ucalgary.ca with any questions or concerns about the research or your participation in this study.

Conjoint Health Research Ethics Board (CHREB):
If you have any questions concerning your rights as a possible participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary at 403-220-7990.
WHAT ARE MY RIGHTS IF I TAKE PART IN THIS STUDY?

Taking part in this study is your choice. You can choose whether or not you want to participate. Whatever decision you make, there will be no penalty to you.

- You have a right to have all of your questions answered before deciding whether to take part.
- Your decision will not affect the standard medical care you receive or your education.
- If you decide to take part, you may leave the study at any time.

HOW DO I INDICATE MY AGREEMENT TO PARTICIPATE?

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to take part in the study. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities.

SIGNATURE OF STUDY PARTICIPANT

Name of Participant ____________________________

Signature of Participant ____________________________ Date __________

SIGNATURE OF PERSON OBTAINING CONSENT

Name of Person Obtaining Consent ____________________________ Contact Number __________

Signature of Person Obtaining Consent ____________________________ Date __________

SIGNATURE OF THE WITNESS

Name of Witness ____________________________
Signature of Witness ___________________________ Date ___________________________

A signed copy of this consent form has been given to you to keep for your records and reference.
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Figure 1. The Sequence of Prevention - page 84

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Portions Fig. 1. The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading to real-world sports injury prevention.

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Pre-Season Screening and Injury Surveillance in Pre-Professional Dancers: A Longitudinal Study

Institution name  
University of Calgary

Expected presentation date  
Sep 2022

Portions  
Figure 1. Complex model for sports injury on page 4
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