Incidence of Musculoskeletal Injuries in Professional Dancers

A DISSERTATION BY HEATHER BROOKER (BRKHEA001) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN EXERCISE AND SPORTS PHYSIOTHERAPY FROM THE UNIVERSITY OF CAPE TOWN

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Declaration

I, Heather Brooker (BRKHEA001), hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed by candidate

……………04/02/2020……………………………….

(Signature)

_________08/02/2020________

(Date)

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List of Abbreviations

ACL	Anterior Cruciate Ligament
BMD	Bone Mineral Density
BMI	Body Mass Index
DEXA	Dual-Energy X-Ray Absorptiometry
EA	Energy Availability
FAT	Female Athlete Triad
FLEE	Functional Lower Extremity Evaluation
GRF	Ground Reaction Force
GPS	Global Positioning System
LEA	Low Energy Availability
LEFT	Lower Extremity Functional Test
LH	Luteinizing Hormone
MRI	Magnetic Resonance Imaging
NSAIDs	Non-Steroidal Anti-Inflammatory
OA	Osteoarthritis
PF	Plantarflexion
RED-S	Relative Energy Deficiency in Sport
RFD	Rate of Force Development
RMR	Resting Metabolic Rate
RTP	Return to Play
US	Ultrasound

Glossary of Terms

Acute Injury	An injury resulting from a single, traumatic event (1).
Acute:Chronic Training Ratio	Considers current and previous training load over a period of time (2).
Arabesque	A ballet posture whereby one leg is extended and rotated at right angles to the body, with the trunk bending forwards and arms outstretched in alternating positions (3).
Dehors	The lateral rotation and execution of a step, from anterior to posterior (4).
Demi pointe	A ballet position whereby the dancer dances on the balls of her feet (5).
En pointe	A ballet position whereby the dancer dances balancing on the tip of her toes(5).
Ground reaction force	The force equal in magnitude and opposite in direction exerted by the ground on a body in contact with it (6).
Jete	A ballet jump with the dancers springing from one foot to another while the opposite leg is extended outwards while in the air (7).
Overuse Injury	An injury resulting from a repeated microtrauma to musculoskeletal structures (4).
Plie	A ballet movement with the feet externally rotated and heels planted firmly on the ground while the dancer bends and straightens the knees (3).
Pointe Shoes	Specialised ballet shoes allowing the dancer to dance en pointe (8).
Porte	The action in which a male ballet dancer carries his partner through the stage (4).
Training loads	The physiological feedback of a single training session (9).
Traumatic Injury	An acute injury, most commonly resulting from an external force (4).

Abstract

Background

Professional ballet dancers focus on the high levels of discipline, perfection and mobility to achieve the fluid, controlled lines of movement presented on the stage. Dancers undergo long hours of strenuous, repetitive training which increases the risk of developing overuse or traumatic injuries and may compromise the longevity of dancers' careers. Relevant research, particularly in the South African context, is needed to provide recommendations on the intrinsic and extrinsic factors contributing to musculoskeletal injuries in professional ballet dancers.

Aim

The aim of this study was to determine the incidence of musculoskeletal injuries and their associated risk factors over a three-month period in adult female professional ballet dancers in South Africa.

Specific Objectives

The specific objectives of this study were:

- To determine the incidence of traumatic and overuse injuries per 1000 dance hours over a three-month training and performance period in South African female professional ballet dancers;
- To determine the relationships between a) Functional Lower Extremity Evaluation (FLEE) scores and injury incidence; b) intrinsic factors (amenorrhoea; body mass index; skinfold measurements; caloric intake) and injury incidence; and c) extrinsic factors (training hours; performance hours) and injury incidence respectively, in South African female professional ballet dancers.

Methods

This study had a prospective, descriptive design. Eighteen female dancers were recruited from professional dance companies in the Gauteng, Western Cape and North West provinces of South Africa.

Data were collected over a three-month period and included a subjective questionnaire, three-day food diary, skinfold measurements and the Functional Lower Extremity Evaluation (FLEE). Injuries were reported using an injury reporting form over the three-month period.

Results

Participants had an average age of 22.1 ± 3.0 years. The dancers had an average BMI of 21.4 ± 2.1 $kg.m^{-2}$; LBM of 41.7 ± 4.9 kg and body fat percentage of 24.7% ± 2.9%. Injury incidence was 3.3 injuries per 1000 dance hours with a total of 4605.58 hours reported overall. Of the 15 injuries reported, 13 occurred in the lower limb, with eight in the ankle and foot. Overuse injuries accounted for 93.3% of the total injuries, with only one traumatic injury reported. None of the descriptive characteristics was associated with increased injury risk. The average caloric intake of 1810.0 ± 503.7 calories, while lower than what is recommended for female athletes, also showed no significant relationship to injury. There were also no significant associations between pre-injury FLEE measurements and training loads; and injury incidence over the course of the study.

Conclusion

An overall injury incidence of 3.3 injuries per 1000 dance hours was found in professional female ballet dancers in South Africa, which is higher than the injury incidences identified in previous studies in high-income countries. With regards to injury profile, overuse injuries are 86% more prevalent than traumatic injuries among this population type. We were unable to identify any intrinsic or extrinsic risk factors associated with injury incidence; however, we recognise the limitations of the small sample size in this study.

With a high level of injury incidence and inconclusive results on injury risk factors, there is a clear need for significant further research in the field of injury prevention in professional ballet dancing. Further, this study identified a strong need for further research in South African dance companies to facilitate injury prevention and management in South Africa.

Chapter 1: Introduction and Scope of the Dissertation

1.1. Introduction

Professional ballet dancing requires high levels of technical skill and proficiency. As an art form, it involves performing repetitive, complex and physically demanding movements over a period of time (10). The demands of ballet combine the physiological requirements of an elite athlete with rigorous aesthetic demands. This is due to the dual athletic and artistic nature of ballet (11). The unique demands of flexibility, strength and body aesthetics combined with the high pressures of professional ballet training and performances place high levels of stress on the body's structures. These repetitive loads contribute to a high incidence of injury in ballet dancers (10,12).

The estimated cumulative incidence of musculoskeletal injuries in ballet ranges between 40% and 94% annually in professional and pre-professional dancers. This translates to 0.18 to 5.6 injuries per 1000 dance hours, with male and female dancers being equally affected (13,14). Overuse injuries have a higher incidence rate in comparison to traumatic injuries, with primary injury cause identified as repeated submaximal training loads without sufficient rest periods (15,16). Jumping movements, arabesques and lifting manoeuvres have been identified as the activities most commonly associated with injury development in ballet dancers (15).

The lower limb is the most commonly injured bodily region in ballet dancers, with the ankle (25%) and foot (21%) pathologies being most prevalent (17). Spinal injuries (cervical spine, 24%; lumbar spine, 17%) are also commonly encountered in this population (9). Common injuries include ankle impingements, tendon injuries of the ankle and foot, muscle strains of the lower limb muscles, ankle and knee joint sprains, sinus tarsi syndrome and spinal joint pathologies (17,18). Bone injuries such as tibial and metatarsal stress fractures, meniscal injuries and lumbar disc pathologies have been shown to result in the longest time loss from injury (17,18). Ballet dancers also suffer from higher rates of joint arthroses compared to the sedentary population (19).

Numerous contributing factors to the high injury incidence associated with ballet dancing have been identified (19). Extrinsic factors range from the style of dance techniques to psychological factors such as stress, tension and working conditions. Intrinsic factors such as previous injuries, joint hypermobility or hypomobility, excessive hip turnout, poor posture and strength and flexibility imbalances have also been identified (14,19,20). Age seems to be an important factor in the development of overuse injuries, as overuse injury prevalence increases with age (19).

In addition to the heightened musculoskeletal injury risk, the various pressures of professional ballet training and performance can result in the development of a variety of nutritional and metabolic disorders (13). This is most evident amongst female ballet dancers (13,21). These disorders may result in disordered eating patterns, bone mineral loss and dysmenorrhoea and are collectively referred to as the Female Athletic Triad (FAT) (21).

The Female Athlete Triad is most commonly observed in female athletes participating in “lean” or “aesthetic” sports (21). It is characterised by low energy availability secondary to nutritional deficiencies, which triggers alterations within the hypothalamic-pituitary axes of the body’s endocrine system (21,22). These changes result in altered secretion and function of the hormones typically involved in the regulation of menstrual function and can result in an increase in bone catabolism. These dysfunctions lead to the development of menstrual irregularity, osteopenia and osteoporosis (22). Nutrition has been found to have a significant impact on injury rates among dancers, mostly due to insufficient caloric intake (13).

Ballet dancers perform repetitive movements and actions over prolonged periods of time (12). Many of these movements occur in extreme positions or involve moving joints towards the ends of their range (12,19). With the repetitive application of these demanding movements and the associated higher injury risk, it is important to identify factors that could predispose to injury. This study will attempt to identify possible intrinsic and extrinsic risk factors that may predispose female ballet dancers to injury within a South African context. Similar research has yet to be undertaken in a population of South African professional ballet dancers specifically. The results of this epidemiological study will assist in developing an injury profile for female dancers in South Africa. This may assist dancers and dance instructors in South Africa with injury identification, injury prevention strategies and return to dance rehabilitation practices.

1.2. Aim and Objectives

1.2.1. Aim

To determine the incidence and associated risk factors of musculoskeletal injuries over a three-month period in adult female professional ballet dancers in South Africa.

1.2.2. Specific Objectives

The specific objectives of this study were:

- To determine the incidence of traumatic and overuse injuries per 1000 dance hours over a three-month training and performance period in South African female professional ballet dancers.
- To determine the relationships between a) Functional Lower Extremity Evaluation (FLEE) scores and injury incidence; b) intrinsic factors (amenorrhoea; body mass index; skinfold measurements; caloric intake) and injury incidence; and c) extrinsic factors (training hours; performance hours) and injury incidence respectively, in South African female professional ballet dancers.

1.3 Significance of this Study

The overarching significance of this study is that it will serve as a starting point for dance injury research in a South African context. This study will begin to build dance injury profiles for female professional ballet dancers in South Africa. The study findings may facilitate the implementation of injury prevention and management strategies to improve the health of ballet dancers in South Africa. The study findings may also serve to improve dancers' and instructors' knowledge regarding injury identification, possible injury prevention strategies, and return to dance decisions.

1.4 Plan of Development

Initially, the scope and significance of this dissertation will be outlined. This will include an introduction to the study and a description of the study aims and objectives (Chapter One). Literature pertaining to ballet injuries and the associated risk factors will be explored in the literature review (Chapter Two). The methodology of the prospective, descriptive study titled "Incidence of Musculoskeletal Injuries in Professional Ballet Dancers" will be outlined in Chapter 3. This study's results will be reported in Chapter 4 and discussed in Chapter 5. Chapter 6 will conclude the dissertation with a summary of key findings and recommendations for future research.

Chapter 2: Literature Review

2.1. Introduction to Professional Ballet Dancers

The study of ballet as an art form has evolved since the 1500s, gradually developing into classical ballet as we recognise it today (23). Ballet has a broad base of participants, ranging from recreational dancers and ballet students to professional dancers (23). Ballet combines the physiological requirements of an elite athlete with the aesthetics required due to the artistic nature of ballet (11).

The physiological demands of explosive bursts of movement required by all levels of ballet dancers are combined with extreme precision and control (24). The unique demands of flexibility, strength and body aesthetics, combined with the high pressures of professional training levels increase the risk for traumatic and overuse injuries (11). Performances and repetitive high impact dance movements place excessive amounts of physical stress on the bones, joints and muscles further increasing this risk (10,12).

Multiple intrinsic and extrinsic factors contributing to the high injury incidence in ballet have been identified (19). Intrinsic factors such as factors associated with the Female Athlete Triad (FAT), and previous injuries, have been acknowledged (14,19,25). Extrinsic factors range from dance shoes, flooring and presence of a medical team (15).

The interplay of the physical and aesthetic demands may lead to a variety of health problems including metabolic and nutritional disorders. These include bone mineral loss, disordered eating patterns and dysmenorrhoea (13). When combined, these result in the Female Athletic Triad (FAT) and the more recently defined Relative Energy Deficiency in Sports (RED-S) (21,26). These are most commonly observed in female athletes participating in 'lean' sports and is primarily characterised by low energy availability (LEA) which catalyses menstrual dysfunction and bone mineral loss (22).

This literature review will discuss the possible intrinsic and extrinsic risk factors that may predispose professional ballet dancers to injury. Multiple resources focusing on sport injury literature as well as dance medicine literature will be utilised to optimise findings, particularly in the South African context.

The following online databases were utilised for data used in this review: Google Scholar, Cochrane, Science Direct, and PubMed. These databases were searched from 1990 through to January 2020 utilising the following keywords: *"ballet", "ballet injuries", "musculoskeletal injuries in ballet" "professional ballet dancers", "female athlete triad", "relative energy deficiency in sports", "workload", "training loads", "intrinsic and extrinsic factors in ballet injuries"*, *"screening tests", "functional lower extremity evaluation".*

2.2. Ballet and Development of Ballet in South Africa

Ballet is a sport that crosses the artistic and cultural divide, being aesthetically pleasing and physically demanding, ballet dancers (and particularly female dancers) suffer similar struggles to gymnasts and endurance athletes (15). The combination of strict diets, stringent training regimes from young ages, the execution of repetitive movements through extreme ranges of motion, contribute to the elitism of professional ballet dancers and longevity as an athlete overall (4,10,27).

Ballet and dance as a whole have had a tumultuous history in Apartheid and Post-Apartheid South Africa, evolving from being associated with the white, privileged minority with generous government support, to being widely accessible across communities as part of community interactions and development (28). Cape Town City Ballet and what is now known as Joburg Ballet (originally the South Africa Ballet Theatre (SABT)) are some of South Africa's oldest and most established ballet companies and have successfully produced dancers who have performed throughout South Africa and on international stages (28,29).

Funding has been a challenge for professional ballet companies in South Africa in more recent years, resulting in many graduates (or entry-level dancers) paying to perform and train with these companies, often while studying part-time (29,30). This brings forth the challenges of successfully becoming a professional ballet dancer, nationally or internationally, with funding, accommodation and general daily costs of living, making many underprivileged or low-income dancers unable to fully complete their training and development to become professional ballet dancers (31).

With numerous factors affecting the development of ballet in a lower-income country, such as South Africa, ballet dancers are unique to their training, exposure and individual challenges, making research into South African ballet dancers vital when comparing data collected and results from higher-income countries.

2.3. Injuries in Ballet Dancers

2.3.1. Injury Definitions and Surveillance Systems

Injury definition and reporting methods vary within the literature and a study by Liederbach et al. (2012) demonstrated the lack of uniform injury surveillance systems within the dance community (32). They identified several versions of injury definitions:

- Tissue pathology and nature of the injury (such as a stain, sprain, inflammation or concussion);
- Duration and nature of necessary treatment;
- Time lost from a particular task or activity;
- Time lost from work or participation;
- Measure of permanent loss of function;
- And by cost of care.

Time lost from work or participation is the most commonly utilised injury definition across sporting fields, however discrepancies arise between reportable injuries that result in time loss and non-reportable injures which result in no time loss (32). Injury definitions typically have a high potential for error when it comes to reporting (32). Depending on a dancers threshold for pain, some may continue dancing with severe tissue damage, whilst others may not with a more mild complaint (32). For this reason, the only reliable definition of an injury is one that resulted in missed participation of a training session or performance (32).

Unfortunately, most injury incidence studies within the dance community have a variety of methods for collecting injury data without standardised injury definitions and exposure records, essentially only catching “the tip of the iceberg” (32).

2.3.2. Epidemiology

Allen et al. (2012) reported the incidence of injuries in professional ballet dancers as 4.44 injuries per 1000 dance hours. Male and female dancers had an average of 4.76 and 4.14 injuries per 1000 dance hours respectively (15). The estimated cumulative prevalence of musculoskeletal injuries ranges between 40% and 94% annually in professional and pre-professional dancers (11,14,15). This high injury rate has been attributed to training errors and biomechanical imbalances caused by technique flaws (33). Additionally, the absence of adequate recovery periods has also been implicated in injury development in dancers (34). Table 1 depicts injury incidence data from numerous studies on ballet dancers in the literature.

Table 1: Injury Incidence per 1000 Dance Hours.

Reference	Type of Dancers	Injury Definition	Injury Incidence (95% CI)	Male (95% CI)	Female (95% CI)
Allen et al. (2012)	Professional	Need to seek for care.	4.44 (4.00-4.93)	4.76 (4.12-5.51)	4.14 (3.57-4.81)
Ekegren et al. (2014)	Amateur	Full time loss of activity.	0.76 (0.71-0.81)	-	-
Gamboa et al. (2008)	Amateur	Need to seek for care.	0.77	-	-
Leanderson et al. (2011)	Amateur	Need to seek for care.	0.79	-	-
Nilsson et al. (2001)	Professional	Need to seek for care.	0.62	-	-

Overuse injuries have a higher incidence rate than traumatic injuries (15). The primary cause of these overuse injuries is thought to be high levels of repetitive submaximal training loads without sufficient rest (15,16). Both male and female dancers typically sustain transient, mild to moderate severity injuries, with few severe injuries being reported in previous studies (15).

The most commonly reported injuries involve the lower limb. Lower limb injuries include ankle impingements, tendon injuries, muscle strains, joint sprains (typically of the ankle and knee) and sinus tarsi syndrome (18,34). Anterior cruciate ligament (ACL) injuries are identified as the highest occurring acute lesion in the dancing population, particularly in classical ballet dancers (34). As ballet dancers age, joint arthroses and chondral pathology become more prevalent. This is most likely due to the recurring overuse injuries and high cumulative training loads experienced over their dancing careers (19). Table 2 shows the bodily regions most commonly injured, as reported in previous studies.

Table 2: Commonly Reported Injury Regions

<table>
<tr><th></th><th>Upper Extremity (%)</th><th>Trunk (%)</th><th>Lower Extremity (%)</th><th>Specifically, in the Foot and Ankle (%)</th></tr>
<tr><td>Costa et al. (2016)</td><td>17.0</td><td>28.3</td><td>33.9</td><td>71.7</td></tr>
<tr><td>Ekegren et al. (2014)</td><td>6.0</td><td>16.0</td><td>77.0</td><td>39.0</td></tr>
<tr><td>Gamboa et al. (2008)</td><td>-</td><td>9.0</td><td>38.0</td><td>53.0</td></tr>
<tr><td>Leanderson et al. (2011)</td><td>3.9</td><td>13.0</td><td colspan="2">83.1</td></tr>
<tr><td>Nilsson et al. (2001)</td><td>7.2</td><td>19.8</td><td>18.0</td><td>54.0</td></tr>
<tr><td>Sobrino et al. (2017)</td><td>2.2</td><td>20.5</td><td>42.3</td><td>34.7</td></tr>
<tr><td>Steinerg et al. (2013)</td><td>-</td><td>19.2</td><td>40.4</td><td>17.0</td></tr>
</table>

Male dancers suffer significantly more traumatic injuries compared to female dancers (19). However, female dancers have a higher incidence of overuse injury compared to male dancers (19). These overuse injuries in female dancers most commonly include tendinopathies of the flexor hallucis longus and the peroneal tendons (19).

The largest proportion of both traumatic and overuse injuries are sustained through jumping movements (24.8%) (15), whilst arabesques (7.1%), pointe or demi-pointe work (5.2%) and lifting movements (5.9%) also frequently resulted in injury (5,15).

The substantial difference in injury type, frequency and location between male and female dancers reflects the difference in dance techniques encountered by the sexes (5). Male dancers typically perform more equilibristic movements as well as higher, fuller jumping movements, such as portées (4,5). In addition, male dancers suffer a higher rate of traumatic injuries from lifting manoeuvres (4). In contrast, females dancers are exposed to significantly more dancing en pointe and demi-pointe, with high quantities of repetitive forced dehors (repeated rotation) movements being performed (4,19). This results in repeated excessive loads on the joints of the foot, leading to a higher rate of overuse knee and ankle injuries amongst female dancers (4,19)

There are minimal data on the effect of overuse musculoskeletal disorders on dancers once they have retired from their professional careers (17). However, the risk of sustaining injuries increases substantially with age and progression of performance levels (35). This makes injury prevention strategies of paramount importance in ballet dancers from a young age (12). In retired dancers, musculoskeletal pain and osteoarthritis (OA) are common complaints in the weight-bearing and spinal joints (25). Most dancers attribute these disorders to their profession and training specialisation from a young age (25). Factors, like performing and training surfaces, awareness of rest, identifying optimal training programmes, training load, age of initiating specialisation and the style of ballet, all contribute to the longevity of professional ballet dancers (20,25). One of the most frequent causes for the cessation of training in retired ballet dancers was OA of the hip joints and lumbar spine (25).

Injury epidemiology in South African ballet dancers is limited. The studies that have been completed have had samples from mixed dance disciplines, as well as varying levels of dance participation. This has led to little clear evidence of specific intrinsic and extrinsic factors associated with injury in professional ballet dancers.

2.3.3. Overuse Injuries

Overuse injuries are defined as tissue damage caused by repetitive, submaximal loading occurring over time without sufficient recovery (18,36). Exposure to high impact, repetitive dance movements in both training and performance, with insufficient recovery time between loading bouts, contribute to the high incidence of overuse injuries among the ballet dancing population (4,15). Dancers are exposed to these high training volumes and intensities from an early age. With inadequate healing and recovery time, the progression from acute to overuse injury occurs (4,18). Other than training and performance load, another prominent etiologic factor in the development of overuse injuries among professional ballet dancers is altered, non-optimal biomechanics. (4). Poor technique is a significant risk factor for the development of overuse injuries in dancers (4).

Overuse injuries account for 60% of all injuries reported in professional dancers. This figure rises to 68% when considering only female dancers (15). Overuse injuries also result in more significant time-loss from participation compared to acute traumatic injuries in both male and female dancers (15). Table 3 describes the prevalence of overuse injuries among professional and amateur ballet dancers, as reported in the literature.

Table 3: Prevalence of Overuse Injuries in Combined Professional and Amateur Ballet Dancers.

Reference	Male Dancers (%)	Female Dancers (%)	Overall (%)
Allen et al. (2012)	48.8	66.3	56.7
Ekegren et al. (2014)	-	-	72.0
Gamboa et al. (2008)	-	-	72.7
Leanderson et al. (2011)	76.9	77.0	76.9
Nilssen et al. (2001)	52.7	61.5	57.4
Sobrino et al. (2017)	-	-	75.3

Female dancers suffer 2.82 overuse injuries, in comparison to 1.49 traumatic injuries per 1000 dance hours (15). Overuse injuries in females typically result in three days of time loss compared to six days for traumatic injuries (7). Dancers are however able to continue to dance in a restricted manner despite the presence of an overuse injury result in prolonged recovery and delayed return to full training load (19,37). Traumatic injuries are associated with longer recovery periods away from dance participation, but potentially a shorter time until return to unrestricted dance participation in comparison to overuse injuries (15). Male dancers have a higher incidence of both overuse and traumatic injuries, reflected by incidence rates of 2.84 and 1.93 for overuse and traumatic injuries respectively. They also typically have a longer period of time-loss due to injury, with a mean nine-day injury time-loss reported for overuse injuries and ten days reported for traumatic injuries respectively (15).

2.3.4. Traumatic injuries

An injury is classified as a traumatic injury if it results from a precisely defined event with sudden onset of pain (15,19). Traumatic injuries are most typically seen in young, male soloist dancers, with ankle sprains and acute knee injuries being the most prevalent (12,19). Traumatic injuries account for 43% of all dancing injuries (19). Table 4 describes the incidence of traumatic injuries found in male and female dancers.

Table 4: Prevalence of Traumatic Injuries in Combined Professional and Amateur Ballet Dancers.

Reference	Male Dancers (%)	Female Dancers (%)	Overall (%)
Allen et al. (2012)	51.2	33.7	43.3
Ekegren et al. (2014)	-	-	28.0
Gamboa et al. (2008)	-	-	27.3
Leanderson et al. (2011)	23.1	23.0	23.1
Nilssen et al. (2001)	47.3	38.5	42.6
Sobrino et al. (2017)	-	-	24.7

Female ballet dancers suffer 1.49 traumatic injuries per 1000 dance hours compared to 1.93 traumatic injuries per 1000 dance hours in male ballet dancers (15). Traumatic injuries are significantly less frequent in ballet dancers, but were more severe when comparing recovery time and return to dance time (15). Traumatic injuries typically double the return to dance time in females and increase to between nine and ten days in males (15).

2.4. Intrinsic Risk Factors to Injury

Multiple intrinsic (person-related) risk factors to injury have been identified among ballet dancers. These include increased age, previous injury, career length, muscle strength, proprioception and flexibility imbalances, insufficient or excessive joint ranges and poor postural alignment (13,14,38,39). Modifiable intrinsic risk factors have been identified by Campbell (2019) (40) as the range of motion (ROM discrepancies, joint hypermobility, weak core and lower limb musculature as well as fatigue and overuse) (40). Features of the Female Athlete Triad (FAT) are commonly under-reported but remain an important intrinsic risk factor to injury in ballet dancers (39).

2.4.1 The Female Athlete Triad

The FAT was initially identified as three interrelated conditions, namely disordered eating (measured by energy availability), amenorrhoea (measured by menstrual function) and osteoporosis (measured by bone mineral density) (5,21,36,41). The FAT initiates with disordered eating, and the insufficient caloric intake negatively affects the hypothalamic-pituitary-ovarian (HPO) axis. This results in menstrual irregularities and hypoestrogenism, which leads to decreased bone mineral density and progression of osteoporosis (3,36).

Risk and contributing factors to the FAT include participation in endurance sports with aesthetic or weight-class components such as ballet, gymnastics and long-distance running. These sports are associated with an increased emphasis on diet, early sport specialisation and family dysfunction (21,36). Prevalence of all three individual components of the FAT in high school girls ranges between 1% to 1.2%. This prevalence increases by up to 16% in high school female athletes (21). Individual components of the FAT have a prevalence of up to 54% in high school female athletes, but these athletes are not defined as those with FAT (21).

Methods for identifying those at risk for developing the FAT include monitoring of menstrual patterns, body composition, body mass index (BMI), daily nutritional intake and DEXA scans to detect bone density abnormalities (13).

2.4.1.1. Energy Availability

Energy availability (EA) is defined as the daily dietary intake minus the daily exercise energy expenditure corrected for fat-free mass (FFM) (21). Optimal EA in adult female athletes has been identified as 45 $kcal.kg^{-1}$ FFM per day (21,41). When values drop below 30 $kcal.kg^{-1}$ of FFM, reproductive function and bone formation being compromised to restore energy balance (41). Studies have found that ballet dancers typically consume 70% to 80% of their recommended daily caloric intake (3,42)

Risk factors identified with disordered eating are periods of prolonged dieting, weight fluctuations, general anxiety, depression, power and with control driven personalities, injury, coaching changes and negative comments on body mass from coaches, parents or friends (4,21,36). The prevalence of disordered eating in female athletes has been reported to be as high as 62%, with an incidence of 1% occurring in the general population (36).

Inadequate nutrition resulting in low energy availability (LEA) has a significant impact on injury rates. This occurs when athletes fail to reach the required caloric intake to meet their training needs, resulting in a caloric deficit or energy insufficiency (13). This insufficiency adversely affects bone remodelling, bone mineralisation and also disrupts menstrual function (21). Even in the absence of amenorrhoea, disordered eating patterns have a strong association with a lower bone mineral density (BMD) in female athletes (21).

Treatment for the FAT takes a multi-disciplinary approach. This approach should involve a medical practitioner, dietician and mental health practitioner. In addition, interventions need to incorporate the coaching staff and family of the athlete, with the focus on body mass control and restoration of a regular menstrual cycle (3,36). Formation of goals, increasing caloric intake and reducing energy expenditure are the first steps towards recovery (36). Typically, this includes a decrease in training by approximately 10% to 20%, an increase in caloric intake to gain 2% to 3% of body mass, adding resistance training and calcium supplements (up to 1500mg/day), and monitoring bone mass and success of treatment with DEXA scans (36).

2.4.1.2. <u>Menstrual Dysfunction</u>

Menstrual dysfunction in the FAT is dependent on the normal function of the pituitary gland, hypothalamus, ovaries and endometrium (36). It may include anovulation, luteal dysfunction (characterised by a luteal phase shorter than 11 days), decreased progesterone concentration, and ultimately dysmenorrhoea (menstrual cycles lasting longer than 35 days) and amenorrhoea (21,36). Amenorrhoea may be further divided into primary (absence of menarche by the age of 15 years), and secondary (absence of menses for a minimum of three consecutive months) amenorrhoea (36).

Amenorrhoea due to inadequate energy availability is diagnosed as functional hypothalamic amenorrhoea (21) or exercise-associated amenorrhoea (EAA) (36). It is typically caused by a combination of low caloric intake and intense training with an underlying pathophysiological mechanism such as irregular pulsatile luteinizing hormone release and total suppression of diurnal leptin rhythm (36).

Dysmenorrhoea, and more importantly, amenorrhoea, occur commonly once body mass index (BMI) is below 17 or if the body fat percentage falls below 17% (42,43). Combined with levels of high-intensity training and diets with low-calorie intakes, a low BMI or body fat percentage contributes to delayed menarche and low basal metabolic rates (42).

Incidence of menstrual irregularities in female adolescent athletes is reported to be between 54% to 66%, compared to 5% to 21% in their sedentary counterparts (21,36,44). Primary amenorrhoea contributes between 1.2% and 6% to this total in athletes, with secondary amenorrhoea accounting for between 5.3% and 30% (21). Dysmenorrhoea and amenorrhoea are associated with cardiovascular risk factors and present with abnormal endothelial function and increased serum cholesterol (21).

The production of oestrogen protects the bone from bony resorption (36). Due to the hypo-oestrogenic state as a result of menstrual irregularities, amenorrhoea is associated with premature bone loss and increased risk of both acute and stress fractures in female athletes (36).

Athletes identified with menstrual dysfunction are three times more likely to sustain musculoskeletal and bone stress injuries and have a lower performance level than their eumenorrheic counterparts (21,36). Even in the absence of amenorrhoea, disordered eating patterns have a strong association with a lower bone mineral density (BMD) in female athletes (21). Athletes with amenorrhoea or dysmenorrhoea for periods lasting longer than six months have a 93% higher risk of stress fractures in comparison to those with regular menstrual cycles (14).

2.4.1.3. Bone Mineral Density (BMD)

Ballet dancers undergo intense training during their pre-adolescent and adolescent careers. These times are critical periods for bone mass accumulation (21). Interventions such as optimal caloric intake and hormone therapy during the early stages of training have been shown to be beneficial for peak bone mass accrual, lowering the risks of postmenopausal osteoporosis and the incidence of stress fractures in athletes (21,36). Ideally, 90% of bone mass accrual occurs by the age of 18 years in most females (3). The maximum rate of bone mass formation occurs between the ages of 10 to 14 years, with 95% of peak bone mass in females obtained by the age of 18 years. Thereafter, females lose bone mass at a rate of 0.3% to 0.5% per year (21,36).

Cortical bone sites (such as the proximal femur) benefit from optimal weight-bearing exercise to increase BMD, compared to sites containing more trabecular bone (such as the lumbar spine) which are more commonly adversely affected and have a minimal beneficial impact from weight-bearing exercise (45). However, the combination of vigorous exercise, hypogonadism and low BMI with amenorrhoea or dysmenorrhoea has been found to negatively alter BMD at cortical bone sites (45).

Adolescent female athletes who are amenorrhoeic may fail to lay down sufficient bone mass during these critical years of bone development or may lose previously accumulated bone mass (36). The amenorrhoeic athlete has been shown to lose 2% to 6% of accumulated bone mass per year, in comparison with the average rate of 0.3% to 0.5% per annum (36).

Genetics, weight-bearing sports and diet have an essential influence on BMD. Early interventions such as improved energy availability and resumption of menses have been shown to be beneficial in the prevention of the progression of BMD loss in some instances. However, only partial recovery may occur with a long term deficient BMD in comparison to typical healthy athletes (21,36). Amenorrhoeic athletes have been shown to have a significantly lower BMD in their lumbar spines, the neck of femur, greater trochanter, intertrochanteric region, shaft of femur and tibia when compared to healthy athletes (36).

2.4.2. Relative Energy Deficiency in Sports (RED-S)

Relative Energy Deficiency in Sports (RED-S) is a more recent inclusive variation from the FAT definition and extends to include male athletes with low energy availability (LEA) such as in weight class sports, cyclists, rowers and jockeys (26). The different biological and physiological responses associated with RED-S affect the testosterone levels in males, which results in a sequence of events similar to that seen in females suffering from the FAT (26).

In addition to LEA, menstrual dysfunction and compromised bone health, metabolic dysfunction may occur with significant reductions in resting metabolic rate (RMR) (26). Haematologically, iron deficiency contributes directly and indirectly to energy deficiency affecting bone health, thyroid function, fertility and haematological dysfunction in adolescent and young adult female athletes (26).

Growth and development are hindered in adolescent athletes with severe anorexia nervosa and partially affected in amenorrhoeic athletes with disordered growth hormone (GH) levels (26). Amenorrhoea in professional athletes has also been shown to result in endothelial dysfunction leading to lower heart rates and systolic blood pressure in athletes (26). This may result in more severe valve abnormalities, pericardial effusion, severe bradycardia, arrhythmias and hypotension affecting the cardiovascular system (26). Adverse effects of RED-S on the gastrointestinal tract include constipation, delayed gastric emptying and altered sphincter function due to the severe LEA state resulting from severe forms of anorexia nervosa (26).

Ballet dancers in particular have a high risk of developing RED's, up to 65% of vocational dancers were identified by Civil et al. (2019). Of those dancers, 40% reported menstrual dysfunctional, with lower energy balances and higher energy expenditures on weekdays as opposed to weekend days (44). The energy deficit noted was attributed to insufficient energy intake, with dancers being unable to meet energy requirements during ballet training days substantially increasing their risk of RED-S (44).

2.4.3. <u>Age</u>

Increasing age or certain periods of development (i.e. puberty or growth spurts) can act as significant risk factors for injury in dancers (46). In females, the age with the highest risk of injury in the lower limb is between 12 and 15 years (46). This is consistent in the adolescent ballet population, with the risk of injuries substantially increasing between 11 and 14 years of age (12). This increased risk in these age groups may be due to growth spurts, the onset of pointe training and increasing training loads that are all typical for this age group. The high injury risk in this adolescent age group supports the implementation of injury prevention programmes in young ballet dancers to reduce the risk of developing injury (12,27,46).

As dancers mature, the frequency and types of injuries reported change (4). This is due to increased training loads resulting in increased exposure to repetitive mechanical loading of the lower extremities. With increasing age beyond 30 years, cartilage-related injuries, lumbar disc diseases and Achilles tendinopathies become more prevalent (4).

2.4.4. <u>Body Size</u>

Factors including height, body mass, lean body mass, body fat content and body mass index (BMI) are considered intrinsic risk factors related to body size (46). An increase or decrease in one or more of these factors creates a disproportionate change in the forces transmitted through the body's musculoskeletal structures (46). High and low BMIs, high body fat content in males and shortened height in females are considered risk factors for injury in military recruits (46,47).

Body fat percentages range between 16% and 18% in professional female dancers, who represent the leanest figures for all types of dancers (42). Ballet dancers of all ages tend to have average heights; however, they fall below 82% of normal healthy body mass compared to matched controls. Higher reports of disordered eating among dancers could explain this deficit in healthy body mass (42).

Professional dancers have also been found to have a higher body mass index (BMI) in comparison to their younger counterparts, relating to an improved nutritional knowledge associated with age (48).

2.4.5. Previous Injury

Previous injuries have been shown to be significant predictors of injuries in ballet dancers and other athletes, creating a cumulative effect of injury throughout their dancing careers and training (18).

Previous injuries have a reported prevalence as high as 47% in previous studies in ballet dancers (39). The essential static and dynamic stabilisers of the joints of the lower extremity are affected following an injury. This may negatively affect muscle strength and endurance properties, proprioceptive feedback and the feeling of stability in the knee and ankle (46). Proprioceptive deficits, functional stability, ligament laxity, reduced muscle strength and subsequent imbalance are all factors related to previous injuries that may increase the risk of re-injury in the same location within a period of eight weeks in female athletes (46). This is particularly relevant in the lower limbs (46). Inadequate rehabilitation or hasty return to play (RTP) in general female athletes also increases the risk of a significant re-injury occurring within two months of RTP by 26% (46).

2.4.6. Hip Turnout

Ballet requires extreme ranges of movement for the ‘turnout’ position of the lower limbs, which ideally requires 180° of hip external rotation (33). The degree of turnout alters joint biomechanics and increases the susceptibility to injury along the kinetic chain. This results from the hip muscles providing insufficient strength and stability to the pelvis (33,49). The classic hip turnout position is seen in all five of the basic ballet positions, making it an essential component of dance technique and providing freedom of movement (33). Compensatory mechanisms present in the lower back, by tilting the pelvis anteriorly into a hyperlordosis of the lumbar spine resulting in a higher risk of developing spondylolysis (34). The associated hyperextension in the knees (i.e. genu recurvatum), and overactivation of the quadriceps to maintain the extended position required for pointe shoes, results in ligamentous laxity and increased risk of tendon injuries (33,34).

2.4.7. Psychological Factors Pertaining to Injury Prevention, Injury Development and Return to Play (RTP)

Injury in amateur and professional athletes has been associated with negative psychological responses, such as depression, anxiety, tension and low self-esteem (50). The psychological response to injury changes throughout rehabilitation and follows a U-shaped curve. Negative responses peak at the time of injury and again once cleared for RTP (50). The most detrimental emotional response at the time of RTP was identified as fear. This maladaptive response after injury may affect the quality of sports performance and increase the risk of re-injury (50).

Adverse life events, pressure to perform and low levels of social support have been identified as psychological risk factors for injury in ballet dancers (51–53). Factors identified as significant predictors for frequency of injury and duration of injury include freedom from worry and negative dance stress (52). Conversely, high levels of social support are seen as a resilience factor (51,54). Absence from dancing due to injury is significantly correlated to stress, sleep disturbances and negative mood states like depression, fatigue, confusion and anger (51,53). Rest and activity modification, when used as interventions, may also result in intense negative emotional and psychological reactions (3).

Psychological interventions, such as coping skills conditioning, imagery, self-talk and autogenic training have shown positive results in reducing injury time in professional ballet dancers (52). Coping skills include peaking under pressure, coping with adversity, confidence and achievement motivation and training aspects of concentration (52).

The overall evaluation of professional ballet dancers needs to include assessment and treatment of psychological distress. This includes sleep problems, perceived levels of stress, negative mood states and levels of social support. Addressing these risk factors could assist in injury prevention or rehabilitation strategies among dancers (51).

2.5. Extrinsic Risk Factors to Injury

Extrinsic risk factors to injury are defined as factors occurring outside of the person and typically include environment-related factors, footwear, training load parameters and the level of competition (46). The incidence of injuries due to an interplay of intrinsic and extrinsic factors are, however, considered higher than those injuries related to extrinsic factors alone (15).

2.5.1. Training Load

Ballet choreography is known to be complex and requires repetitive training (55). Optimal periodization is often absent in dance training and performance seasons, resulting in overtraining (55). The primary goal of the training stimulus is to improve performance and minimise the risk of injury and overtraining (9). To maximise this positive adaptive response to training, the stresses applied need to be managed individually for each athlete (56). The physical conditioning required for ballet dancing includes high training loads to achieve the necessary levels of aerobic fitness, neuromuscular coordination, agility, flexibility, muscle strength and power to perform the specialised movements associated with ballet (34). The performance of an athlete in response to their training load can be defined as either negative (fatigue) or positive (performance improvement). Training load has both intrinsic and extrinsic components specific to the nature, duration and intensity of training (9,56). Higher or excessive training loads tend to contribute to a higher injury rate in the pre-season or pre-performance period in collision sports, according to Gabbet & Domrow (2007) (9). They concluded that a slight reduction in training load lowered the injury incidence (9).

The physiological response to exercise provides the stimulus for adaptation, as opposed to the training itself (56). This balance to avoid fatigue is achieved through periodization. This maximises overuse training loads to optimise fitness adaptations and reduces loads prior to competition or performance to limit levels of acute fatigue (57).

Professional dancers can spend up to 40 hours per week training, with the volume often substantially increasing up to 10 hours a day during high-performance schedules (20,55). Performance schedules can often include eight performances per a week for a period of four to eight weeks, running concurrently with normal class and rehearsals (55). These significant volumes of training coupled with the high skill requirement of ballet dancing and the physiological loading may contribute to impaired performances and high injury rates associated with ballet (55). Training five hours or more per day has also been associated with increased risk of stress fractures in the lumbar vertebrae and lower limbs of ballet dancers (20). The combination of a poorly developed physiological system and high skill requirements often results in high levels of fatigue, impaired performance and increased injury incidence (55,58).

2.5.2. Overtraining

Overtraining (an extrinsic factor) commonly results in chronic fatigue (an intrinsic risk factor) (55). This negatively impacts the body's immune system, resulting in increased susceptibility to infections during periods of high training loads (41). The length of the season and high levels of prolonged loading over performance periods may have a considerable influence on the risk of developing overtraining syndrome (24,42). The positive effects of tapering have been shown to reduce the total mood disturbance rate by up to 50% in professional dancers when introduced one week prior to a performance and should include a reduction in the volume of training, not the intensity thereof (55).

Rest periods averaging between three and four weeks following the performance season have been shown to reverse the harmful effects of high training loads in vocational and professional ballet dancers (42,43). Tapering has also been shown to significantly improve performance when introduced one week prior to performance (55). However, rest periods of this length are not consistent and may occur two to three times a year, as the ballet season runs throughout the year and is based around rehearsals, performances and normal training periods (55).

2.5.3. Training Environment

Professional ballet dancers perform and rehearse at multiple venues, with little thought given to the mechanical properties of the surfaces on which they dance (20). Floor surfacing has been implicated in 20% to 28% of injuries reported in ballet dancers (20). An essential factor is the energy return and force reduction, or absorption properties of the flooring. Due to the style of ballet dancing, professional performances are recommended to take place on stages with optimal floor surfacing compared to generic sports halls where most adolescent and pre-pubescent training takes place (20). For example, sprung-floor staging is found in professional dance environments; in contrast to typical wooden flooring found in most school halls, where the majority of dancers begin their training. This may potentially contribute to the development of preventable injuries early in dancing careers. However, obtaining optimal flooring is a financial burden to schools and is difficult to modify and control (15).

2.5.4. Level of Competition

The level of competition is an important extrinsic risk factor which needs to be considered. Ballet dancers range from amateur, to pre professional and professional dancers, as well as dancing on national or international levels. Competition or performance environments carry a higher risk of injury than training (15). Injury incidence rates during competition maybe 24 times greater than incidence rates during training in sports such as handball, basketball and football (46). Unfortunately, there is no dance-specific research in this area.

2.5.5. Dancing Shoes

Classical female ballet dancers place unique stresses on their feet throughout their career. This is mostly due to their dancing in pointe shoes (59). Female dancers begin en pointe training from 11 years of age. Dancers progress from barefoot dancing to soft shoes, demi-pointe and then pointe shoes to allow sufficient preparation of the associated anatomical structures and reduce the risk of injury (60). Pointe shoes typically have a leather sole with a hard toe piece set in a canvas and silk sheath. The structure of these shoes allows dancers to balance on the tips of their toes (59). These materials have low shock-absorbing properties, consequently increasing the forces and demands placed on the foot while dancing (60). Demi-pointe shoes are used as an intermediary between soft and pointe shoes, allowing for the gradual distribution of pressure and lowering the risk of injury by 8%; compared to progressing directly from soft shoes to pointe shoes (60). The onset of pointe training in adolescent dancers marks the point of increase in the incidence of lower limb overuse injuries (60).

The extreme ranges of the foot and ankle reached in these shoes result in 14% to 57% of overuse injuries in the foot and ankle (8,59). The pointe shoe is designed to protect the feet during impact and to provide stabilisation with its rigid toe box (8). As the shoes age, they lose their structural firmness, resulting in significant changes in midfoot flexion and plantarflexion (PF). These changes in foot dynamics lead to altered bodyweight distribution through the metatarsals and phalanges (8). Older shoes result in accelerated rates of muscle fatigue, increased postural sway and decreased shock-absorption. This subsequently results in lower limb pain and increased injury incidences (8).

The high vertical ground reaction force and rate of force development (RFD) encountered during take-off and landing whilst jumping, repeated high impact loading and type of training shoe are all strongly associated with lower limb injuries in dancers (61). Ground reaction force reflects the duration and stresses placed on the lower extremities as the foot makes contact with the floor. The rate of force development (RFD) is the change in force over the change in time and reflects the speed at which force is developed in jump landing tasks (61).

Pearson & Whitaker (2012) (60) compared the pressures endured by the foot in ballet dancers while wearing soft, demi-pointe and pointe shoes respectively. They found soft shoes imposed the least amount of pressure on the foot with the highest amount of contact surface. Pointe shoes imposed the most pressure onto the plantar surface of the foot with the least amount of available contact surface (60). Demi-pointe shoes are designed from more flexible, shock-absorbing materials, which result in an increased contact surface area and an associated decrease in load and pressure placed on the foot. The increase in plantar surface pressure incurred in pointe shoes is a predictor of lower limb pain with exercise-related activities, and more specifically, a high predictor of overuse injuries (60).

2.5.6. Involvement of a Medical Team

Involvement of a medical team has been shown to reduce injury incidence by 34% in professional ballet companies measured over an eight-year period, with 56% fewer days of training lost overall (62). However, the absence of a fully involved medical team was found in 50% of professional companies based in Europe and North America (34). Reasons for this noticeable absence of a fully involved medical team may be related to the fear of interference in training practices and removal of dancers from full participation in the event of an injury. In addition, lack of funding was also a major factor associated with the lack of medical resources, as most professional dance companies rely on investors and sponsors for financial support (34).

Research has found numerous benefits of an in-house medical team. Direct access to rehabilitation and treatment reduces the financial burden on individual dancers and does not significantly interfere with training and rehearsal practices (62). Early intervention and reduced levels of anxiety assist to reduce injury incidence, with a positive relationship between the medical team, company directors, instructors and choreographers essential for these benefits to occur (62).

2.6. Measurement Instruments

This section of the review provides a brief overview of the Functional Lower Extremity Evaluation (FLEE) that was used as a measurement instrument in this study.

The process of injury screening has recently been identified as having numerous limitations, namely the process to develop and validate a screening test poses multiple factors which may affect the outcome, particularly with sport-specific outcomes (63,64).

2.6.1. Functional Lower Extremity Evaluation (FLEE)

The primary goal of the Functional Lower Extremity Evaluation (FLEE) is to identify the rehabilitation status of athletes before their return to play (RTP) following injuries of the lower limbs (65). The FLEE is a reliable assessment and clinically significant when determining RTP in athletes in field sports (65). This method assists in preventing re-injury of a limb following premature return to play as the risk of re-injury is considered to be four times that of the original injury (65). The FLEE takes approximately 45 minutes to complete, mimicking the high workload on the lower extremity and functional demands of movement, strength and endurance of typical field and contact sports and possibly ballet.

The test-retest reliability for the FLEE was found to be moderate to excellent, with an ICC ranging between 0.71 to 0.95. The inter-rater reliability was found to be high to excellent with an ICC ranging between 0.83 to 1.00 in healthy, uninjured athletes (65). It has not previously been validated on ballet dancers; but imitates similar requirements of lower extremity control, balance and proprioception required in ballet dancers (65).

The FLEE is a combination of eight tests used to increase the overall sensitivity of the end result (66). A detailed description of the components of the FLEE may be found in Section 3.5.4 of Chapter 3. Components of the FLEE assess balance and proprioception, agility and speed, aerobic and anaerobic conditioning, muscle flexibility, power, strength and endurance (67). The athlete needs to complete each level effectively and in the absence of pain before progressing to the next test (65).

The FLEE also assesses and analyses the normal alignment of the hip, knee and ankle, the accuracy of foot placement, balance and control within multiple planes of movement, deceleration control and landing skills/technique (65). These variables are associated with normal lower extremity function; and alterations in these variables identified in preseason screening may identify predisposing factors for injury, as well as provide baseline measurements for RTP decisions (65).

With limited injury research in ballet dancers and the use of objective screening tests, the FLEE may assist with the screening for potential predisposing factors for injury, specifically in professional ballet dancers.

2.7. Summary of the Literature

Pre-professional and professional ballet dancers have a high incidence of overuse and traumatic injuries due to multiple intrinsic and extrinsic risk factors (13,15). Stress fractures, lower back pain, hamstring strains and lower limb tendinopathies are the most common overuse injuries, while acute injuries include injuries of the medial structures of the knee and ankle sprains (14,34). Overuse injuries are more common, but are often under-reported and have prolonged recovery times; as dancers are typically able to train and perform with these injuries (14,15).

Intrinsic risk factors have been identified as the multifaceted FAT, growth spurts during periods of intense training, increasing age in dancers, hip turnout and compensatory mechanisms to achieve the desired range (17,21,36). The aesthetic demands of ballet create pressure on dancers to restrict caloric intake and energy availability resulting in factors associated with the FAT such as dysmenorrhoea and osteopenia (14,21,26,36,41). These factors increase the risk of stress fractures, specifically in the lower limbs (14).

Extrinsic factors include training surfaces, shoes and excessive training loads (15,20,46,59,60). The high impact and repetitive nature of loading, as well as training loads of 30-40 hours per week, have a substantial impact on the incidence of overuse and traumatic injuries in ballet dancers (9,56). Similarly, the progression from soft and demi-pointe shoes to pointe shoes appears to be significantly associated with injury development (59,60).

Overall, further research is necessary on dance injury epidemiology in a South African context. Research specifically in relation to the FAT, correct technique and staged training progression is required. Greater knowledge in this regard would allow for early identification of injury risk factors among young dancers and would significantly aid injury prevention and management plans. Through optimal training and conditioning, injury prevention strategies and injury management procedures, the health and performance of ballet dancers can be optimised.

Chapter 3: Methodology

3.1. Introduction

Ballet dancers are exposed to high loads and strains on their bodies due to the requirement of being both aesthetically pleasing and physically strong (15). Ballet dancers undergo repetitive extreme movements over prolonged periods (12). These high training and performance loads involving repetitive extreme movements contribute to an injury rate of between 0.18 to 5.6 injuries per 1000 dance hours (4,15).

Factors associated with the Female Athlete Triad (FAT) such as low caloric intake, dysmenorrhoea or amenorrhoea and bone mineral loss, make these athletes additionally more prone to overuse and chronic injuries, particularly of bony structures (19,43).

Training hours have been shown across numerous sporting disciplines to have a substantial influence on injury development (68). The relatively modern concept of analysing levels of both acute and chronic loading to determine the relationship between injury incidence and training load provides an objective and measurable method to assist in the prevention of injuries from training errors before and during performing seasons (2). In professional ballet dancers, this may provide valuable data on individual training and performing loads to optimally guide dancers' training and conditioning with the aim of preventing injuries which negatively affect their professional dancing careers (19).

This study aimed to determine the incidence of musculoskeletal injuries of professional female ballet dancers in South Africa; and to establish potential associations between injury and training loads, physical characteristics and components of the FAT respectively over a three-month period.

3.2. Study Design

This study was a prospective, descriptive study within the cohort population of adult female professional ballet dancers in South Africa.

3.3. Participants

Following ethical approval (HREC REF 838/2017) (Appendix 1), eligible participants from professional ballet companies within the Gauteng, North West and Western Cape provinces of South Africa were requested to volunteer for the study.

3.3.1. Inclusion Criteria

Professional female ballet dancers aged 18 years or older, who were actively dancing for professional ballet companies in the Gauteng, North West and Western Cape provinces of South Africa (provinces with active ballet companies) over the three-month data collection period and performing in a minimum of one production, and its associated regular training routine were included in this study.

The inclusion criterion of age (greater than 18 years) was included to prevent growth-related injuries from confounding the data (17,27). Only females were included in this study as one of the objectives of the study was to investigate associations between aspects of the FAT and injury incidence in female dancers specifically.

3.3.2. Exclusion Criteria

Dancers who were unable to train or perform at the initiation of the study due to injury or any other reason were excluded from the study. Dancers who did not provide written informed consent to take part in the study were also excluded.

3.3.3. Sample Size Calculation

Data from a previous study on injury incidence in ballet dancers (15) was used to determine the proposed sample size for this study. With a population of 50 dancers and an expected injury frequency of 30% and 95% confidence intervals, sample sizes of 37, 41, and 43 participants would have provided 80%, 90% and 95% statistical probability for injury incidence respectively (Epi Info™ Version 7.2.3.1, 2019).

This study used a sample of convenience. A total of 29 professional female ballet dancers were based at the professional dance companies that gave permission for their dancers to be approached to take part in this study. However, only eighteen dancers met the inclusion criteria and consented to take part in this study.

3.4. Recruitment and Enrolment

Professional ballet schools and individuals were approached through their artistic directors and social media channels (Facebook). Dancers were contacted through their class and training environments to take part in the study. Group contact sessions were arranged to inform and recruit eligible dancers who fell within the inclusion criteria to participate in the study, where they received recruitment letters containing information about the study (Appendix 2). Once dancers provided the completed informed consent form (Appendix 3), an appointment made for the evaluations to take place. Data collection and the surveillance over the three-month period was staggered to accommodate dancers from different provinces.

3.5. Measurement Instruments

Participants completed the questionnaire (Appendix 4), body composition and physical testing at initiation of the study. Participants were requested to complete a three-day nutrition diary within one week of commencing the study (Appendix 5) as described below.

3.5.1. Questionnaire

A self-developed questionnaire was used to gather data on participant's demographic information, training history, injury history and menstrual history (Appendix 4). This questionnaire was adapted from a previously validated questionnaire used in swimmers by Scorgie (2016) (69). This questionnaire was not independently validated, as only minor adaptations were made to the previously validated questionnaire for ballet dancers such as ballet specific movements, menstrual history and previous injury documentation (69). The questionnaire was made available to participants as a hard copy or as an electronic version via email. The initial subjective questionnaire was completed once at the beginning of the study.

3.5.2. Three-day Nutrition Diary

The three-day nutrition diary was used to determine average daily caloric intake and included two weekdays and a weekend day (Appendix 5). Validity and reliability of the three-day nutrition dairy have previously been established by Goulet (2004) (70) and Schröder (2001) (71). The diary comprised of two weekdays and one weekend day to ensure optimal averaging of the results to best reflect an average week as eating habits and training routines may vary between weekdays and weekends with the consistency of routine during the week and social events over weekends (71). Nutrition diaries are difficult when it comes to accurate recording and recall over time, thus the three-day diary was selected (71).

Participants recorded all meals, snacks and beverages throughout the day. They identified individual components of each and the estimated portion size, as closely related to a ¼ cup (golf ball size), ½ cup (tennis ball size) or a 1 cup (fist size) as possible. Beverages were recorded in millilitres (ml) and litres (l). The estimated caloric intake subsequently was measured by the investigator using "MyFitnessPal" (20.1.0) Location: MyFitnessPal, Inc (2010) (72,73). Participants were requested to complete the food diary within one week of commencing the study.

3.5.3. Body Composition and Skinfold Measurements

All participants underwent body composition measurements (74,75) by a trained dietician with no association to the relevant ballet schools before initiating the FLEE. Body Mass Index (BMI) was calculated using body mass (kg) and height (m), which were measured using a calibrated scale and stadiometer respectively. Body fat was described as the sum of seven skinfolds (biceps, triceps, subscapular, suprailiac, calf, thigh and abdomen) (75) and was expressed as a percentage of body mass (76) (Appendix 6). These tests were shown to be valid and reliable in average to underweight adults by Kapoor (2012) (77).

3.5.4. Physical Testing: Functional Lower Extremity Evaluation (FLEE)

The FLEE is a 45-minute battery of eight standardised functional performance tests that measure components of lower extremity function, namely: control, power, and endurance (65). The FLEE had been validated by Haitz (2014) (65) as an assessment tool for lower extremity function and included a combination of existing lower extremity functional performance tests to assess dynamic postural balance, coordination and strength (Appendix 7).

Participants warmed up using their regular ballet warm-up routine and performed the test on their dominant leg, followed by the non-dominant leg to a pace maintained by a metronome (test dependant). Each participant was exposed to a familiarisation session on the tests to reduce the risk of injury during testing. Each test was then completed once on each leg (65). A "strike" is an adverse movement which indicates the failure to maintain specific components of each test and was determined by a valgus movement of the knee, missing the metronome beat, loss of balance or hitting a line in the various tests. The final component of the FLEE test was the Lower Extremity Functional Test (LEFT) which comprised multidirectional drills performed in each direction in a 16-step sequence using a diamond-shaped course. The FLEE results were recorded on a data collection form (Appendix 8).

(1) Control Sequences

i) Lateral Timed Step Down

The Lateral Timed Step Down consisted of continuous single-leg squats where the athlete started in a squat position with one leg on the lateral edge of the step and tapped the heel of the bottom leg down to the floor while squatting the top leg to the beat of a metronome (80bpm). The step was adjusted to achieve between 60° and 70° knee flexion with the recorded measure of the test being the amount of time (seconds) taken for three strikes to be recorded or the full-time period of 180 seconds, whichever occurred first (65).

The test was completed on each side for up to 180 seconds each with strikes awarded for loss of neutral knee alignment, balance, ability to maintain the pace, removing hands from hips, knee valgus movement (patella crossing medially over the first toe) and inability to continue due to pain.

ii) The Lateral Leap and Catch

The Lateral Leap and Catch took place over a 60 second period whereby a distance for the lateral leap (60% of the height of the participant) was marked (65). The participant was required to jump unilaterally (side to side) on one leg to the beat of a metronome set to a 40bpm pace, with one beat per jump across the predetermined distance. A practice round before testing was performed. Strikes were awarded if the participant lost control of the landing, demonstrated a pelvic drop or valgus knee movement, performed a faulty manoeuvre or had significant loss of balance throughout the test (65).

The number of times the participant managed to cross the line in the 60 second period were recorded, and the number of strikes obtained. A maximum of three strikes was allowed and once this was exceeded, the participant failed the test. The time at which this occurred was recorded for future comparisons. The test was performed on both lower limbs.

b) The Hop Sequences

Single-leg hops have been used clinically to assess knee function post-injury as they place high demands on musculoskeletal structures and indicate the ability to generate power for take-off (78,79). It was designed to replicate the demands of the sport with functional and multiplanar muscular stabilisation (66,79). The test has been validated as an objective and reliable test to assess knee and ankle strength and proprioception for RTP by Augustsson(2006) (78) and Yildiz(2009) (66) respectively.

The hop sequences consist of a six-metre distance measured along a floormat. This set-up was used for multiple tests, including the Single-Leg Hop for distance, Single-Leg Timed Hop Test, Single-Leg Triple Hop for Distance and Crossover Hop for Distance. The participants practised the tests initially on the dominant leg and completed the test on the non-dominant leg. They were required to maintain the landing for two seconds without losing balance or removing hands from the hips (65). Once they completed the two-second hold, they placed the opposite foot down while the jump distance was measured to where the hopping heel had landed (65). Disqualified attempts were excluded in the average (65).

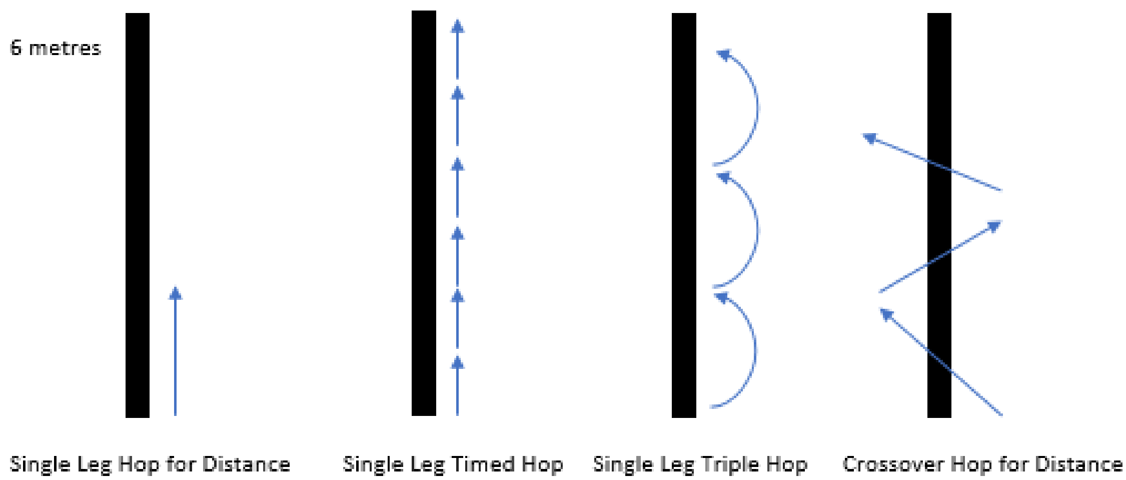

Figure 1: Functional Lower Extremity Evaluation - Hop Sequence

i) <u>Single-Leg Hops for Distance</u>

For the Single-Leg Hop for Distance, the average of three movements was used to determine the distance achieved on each leg (65). Strikes were awarded if the participant lost control of the landing or removed their hands from their hips (65).

ii) <u>Single-Leg Timed Hop</u>

The Single-Leg Timed Hop measured the average time taken for the participant to hop the six-metre distance and was the mean measured over three attempts. Strikes were given if the participant lost their balance, were unable to maintain the landing or performed faulty manoeuvres. Once three faults were recorded, the participant failed the test, and the attempt was then disqualified and repeated until all three attempts were measured (65).

iii) **Single-Leg Triple Hop for Distance**

The Single-Leg Triple Hop for Distance was a functional test that required postural stability, strength and balance (79). It was designed as a branch of the Single-Hop Test to detect imbalances in strength, power and postural stability (79). Participants made three forceful hops from the beginning of the six-metre line, and the average distance of three attempts was used. This test was performed on each leg (65,66).

iv) **Crossover Hop for Distance**

Participants hopped in a powerful continuous movement on one leg over six metres crosswise over a line of 10 cm width. The participants completed the test three times, with the average distance covered for each limb being recorded (66).

c) **Endurance Sequences**

i) **Square Hop Test**

The Square Hop test (Figure 2) was used to identify specific performance deficits in athletes with ankle instability and assessed endurance, dynamic balance, coordination and strength of the calf and thigh muscles (65).

A square block measuring 40 cm x 40 cm was outlined on a smooth floor. Participants hopped into the square to the left and continue in a clockwise motion around the edges of the square. Strikes were awarded if the participant hopped outside the square, or if the opposite foot touched the ground. Participants completed 30 seconds on the route and verbalised once every revolution was completed within the 30 second period. There was a practise round before the test, which consisted of one round on each limb to familiarise themselves with the test (65,80)

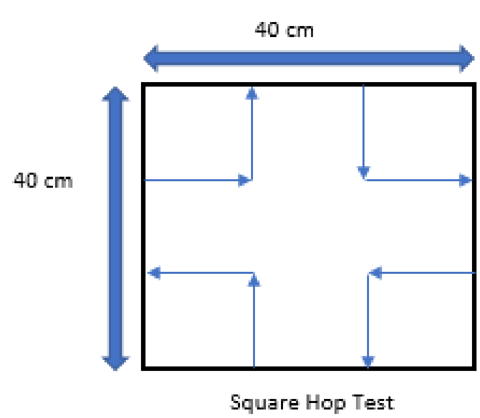

Figure 2: Functional Lower Extremity Evaluation - Square Hop Test

ii) Lower Extremity Functional Test

The Lower Extremity Functional Test (LEFT) was a multidirectional combination of tests involving eight different drills performed in each direction continuously of a 16 step sequence within a diamond-shaped course (65).

The participants were familiarised with the test before testing. Cones were placed in a diamond shape measuring 30 ft x 10 ft distance. The test order was performed to left and right where applicable: a forward run (A-C-A), backward run (A-C-A), side shuffle (A-D-C-B and A-B-C-D), carioca around the perimeter (right/left), figure 8 run looping around cones C and A, 45° cuts around the perimeter cutting at B and D, 90° cuts (from A-B-D and back A-B-D), 90° crossover cuts (A-D-B and back A-B-D), followed by a forward and backward run (65). The score for the LEFT test was recorded as the time taken to complete one full sequence as described above (81).

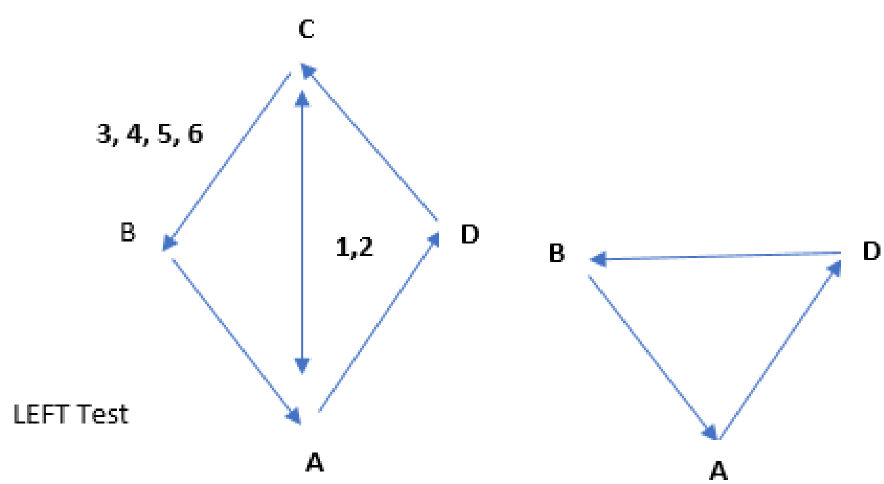

Figure 3: Functional Lower Extremity Evaluation - LEFT test

3.5.5. Injury Reporting Form

A self-developed injury reporting form was used to monitor injuries that occurred during the study period (Appendix 9). The forms were completed by the participant and handed over to the investigator at the time of injury. The injury reporting form was established by Allen (2012) (15) and was not further validated as it was developed from an injury reporting study on professional ballet dancers. The form was accessed by the participants as a hard or electronic copy according to the participant's preference. Reminders were sent via regular text messaging by the researcher to ensure all injuries were reported and recorded over the three-month period.

For the purpose of this study, an injury was defined as any physical complaint sustained by a dancer resulting in consequences on participation, training volume and/or performance, irrespective of the need for medical attention or time loss from dance activities (82).

3.5.6. Training and Performance Logbooks

The ballet instructors were requested to keep a logbook of training and performing times for the duration of this study. The training and performance periods were recorded as hours and minutes (Appendix 10). Ballet instructors assisted with the collection of the training and performance data, due to their presence at practices and performances. All instructors involved signed a consent form (Appendix 11) for their participation in data collection. Logbooks were submitted to the investigator each week for the duration of the study. Day to day recordings included training and performance slots providing an accurate record of training and performing times. Participants who danced outside of the ballet company environment were requested to keep individual records of training and performance times using the same logbook.

3.6. Procedure

The study received ethical approval from the University of Cape Town (UCT), Faculty of Health Sciences Human Research Ethics Committee (HREC) (HREC REF 838/2017) (Appendix 1). Once ethical approval was granted, professional ballet companies and individual dancers associated with these professional ballet companies based in the Gauteng, North West and Western Cape provinces were approached through their artistic directors and social media. A recruitment letter was given to prospective participants with information regarding the study (i.e. voluntary participation, the purpose of the study, the risks and benefits involved and their right to withdraw at any time) (Appendix 2).

All participants were requested to complete an informed consent form (Appendix 3). This included a description of all study tests and procedures, information regarding ethical approval, risks and benefits associated with the testing, the study significance, participant confidentiality and specifically the right to withdraw from the study at any time without any consequences.

Once informed consent was obtained, participants completed the questionnaire (Appendix 4), and a date was set for the body composition and physical testing. Participants were requested to complete a three-day nutrition diary within one week of commencing the study (Appendix 5). All physical testing was completed outside of the participants' usual training or performance times to ensure minimal disruptions to their schedules. The FLEE took approximately 45 minutes per participant to complete, including the familiarisation warm-up (Appendix 8).

Once the informed consent, questionnaire and physical testing were completed, the participants were requested to continue with their regular dancing routines. Dancers were requested to complete an injury report form if they sustained an injury during the three-month study period (Appendix 9). A training and performance logbook was used to prospectively monitor training and performance loads over a three-month period (Appendix 10).

3.7. Data and Statistical Analyses

Statistical analyses were performed using STATISTICA (StatSoft. Inc, 2004, Data analysis software system, version 13). Dancers were grouped into injured and uninjured groups at the end of the study period for statistical analyses. All descriptive data, demographic and anthropometric data, were tabulated and assessed for normality using the Shapiro-Wilkes test. The parametric data were then described using means and standard deviations. The independent t-test was performed on the parametric data to determine whether there were any significant differences between the two groups for these data. The non-parametric data was further described using median and range and was subjected to a Mann-Whitney U test to assess for significant differences in these data between the two groups. Injury incidence was calculated per 1000 dance hours with a 95% confidence interval over the three-month data collection period. Odds ratios were performed to determine possible associations between injury and intrinsic (Body Mass Index (BMI), Lean Body Mass (LBM), fat percentage, caloric intake, incidence of amenorrhoea and dysmenorrhoea) and extrinsic factors (training loads) in the injured and uninjured groups. Statistical significance was accepted as $p < 0.05$.

3.8. Ethical Considerations

This study was conducted per the principles and guidelines of the Declaration of Helsinki (Fortaleza Version, 2013). The research proposal was approved by the HREC of the Faculty of Health Sciences at the University of Cape Town (HREC REF 838/2017).

3.8.1. Risks to Participants

The physical testing using the Functional Lower Extremity Evaluation (FLEE) carried minor to moderate injury risks associated with the physical nature of the test (such as minor muscle strains or joint sprains). The participant completed their usual ballet warm-up routine to reduce the risk of injury. Testing movements were also fully explained and practised during a familiarisation session prior to testing. If the individual was injured or unable to complete any of the FLEE components due to pain, the tests were not performed. Only one participant was excluded from FLEE measurements due to an injury that prevented the safe performance of all components of the FLEE.

3.8.2. Benefits to Participants

The results obtained through the evaluation and data collection were made available to the participants following the completion of the study. Recommendations were made for training load adjustments and caloric intake for optimal injury prevention. Injured participants were also advised regarding their injuries and were referred for further management where appropriate. All participants who participated in the study received an information booklet on the Female Athlete Triad (Appendix 12).

The dietician involved, and the investigator offered individual sessions with the participants to discuss test results and to further educate dancers on the importance of adequate nutrition without compromising vital bodily functions, including the development of the FAT.

3.9 Confidentiality and Justice

Participants were invited to schedule private feedback sessions to receive the overall study results either in person or over a video call. Participants received either a hard copy or electronic copy of their results depending on personal preferences and internet access. All paperwork collected from participants was stored in a locked drawer, while electronic data was stored in a password-protected file on the student investigator's laptop. All data were coded for analysis to ensure confidentiality. Data of individual participants were not made available to the ballet company to ensure privacy and confidentiality.

The study was restricted to female participants to assess factors predominantly associated with the Female Athlete Triad (FAT). These were measurable using the three-day nutrition diary and menstrual history assessments in combination with the anthropometric measurements (Body mass index (BMI), body fat percentage and lean body mass (LBM). To include male dancers into the study, blood tests and DEXA scans would have been necessary to expand the study to further measure testosterone levels and bone mineral density (BMD), which were unfeasible in cost and time for a mini dissertation.

Chapter 4: Results

4.1. Participants

Twenty-nine participants were approached for recruitment to this study. Twenty-five dancers met the inclusion criteria and of those, nineteen dancers signed the informed consent form and were included in the study. One participant fell out of the study due to noncompliance. The study participants were further divided into two groups for analysis: an injured group (n=14) and an uninjured group (n=4). The study sample is summarised in Figure 4.

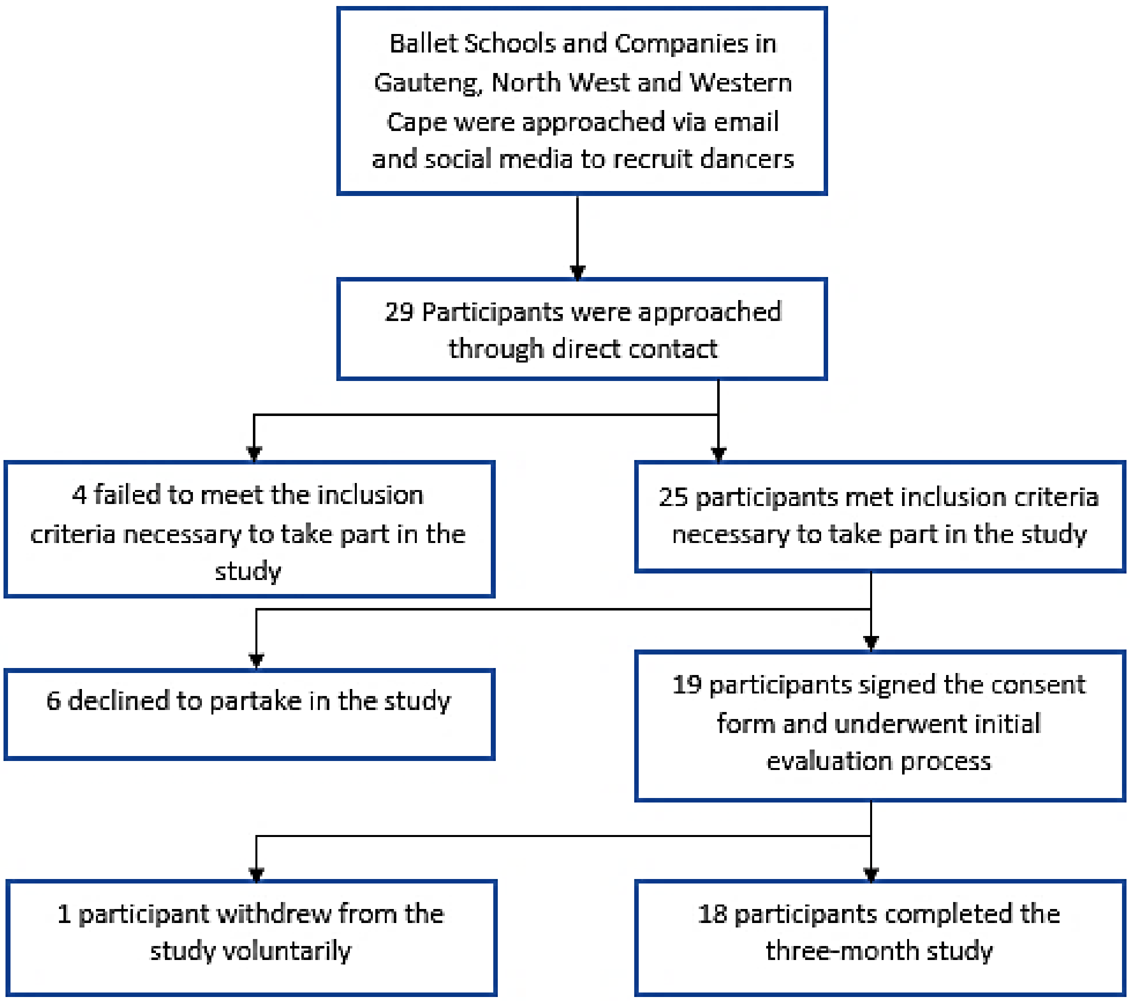

Figure 4: Summary of the Study Sample

4.1.1. <u>Demographic data</u>

The descriptive characteristics of participants are shown in Table 5. No significant differences were found between the injured and uninjured groups in any of the descriptive characteristics.

Table 5: Descriptive Data of Participants in the All, Injured and Uninjured Groups. Data are presented as the Mean and Standard Deviation.

	All Groups (n=18)	Injured (n=14)	Uninjured (n=4)	p-value
Age (years)	22.1 ± 3.0	22.3 ± 3.2	21.5 ± 2.5	0.66
Height (cm)	161.02 ± 5.1	160.2 ± 5.2	163.7 ± 3.8	0.23
Body mass (kg)	55.51 ± 7.4	54.3 ± 6.9	59.4 ± 8.6	0.25
BMI ($kg.m^{-2}$)	21.35 ± 2.1	21.1 ± 2.1	21.6 ± 1.6	0.69
LBM (kg)	41.71 ± 4.9	41.1 ± 4.9	43.8 ± 4.9	0.36
Body Fat Percentage (%)	24.69 ± 2.9	24.3 ± 1.9	26.0 ± 5.1	0.31
Dancing history (years)	9.65 ± 5.6	9.9 ± 6.0	8.8 ± 4.5	0.73
Previous number of injuries	2.53 ± 1.1	2.5 ± 1.2	2.5 ± 0.6	0.95
Previous number of overuse injuries	1.29 ± 0.8	1.4 ± 0.8	1.0 ± 0.8	0.43
Previous number of traumatic injuries	1.24 ± 0.8	1.2 ± 0.8	1.5 ± 0.6	0.40

4.1.2. Caloric intake

Average weekday and weekend caloric intake of participants in the injured and uninjured groups is shown in Table 6. No significant differences were found between participants in the injured and uninjured groups in average caloric intake (Table 6).

Table 6: Average Caloric Intake of Participants in the Injured and Uninjured groups. Data are presented as the Mean and Standard Deviation.

Caloric intake	All (n=18)	Injured (n=14)	Uninjured (n=4)	p-value
Weekday Average	1626.0 ± 503.6	1618.7 ± 424.8	1649.9 ± 793.5	0.92
Weekend Average	1994.1 ± 637.5	2071.2 ±673.7	1743.5 ± 492.7	0.39
Overall Average	1810.0 ± 503.7	1844.9 ±481.7	1696.7 ±634.4	0.62

Table 7 depicts the associations between caloric intake and injury. Categories were identified as <1499, 1500-1999 and >2000 average caloric intake per day; as 2000-2400 calories are accepted as the regular daily caloric intake for an average to active females (83). No significant relationships were found between caloric intake and injury.

Table 7: Relationship between Caloric Intake and Injury.

Caloric Intake	Number of Participants	Odds ratio (95% CI)	p-value
>2000 (Reference Value)	7	1	1
<1499	7	1.0 (0.1-11.0)	1.00
1500-1999	4	6.1 (0.2-162.8)	0.28

4.1.3. Amenorrhoea and Dysmenorrhoea in Injured and Uninjured Dancers

Three dancers reported amenorrhoea and 10 reported dysmenorrhoea, with an overall prevalence of menstrual dysfunction of 64.7%. The associations between amenorrhoea and dysmenorrhoea and injury are shown in Table 8. Eumenorrhoea was used as the reference value for these results. No significant associations were observed between menstrual dysfunction and injury (Table 8). The duration of menstruation averaged 4.5 days, with the flow ranging between light and moderate in the description. stress and level and intensity of exercise had the most reports on affecting flow incidence, duration and regularity.

Table 8: Relationship between Amenorrhoea and Dysmenorrhoea and Injury.

	Number of Participants	Odds ratio (95% CI)	p-value
Eumenorrhoea (Reference Value)	5	1	1
Amenorrhoea (>6 months)	3	1.8 (0.1-48.7)	0.72
Dysmenorrhoea and Amenorrhoea (<6 months)	10	1.33 (0.1 – 20.7)	0.84

4.1.4. Body Mass Index

The association between BMI and injury is shown in Table 9. No significant relationships were found between BMI and injury. The reference value of 25 was used as the majority of dancers had BMI measurements above 20 but below 25. Only two participants had BMI measurements below 20.

Table 9: Relationship between BMI and Injury.

BMI	Number of Participants	Odds ratio (95% CI)	p-value
>25 (Reference Value)	1	1	1
<25	17	11.57 (0.4-350.1)	0.16

4.1.5. Body Fat Percentage

Table 10 depicts the relationship between body fat percentages and injury. No significant associations were found between body fat percentage and injury. The range of 25-31% was used as the reference value as it was deemed the acceptable average body fat percentage for females.

Table 10: Comparison of Body Fat Percentage results in the Injured and Uninjured groups.

Body Fat Percentage	Number of Participants	Odds ratio (95% CI)	p-value
25-31% (Acceptable) (Reference Value)	8	1	1
14-20% (Athletes)	1	0.2 (0.0-6.8)	0.38
21-24% (Fitness)	9	10.8 (0.5-252.8)	0.14

4.2. Injury Incidence

The number of injuries reported and the total incidence of injuries per anatomical region are shown in Table 11. An overall incidence of 3.3 injuries per 1000 dance hours was found using frequency tables, with a total of 4605.6 dance hours recorded overall.

Lower limb injuries were the most common injuries, with foot injuries accounting for one-third of all reported injuries.

Table 11: Total Number of Injuries Reported in the three-month study period, Incidence per 1000 Dance Hours and Anatomical Location.

	Frequency	Incidence of Injuries per 1000 dance hours (95% CI)
Overall injuries	15.0	3.3 (-65.2-83.5)
Foot	5.0	1.1 (-21.7-27.8)
Knee	3.0	0.7 (-12.8-16.5)
Ankle	3.0	0.7 (-12.8-16.5)
Lumbar spine	2.0	0.4 (-8.9-11.4)
Lower leg /Calf/Shins	2.0	0.4 (-8.9-11.4)

4.3. Functional Lower Extremity Evaluation

The results of the FLEE were not normally distributed and are therefore reported as medians and interquartile ranges. A Mann-Whitney U test was used to assess differences between the two groups. There were no significant differences in any of the components of the FLEE between participants in the injured and uninjured groups in the FLEE test. These results are depicted in Table 12.

Table 12: FLEE results for Participants in the All, Injured and Uninjured groups. Data are presented as Median (Interquartile Range).

FLEE (Median and range)	All (n=18)	Injured (n=14)	Uninjured (n=4)	U-Value	p-value
Right Timed lateral step down (seconds)	24.4 (8.1-80)	24.7 (8.1-68.1)	19.1 (13.1-80.0)	21.0	0.76
Left Timed lateral step down (seconds)	26.7 (11.0-61.0)	28.5 (11.0-60.1)	25.9 (14.7-61.0)	22.0	0.86
Crossed - Lateral leap and catch (count)	36.5 (30.0-40.0)	37.0 (30.0-40.0)	35.0 (32.0-39.0)	18.0	0.51
Hit - Lateral leap and catch (count)	3.5 (0.0-10.0)	3.0 (0.0-10.0)	5.0 (1.0-8.0)	18.0	0.51
Right Single leg-hop (cm)	114.5 (87.3-145.3)	112.3 (87.3-145.3)	121.7 (88.7-137.0)	20.0	0.67
Left Single leg-hop (cm)	115.7 (87.0-138.7)	115.7 (87.0-138.7)	113.8 (91.0-125.0)	24.0	0.95
Right Timed leg-hop (average)	2.6 (2.2-3.7)	2.7 (2.2-3.7)	2.4 (2.3-3.1)	21.0	0.76
Left Timed leg-hop (seconds)	2.6 (2.2-3.5)	2.6 (2.3-3.5)	2.3 (2.2-3.5)	13.0	0.20
Right Triple hop (seconds)	408.3 (274.3-540.7)	390.5 (311.7-528.7)	450.0 (274.3-540.7)	19.0	0.59
Left Triple hop (cm)	391.0 (290.3-488.3)	384.8 (316.0-488.3)	424.8 (290.7-3897)	17.5	0.47
Right Crossover Hop (cm)	354.5 (290.3-488.3)	361.3 (293.0-518.7)	343.67 (290.7-389.7)	22.0	0.51
Left Crossover Hop (cm)	341.5 (273.7-472.0)	330.7 (273.7-472.0)	378.2 (273.67-414.00)	22.0	0.47
Crossed Square Hop (lines cleared)	60.0 (36.0-100.0)	60.0 (36.0-100.0)	58.0 (50.0-72.0)	19.0	0.86
LEFT (seconds)	118.2 (102.7-150.7)	118.2 (103.3-150.7)	118.0 (102.-131.6)	19.0	0.59

4.4. Incidence of Overuse and Traumatic Injuries

Of the 15 injuries recorded during the study, only one was recorded as traumatic, resulting in a ratio of 14:1.

4.5. Training Load

4.5.1. Monthly Training Loads

Median monthly training loads (in minutes) of all, injured and uninjured groups are shown in Table 13. A Mann-Whitney U test to assess for significant differences in these data between the two groups. No significant differences in monthly training loads were found between groups.

Table 13: Monthly Training Load Averages Results for Participants in the All, Injured and Uninjured Groups. Data are presented as Median (Interquartile Range).

	All (n=18) (Minutes)	Injured (n=14) (Minutes)	Uninjured (n=4) (Minutes)	U-Value	p-value
Month 1 Average Training Load	5915 .0 (1563.1-7680.0)	5915.0 (1800.0-5915.0)	5915.0 (4230.0-7680.0)	19.0	0.46
Month 2 Average Training Load	5460.0 (1551.5-7680.0)	5460.00 (1800-6210.0)	5864.00 (5460.0-7680.0)	11.5	0.11
Month 3 Average Training Load	4590.0 (1411.0-7680.0)	4590.0 (1800.0-6300.0)	5655.0 (4590.0-7680.0)	13.0	0.16

4.5.2. Average Training Loads per Month and Injury Correlations

The average acute monthly training loads and their injury correlations are depicted in Table 14 and was measured in minutes. The reference value of 1499-1699 was determined as the midpoint within the range of data collected. No significant associations were found between average monthly training loads and injury incidence.

Table 14: Relationships between Injury and Acute Training Load in Weeks 1-4, 5-8 and 9-12.

Week 1-4	Odds ratio (95% CI)	p-value
1400-1699 (Reference Value)	1.0	1.00
<799	0.9 (0.0-27.9)	0.95
800-1099	0.5 (0.0-14.3)	0.72
1100-1399	8.4 (0.3-250.7)	0.23
>1700	0.9 (0.0-27.9)	0.95
Week 5-8		
1400-1699 (Reference Value)	1.0	1.0
<799	7.0 (0.2-291.4)	0.31
800-1099	-	-
1100-1399	0.3 (0.0-6.4)	0.44
>1700	0.8 0.2-32.3)	0.90
Week 9-12		
1400-1699 (Reference Value)	1.0	1.0
<799	0.1 (0.0-5.5)	0.23
800-1099	-	-
1100-1399	0.2 (0.0-3.8)	0.25
>1700	0.17 (0.0-5.5)	0.23

4.6. Summary of Results

Professional female dancers participating in the study had an average age of 22.1 ± 3.0 years. The dancers had an average BMI of 21.35 ± 2.1 $kg.m^{-2}$; LBM of 41.71 ± 4.9 kg and body fat percentage of 24.7 ± 2.9%.

Injury incidence was 3.3 injuries per 1000 dance hours. Of the 15 injuries reported, 13 occurred in the lower limb, with eight in the ankle and foot. Overuse injuries accounted for 93.3% of the total injuries, with only one traumatic injury reported.

None of the descriptive characteristics were associated with increased injury risk. The average caloric intake of 1810.0 ± 503.7 calories, while lower than what is recommended for female athletes, also showed no significant relationship to injury. There were also no significant associations between dysmenorrhoea or amenorrhoea and injury.

There were no significant associations between FLEE results and injury, or training loads and injury respectively.

Chapter 5: Discussion

This study aimed to determine the incidence of musculoskeletal injuries in female professional ballet dancers over three months. This section will discuss the descriptive characteristics, followed by injury incidence, caloric intake, the Functional Lower Extremity Evaluation (FLEE), previous injuries and training loads (accumulative load and the acute to chronic training load ratio).

5.1. Demographic Characteristics

5.1.1. Sample Size

The sample size of this study was lower than that of similar studies conducted in other dance populations (15,19,39). Other studies' sample sizes ranged between 27 and 80 participants over a one- to five-year period (15,19,84). This study, in comparison, had 18 participants. This is likely to be due to there being fewer professional ballet dancers and companies in South Africa, compared to elsewhere in the world, with less support and resources in comparison to higher-income countries (28). The two major South African ballet companies were observed to only have 20 to 25 female dancers respectively. Factoring in smaller companies and part-time dancers there would be approximately 80-120 professional female dancers in South Africa. This smaller number of professional female dancers in South Africa limited the sample size of this study.

The data collection period was also shorter in comparison to previous studies, with periods of one to five years being utilised in similar studies elsewhere (15,19). The shorter collection period was due to the nature of this study as a mini-dissertation, and to allow flexibility between the data collection groups as they varied in three different provinces and each group had different performing and training schedules. Data collection at three separate sites took place over 9 months.

As this type of dance injury epidemiology study was novel in a South African context, the smaller sample size and shorter data collection period, whilst not ideal, still provides valuable insight and a starting point for dance-related research in the country.

5.1.2 Participant Descriptive Characteristics

The average age of participants was 22.1 years. The average age is lower compared to three previous studies, which reported average ages of 25.5, 26.6 and 34.2 years respectively (19,10,15). This may be due to the smaller than typical sample sizes and the higher amount of younger, graduate dancers within South African professional ballet companies. Some studies have suggested associations between higher age and injury incidences, with a higher risk of overuse injuries and chronicity of injuries as the dancers mature (15).

The average body mass of dancers in this study was 55.5 kg with a wide range of 37.8 kg to 70.7 kg between the 18 participants in the study. The average body mass indicates diversity in the dancers' body compositions within the study. Allen (2012) (15) recorded an average body mass of 59.2 kg (15). Few other studies reported on dancer body mass or relationships between body mass and injury incidence in professional ballet dancers, which may indicate a need for further investigation relating to this factor

The average BMI of dancers in this study was 21.35 $kg.m^{-1}$, with a range of 18.5 to 24.9 $kg.m^{-1}$, which is considered normal for females (22,85). However, it needs to be considered that in combination with dysmenorrhoea and amenorrhoea, a low BMI is seen as a high predictor of low bone density, further increasing the risk of stress fractures and other overuse injuries (15,22,41).

In comparison to previous studies on professional ballet dancers, the average body fat percentage of dancers in this study of 24.7% was within normal ranges for females; and also, above average body fat percentages of 16% to 18% that have been previously reported in dance research (22,42,43). The differences found in the study may be due to improved knowledge on the importance of optimal eating plans, or the general finding that majority of the dancers still resided at home with their families, providing them with regular cooked meals in relation to meals reported. In addition, this could indicate that South African ballet dancers have a different body composition to dancers from North American or European regions that have been previously studied (42,43). The smaller sample size of the study population could also have resulted in the higher than normal body fat percentages reported in this study. There were no contractual body mass obligations disclosed during the study, which may have provided pressure from within the company for leaner builds, lower BMI measurements, and lower body fat percentages in order for dancers to maintain their roles or positions within the company.

5.1.3 Years of Dancing

The overall average of previous years of dancing was 9.7 years, with a wide range between three and 20 years of dancing. The injured group of dancers did have a higher number of years dancing in comparison to the uninjured group, but this result was not significant. Previous studies have not explicitly identified the number of years of training and relationships to injury; however, results from previous studies regarding dancer experience and injury appear to have conflicting results (37). This includes a reported higher risk of overuse injury due to dancer inexperience, and an increase in injury rates associated with more years of training (4).

With an average age of 22.1 years and 9.7 years of dancing, a logical deduction is that most dancers in this study would have begun dancing during their pre-adolescence and adolescent years. These are primarily the periods of significant growth and development (14,27). This may have had an impact on their menstrual development, depending on their degree and intensity of training (18).

The types of injuries also differ in relation to the age group, with a higher incidence of stress fractures in the second metatarsal and patellofemoral pain syndrome (PFPS) found in more skeletally immature dancers (4). Initiating dancing at a younger age may predispose dancers to a higher incidence of overuse injuries from early on in their dancing careers with the progression onto pointe training, and typically females are more likely to be affected due to the higher repeated mechanical loads experienced in the lower extremities during their dancing training (4,86). Cartilage-related injuries, such as chondral injuries in the knee, are found more commonly in older female dancers, which may explain the low incidence of chondral injuries in our study (4).

Due to insufficient data on the optimal years of training required to reduce injury risk from inexperience and to prevent more cartilage-related injuries further on in their career, it may prove beneficial for further research to be undertaken in this field. This could assist in optimising the longevity of professional dance careers.

5.1.4. Previous Injuries

Between 42.2% and 46.5% of adolescent ballet dancers report at least one previous injury (27,39). These studies measured an injury as a dance-related injury requiring medical attention or resulting in training or performing time-loss (39). Of the dancers who participated in our study, all reported a previous injury, with a total of 43 previous injuries reported among the 18 participants. Of these, 51.16% were reported as overuse injuries. These results agree with comprehensive reports for a higher overuse to traumatic injury ratio, with less injury and training time loss reported (15,37). These findings correlate with studies indicating a higher incidence of overuse injuries in younger dancers (18,37,39).

With the injury definition used in this study as training time lost or training altered to accommodate the injury, there may have been a higher reported incidence of injuries in comparison to other studies which measured an injury according to training time loss. The OSTRC questionnaire was developed for identifying overuse injuries but has not been validated in ballet dancers (1). This is a field in which this type of questionnaire may prove invaluable; as many overuse injuries are under-reported, adding to prolonged recovery and an increased risk of the injury becoming chronic in nature (1).

5.1.5. Caloric Intake

The caloric intake from the three-day food diary provided an indication of the dancer's daily nutritional intake. The average caloric intake of 1777 calories observed in this study falls below the average amounts of 2000-2400 calories indicated for active female athletes for optimal energy availability (83). Over a prolonged period and in combination with menstrual dysfunction and intense training programmes, this increases the risk of stress fractures, particularly in the lower limbs (22).

In this study, the caloric intake ranged from 1111 to 2664 calories. These data collected may be misreported due to imperfect recollection, incorrect portion sizes, irregular recordings of meals, the risk of human error and under or over-reporting (87,88). These factors need to be considered when interpreting the findings of this study.

In addition, two of the four dancers in the uninjured group had a caloric intake of below 2000 calories. This finding was more in line when comparing current literature findings but may have been affected by the small sample size, and the subjective nature of the food diary used to collect data on caloric intake (88). The process of assessing caloric intake using the three-day food diary may be further optimised using an app such as “MyFitnessPal” and extending the data collection period (73).

5.1.6. The Incidence of Amenorrhoea and Dysmenorrhoea

Of the 18 dancers who participated in the study, three were defined as being amenorrhoeic, missing six or more menstrual periods in a 12-month cycle. A further six dancers were defined as being dysmenorrhoeic, having missed or altered menstrual patterns over six months. Only six dancers (35%) did not report ever having missed a menstrual period. The duration of menstruation averaged 4.5 days, with the flow ranging between light and moderate in the description. When asked what they felt may have affected their menstruation the most, most dancers stated stress and level and intensity of exercise. These findings correspond with relevant data indicating that menstrual regularity is affected by numerous factors, including those identified in the Female Athlete Triad (21,36).

No significant associations between dysmenorrhoea and amenorrhoea and injury were identified in this study. Menstrual dysfunction has not been specifically investigated in professional ballet dancers but has been evaluated in athletes of similar age groups in competitive sports with similar aesthetic demands, such as athletics and gymnastics (22,36). Some studies have attempted to assess the effect of menstrual dysfunction (e.g. delayed menarche; dysmenorrhoea; amenorrhoea) on injury development in dancers, however, results were inconclusive due to methodological flaws and poor study quality (39,86,89).

5.2. Functional Lower Extremity Evaluation (FLEE)

The results from the FLEE showed no significant differences between the injured and uninjured groups. The results correspond with values and findings from Haitz (2014) (65), in female athletes of similar ages. However, the absence of any significant findings between the injured and uninjured groups may indicate that the FLEE has low sensitivity and specificity in predicting lower extremity injuries in ballet dancers (65). We do acknowledge that the sample size in this study affects the ability to apply these results to the broader population. More extensive research over longer periods may help determine a relationship between the FLEE and risk of injury; however recent research has questioned the efficacy and reliability of screening tests in general, bringing into question the need for future research into screening tests as a whole (63,64).

5.3. Incidence of Injuries

Injuries were defined for this study using a participation definition; whereby data were collected for any injury that prevented full participation in dance-related activities, for a period of 24 hours or longer following the onset of the injury (15,82,90). Dancers who need to adjust their training load or who were unable to train at all due to a physical complaint, irrespective of the need for medical attention, needed to report the injury. The definition allowed for the reporting of less severe injuries which did not result in being completely unable to dance, train or perform; but needed an adjustment to the regular dancing or training routines until full training load could resume (82,90). This is important, especially as dancers needed to determine if injuries were traumatic or overuse in nature and understanding the differences between acute, sub-acute and chronic injuries.

The dancers who participated in the study averaged 3.3 injuries per 1000 dance hours. This incidence rate was greater than the injury incidence of 2.79 injuries per 1000 hours as reported in professional female ballet dancers by Allen (2012) (15). Similarly, lower injury incidences of 0.18 injuries (13), 0.6 injuries (19), 0.24 injuries (4) and 0.77 injuries (14) per 1000 dance hours have been reported in the literature. This may be due to the differing injury reporting methods seen across studies.

These injury incidence data vary quite considerably between studies and may depend on a variety of factors, such as the nature of injury reporting utilised in the study (e.g. self-report in comparison to reporting by medical staff), different injury definitions and study design. The different studies used the definition of injury measuring complete time-loss as opposed to adjusted training time-loss, which may have resulted in under-reporting of overuse or non-traumatic injuries (39,91). Retrospective studies may also result in under-reporting or the misreporting of injuries, as recall has been shown to be inaccurate and unreliable (39).

Of the 15 reported injuries, 13 (87%) occurred in the lower limb, with eight being in the foot and ankle. These findings were similar to results from previous studies when analysing foot and ankle injuries specifically, with incidences between 17% and 71.7% previously reported (10,27). Although the incidence rates differed between studies, the ankle and foot generally have been reported to have the highest injury incidence rates when compared to other regions of the body in amateur and professional ballet dancers (18,34).

Of the 15 reported injuries, 14 (93%) were self-classified as overuse injuries and resulted in minimal time loss from training and performing. Overuse injuries are defined as tissue damage caused by prolonged periods and episodes of submaximal loading over time without sufficient rest or recovery and have a higher risk of progressing to overuse injuries if left untreated (4,36).

Extrinsic factors associated with the injury have primarily been reported as being environmental factors such as training surfaces used, and training errors (36,92). The intrinsic factors previously reported include muscle weaknesses and malalignments as contributing factors to injury incidence (36,92). Both the intrinsic and extrinsic factors were self-reported by the dancers themselves, and not directly by medical professionals, whereas most other studies used an in-house medical staff to collect injury information (15,19). They are factors that may be further investigated in future studies and by the ballet companies to determine ways to limit or reduce the effects of intrinsic and extrinsic factors on injury incidence.

The results show no strong correlation on the effects of intrinsic factors (BMI; caloric intake; previous injuries) and an increased risk of an overuse injury in professional female athletes, specifically in the lower limb as has been demonstrated in previous research (15,41).

Further, ballet companies in South Africa have limited funded access to medical teams. Due to budget constraints, none of the schools or companies included in the study had full- or part-time medical staff associated with the company. Research has shown that access to medical staff has a significant impact on reducing injury incidence rates within dance companies, and if implemented in South African companies they may have a direct impact on injury incidence, chronicity of injuries and the overall longevity of ballet dancers (3,34).

5.4. Training Load

The training load was initially reported in terms of specific extrinsic training load (i.e. minutes danced) for the three months to determine extrinsic factors associated with injury incidence. Professional ballet is similar to numerous other sports demonstrating consistently high training loads, combined with high competition or performance loads and fewer recovery periods (55,93). Unfortunately, no standard method to capture training load in ballet dancers has been developed, nor has the type of exposure (training, performing or other) been normalised (14).

Aspects which may be tracked in ballet dancers in future research to optimise training load assessment include assessing numbers of jumps performed, type of jumping performed, number of lifts completed, sessional rate of perceived exertion (RPE) scores, sessional heart rate monitoring, and total hours danced (93,94). Future research should investigate the validity and reliability of these internal and extrinsic training load monitoring parameters in a dance specific population. By determining the optimal training load for professional female ballet dancers, a company may effectively reduce their injury incidence rates and balance optimal recovery periods, and training for peak performance (95).

It should also be considered that the internal factors, as opposed to the training load extrinsic factors, may have played a larger role in the injury rate than the training load (56). The internal training loads were not assessed during this study. As always, both need to be considered to optimally monitor and manage an athlete's training load (56).

5.5. Limitations of the Study and Recommendations for Future Research

As recognised earlier in the discussion, the main limitation of this study was the sample size. The small sample size reduced the power of statistical analyses and limits the generalisability of the study findings. The study population was a sample of convenience due to the limited population of professional dancers in South Africa. This low number of professional dancers may be due to inaccessibility of training from a young age, costs associated with ballet equipment and training, and that only the most senior of professional dances are paid. The data collection period of this study was also relatively short for an epidemiological study. A longer data collection period would have allowed for more data to be analysed, and therefore would have improved the internal validity of the study. Follow up studies should aim to increase the sample size and lengthen the data collection period, to provide more powerful results. Further recommendations could also include a variety of dance styles within a larger population to further expand results which may be applied over a general dance population as opposed to ballet alone.

Another limitation of the study was the food diary, which collected data over three days and the averages were used to determine average caloric intake. The method used may be improved upon by increasing the collection to a weekly form throughout the study period to obtain more valid measures of caloric intake or by asking the participants to input their data directly onto "MyFitnessPal" for better averaging of portion sizes and to improve accuracy, as periods of prolonged data collection may prove difficult with regards to compliance and consistency (73).

Self-reporting of injuries by the dancers may have affected the accuracy of the injury data collected. This method was necessary as none of the companies involved in the study had permanent medical staff available to assist with the collecting of injury data. Injury data could not be gathered in person by the investigator due to different geographical locations between the participants and the investigator.

The assessment and measurement of training load was limited and may be further developed to include numbers of jumps and lifts which are particularly relevant to this population. The Rate of Perceived Exertion (RPE) has been shown to be a valid measurement of training load in ballet dancers with the use of heart rate monitoring or GPS tracking as supplemental monitoring strategies to assess other contributing factors to the training and associated injury load (93).

The study has demonstrated that further research is needed to determine the effects of intrinsic and extrinsic factors on injury incidence in professional female ballet dancers, particularly in the South African context.

Chapter 6: Summary and Conclusion

Ballet is a highly specialised, aesthetic sport with high levels of discipline, training and commitment. Female professional dancers account for the majority of dancers in South Africa. Ballet is well known to carry a high injury incidence rate, particularly of overuse injuries in the lower limbs. Factors identified by previous studies that contribute to the injury rate include intrinsic factors associated with the Female Athlete Triad (FAT), namely low caloric intake, menstrual dysfunction, previous injuries and excessive training loads.

This study aimed to determine if these and other factors play a significant role within the South African context. Understanding these relationships, will guide future research and provide scientific support for injury prevention strategies in professional South African dance companies.

The following study objectives in adult professional female ballet dancers have been addressed and discussed as follows:

To determine the incidence of traumatic and overuse injuries per 1000 dance hours over a three-month training and performance period in South African female professional ballet dancers.

This study determined the injury incidence rate to be 3.3 injuries per 1000 dance hours, with a total of 15 injuries reported during the study. This injury rate is greater than reported in other studies. The injury rate may be influenced by the injury definition used in the study, whereby an injury may be reported as such even though the dancer could continue training. The definition increases the number of overuse injuries reported, as dancers are often able to dance with an overuse injury without significantly compromising their participation.

To determine the relationships between Functional Lower Extremity Evaluation (FLEE) scores and injury incidence in South African female professional ballet dancers.

No associations were found between FLEE scores and injury incidence. Further research is needed to determine the efficacy of the FLEE in predicting injuries in ballet dancers, as it is used primarily in field sports like hockey and football. However, the results of our study do not indicate a strong likelihood of validity in this population type or the success of injury screening as a preventative tool overall, according to the latest research (63,64).

To determine the relationships between intrinsic factors including amenorrhoea, body mass index (BMI), skinfold measurements and caloric intake and injury incidence in South African female professional ballet dancers.

No relationships were found between intrinsic factors, including amenorrhoea, BMI, body fat percentage and caloric intake, and injury incidence. Further studies with a larger sample size are required to determine the validity of these variables as intrinsic risk factors to injury in South African professional ballet dancers. Furthermore, expanding the research in this field to be inclusive of the RED-S definition and studying both male and female dancers is strongly advised.

To determine the relationship between extrinsic factors, including training and performance hours and injury incidence in South African female professional ballet dancers

No relationships were found between extrinsic factors, such as monthly training load and the acute:chronic training load ratio, and injury. Further research is recommended to assess optimal training load measurements specific to ballet (such as jumps and lifts) and the ideal load to prevent injury and optimise performance in professional ballet dancers.

In conclusion, this study identified an overall injury incidence of 3.3 injuries per 1000 dance hours among professional female ballet dancers in South Africa. This injury incidence is higher than in more high-income parts of the world. There was also a significantly higher prevalence of self-reported overuse injuries. Given the high injury incidence, it is imperative to establish key risk factors driving injury development in South African ballet dancers. Further, this study identified a strong need for medical support services in South African dance companies to facilitate injury prevention and management in professional ballet dancing in South Africa.

Chapter 7: References

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Chapter 8: Appendices

1. **Appendix 1: Human Research Ethics Approval**

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: sumayah.ariefdien@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

05 December 2017

HREC REF: 838/2017

Ms K Buchholtz
Division of Physiotherapy
F-45, OMG

Dear Ms Buchholtz

PROJECT TITLE: MUSCULOSKELETAL INJURIES IN BALLET DANCERS: A PROSPECTIVE STUDY- (MSc-candidate-H Brooker)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 December 2018.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the student: Heather Brooker will also be involved in this study.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical

HREC 838/2017

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

ACA48 – Progress And Planned Activity Report (PPA)

between a returning
Postgraduate Student and Supervisor

For Returning Master's And Doctoral Students

Information:

- The purpose of this annual PPA is to report on progress made in the past year, and to update any agreements in the MoU that may require revision.
- The PPA must be completed for each subsequent year as a precondition for registration.
- Care should be taken in completing this PPA in full, as it is a contractual agreement.
- The MOU and PPA(s) will be used in any disputes that may arise during the period a student is registered for a postgraduate degree.

Note:

- This is a dynamic form where different fields will be displayed depending on your selected options.
- The comment text input fields are expandable and there is no limit on text input.
- Sections / fields requiring information for the student to complete have been indicated with ★.
- The student should electronically complete the required sections / fields and sign the form by entering text in the signatory fields before emailing it to the primary supervisor.
- The primary supervisor should electronically complete the required sections / fields, act as a liaison between any additional supervisors required, and sign the form by entering text in the signatory fields before emailing the form back to the student.

A. Student and supervisor details

★A.1 Student details

Student number	B	R	K	H	E	A	0	0	1
First name(s)	Heather Caitlyn								
Last name	Brooker								
Contact address	44 ST Patrick Road, Houghton, Johannesburg, 2198								
*UCT email	brkhea001@uct.ac.za								
Telephone number	0764106921			Mobile number					
Faculty	Health Sciences								
Department(s)	Physiotherapy								

*Note: It is University policy that your official UCT email address is used for all academic correspondence.

★A.2 Degree (Select the appropriate degree option)

PhD	☐	Masters (by research)	☐	Masters (with coursework & research)	✓

★A.3 Jointly awarded degree

Is this a jointly awarded or co-badged degree [*1]	Yes	☐	No	✓

[*1] A jointly awarded research degree means that you will be registered at two Universities for the same degree in terms of a formal contract. A co-badged degree is awarded by one institution which recognises the contributions of one or more partner institutions by co-badging. The following URL provide a reference for information on jointly awarded and co-badged degrees: https://www.uct.ac.za/downloads/uct.ac.za/about/policies/Joint_Degrees_Policy.pdf

8.2. Appendix 2: Recruitment Letter

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital

To whom it may concern:

Participants required for University of Cape Town MSc Exercise and Sports Physiotherapy study

I, Heather Brooker, am currently a Master's student in the Division of Physiotherapy at the University of Cape Town. I will be conducting a study to determine the incidence of overuse and traumatic musculoskeletal injuries in professional ballet dancers identifying risk factors associated with the Female Athletic Triad.

I am looking to recruit professional female ballet dancers who are over the age of 18 years to take part in the study. The study aims to identify the incidence of acute and overuse injuries over the course of three months, the correlation between body mass index (BMI), body fat percentage, menstrual function and injury in female dancers and the relationship between the Functional Lower Extremity Evaluation (FLEE) scores and injury rates.

Ballet dancers suffer a high incidence of injuries with the repetitive high impact movements placing incredible strain on all soft tissue and biomechanical structures. Injuries for this study are defined as the amount of time taken to return to altered and full training post-injury.

The Female Athletic Triad affects mostly young female athletes and results in altered menstrual cycles (amenorrhoea or dysmenorrhoea), inadequate caloric intake resulting in decreased bone density (osteopenia or osteoporosis). These athletes tend to suffer higher incidences of overuse injuries and stress fractures as a result.

This study will take place over the course of three months. Measurements taken will include body composition, skinfold measurements (by a qualified Dietician) and the Functional Lower Extremity Evaluation as well as a subjective questionnaire at the start of the study. Participants will be required to complete a three-day nutrition diary and a menstrual history diary at the initial evaluation period. Injury reporting will take place and time taken to return to full training will be tracked. Dancing hours will be collected with the assistance of the dance instructors for consistent information collection. All injuries will need to be reported to myself, the investigator, at time of incidence. Participants have a right to withdrawal at any time throughout the study.

All participant’s details and study results will strictly confidential as participation is voluntary. Hardcopies and electronic data will be locked away and under password-protected folders with the allocation of participant numbers. Should you choose to participate and then fail to complete the study your results will be inconclusive, and unfortunately, no feedback will be made available to you. Those who complete the study will have a feedback session with myself and the dietician to identify possible factors that may be contributing to injury incidence.

Should you have any questions concerning the abovementioned study, please do not hesitate to contact me. Your participation will be much appreciated.

Kind Regards,

Heather Brooker

BSc Physiotherapy (University of Stellenbosch)
MSc Exercise and Sports Physiotherapy (UCT) (Student)

8.3. Appendix 3: Informed Consent (Participant)

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital

MSc Exercise and Sports Physiotherapy: Musculoskeletal Injuries in Ballet Dancers: A Prospective Study.

Informed Consent Form

Dear Participant

I, Heather Brooker, am currently a Masters student in the Division of Physiotherapy at the University of Cape Town. The information obtained will be used to complete my mini dissertation in partial fulfilment of the MPhil Exercise and Sports Physiotherapy programme. This study has obtained ethical approval from the Human Research Ethics Committee (HREC), Faculty of Health Sciences, University of Cape Town. (To be inserted).

I will be conducting a study to determine the incidence of overuse and traumatic musculoskeletal injuries in professional ballet dancers as well as screening for risk factors associated with the Female Athletic Triad.

The Female Athletic Triad affects mostly young female athletes and results in altered monthly period cycles (none - amenorrhoea or irregular - dysmenorrhoea), not enough calories in the diet and resulting in a decrease in bone density and strength (osteopenia or osteoporosis). These dancers tend to suffer higher incidences of overuse injuries and stress fractures and a shorter athletic career, hence why early identification and prevention are vital in professional and recreational dancers.

Information obtained during the study will include injury information, previous injuries and those occurring during the study as well as measurements taken with the Functional Lower Extremity Evaluation (FLEE), body mass index (BMI), skinfold tests, menstrual and nutrition information, using a three-day nutrition diary. The questionnaire will be available to you in a hard copy version or as an electronic version which will be sent to you via email.

You will be asked to complete a subjective evaluation form for information on your menstrual cycles and training history, a three-day nutrition diary, undergo the FLEE evaluation, body composition, and skinfold measurements after signing the informed consent form. Following this initial collection period, any injuries over the three-month period will need to be reported to myself and the instructor using the injury reporting form. The dance instructor will record training and performing hours and submit them weekly over the three-month period. If you do any training outside the school environment, you will be asked to complete additional logbooks individually.

The initial subjective questionnaire will be accessed in an electronic or hardcopy version, depending on internet access. This will need to be completed prior to the FLEE evaluation, body composition and skinfold measurements, which will be performed by a trained Dietician. The FLEE is a 45-minute battery of 8 standardized functional performance tests that measure components of lower extremity function: includes the single-leg hop, the timed hop, the triple hop and the crossover hop which is used in conjunction with the square hop test, to assess dynamic postural balance, coordination and strength of the thigh and calf muscles. The final component of the FLEE test is the Lower Extremity Functional Test (LEFT) which comprises of multidirectional drills performed in each direction in a 16-step sequence using a diamond-shaped course.

Following the evaluation, you will be tracked over a period of three months. All injuries, no matter how big or small will need to be reported on the injury reporting form. The severity of injuries reported will be measured by the number of training sessions you have missed or needed to alter before returning to your full training level. You will indicate this on the injury reporting form.

Please note that taking part in the study is voluntary and that you have the right to withdraw from the study at any time.

Potential Risks

This study carries minimal risks with regards to possible injury during the FLEE, however, a full warmup and education on the tests will be done to ensure injury risk is low. The skinfold testing may cause some discomfort from the pinching of the callipers and the grip necessary for the measurement. If you find the discomfort painful, we can readjust or discontinue the measurement immediately. Some muscle soreness might be experienced following the FLEE if the movements required are unaccustomed and the possible muscle soreness from the skinfold testing, but it should resolve within a day or two. All possible efforts will be made to minimise the risk of injury but if you should, however, become injured, referral for appropriate medical care will be provided. Should the results discussed in your feedback session cause emotional distress or have identified the need for a referral to a specialist, it will be further discussed with you.

Benefits

There are no direct benefits to you taking part in the study. The results obtained through the evaluation and data collection will be made available to you once the study has been completed. All participants who take part in the study will have a feedback session with myself and the dietician, irrespective of whether they complete the study or not, to identify possible factors that may be contributing to injury incidence. Recommendations will be provided to the dancers and instructors with regards to possible adjustments of intrinsic and extrinsic factors that are identified through the course of the study as well as an information booklet of the Female Athlete Triad.

What happens if something goes wrong?

Please note that the University of Cape Town (UCT) does offer "no-fault" insurance that will cover all participants if something may go wrong. This insurance may provide prompt payment of compensation for any trial-related injuries that may occur, per the Association of the British Pharmaceutical Industry (ABPI). An injury is defined as "trial-related" if it occurred anytime during the trial activities. Should any injuries occur during the evaluation or the study that are directly caused by the trial or its interventions, you must notify the investigator immediately. UCT also reserves the right not to compensate if the injury occurred in the case where instructions were not followed. However, your right to claim compensation for injury where negligence is proven is not affected.

What will happen to the information about me?

All dancers who take part in this study, their details and results will remain strictly confidential as your participation is voluntary. Hardcopies and electronic data will be locked away and under password-protected folders with the allocation of participant numbers. All participants within the study will have a feedback session with myself and the dietician to identify possible factors that may be contributing to injury incidence, regardless of whether they complete the three-month data collection period or not. Participants have a right to withdrawal at any time throughout the study.

Questions or Concerns:

Should you have any questions in relation to the abovementioned study, please do not hesitate to contact me on 076 410 6921 or heathbrooker@gmail.com. You may also contact my study supervisors: Ms Kim Buchholtz (021 406 6135; kim.buchholtz@uct.ac.za) or Dr Theresa Burgess (021 406 6171; Theresa.burgess@uct.ac.za).

Please contact Prof Marc Blockman, Chairperson of the Faculty of Health Sciences Human Research Ethics Committee (021 406 6338; marc.blockman@uct.ac.za) in case you have any questions or concerns about your rights or welfare as a research participant.

Consent statement

By signing below, you are confirming that you have read and understood the informed consent form. You have the right to withdraw at any time without giving a reason, and that you are welcome to ask questions at any time. All information collected during the process of this study is strictly confidential and no participants will be identified in the event of a publication. Your signature is further confirmation that you understand the possible risks associated with this study.

______________________	______________________	______________________
Signature of Participant	Name (please print)	Date
______________________	______________________	______________________
Signature of Investigator	Name (please print)	Date
______________________	______________________	______________________
Signature of Witness	Name (please print)	Date

8.4 Appendix 4: Subjective Questionnaire

Participant Name:

Section A: Demographic information and medical history

1. Date of birth ______________________
2. Age at which ballet training started (years) ______________________
3. Body mass (kilograms)

   ____

4. Height (centimetres) ______________________
5. Do you take any medication? (Yes/No) ______________________

   Please describe in the table below.

	Name	Dosage and Frequency
Chronic medication (please specify)		
NSAIDs or anti-inflammatories (please specify)		
Analgesics (please specify)		
Other (please specify)		

6. Have you undergone any of the below mentioned medical tests in the previous six months?

6.1. Reason for tests (Please describe) ____

6.2. X-rays YES/NO

6.3. Blood tests YES/NO

6.4. Bone density tests YES/NO

6.5. Other YES/NO

6.6. Test result (optional) ____

7. Menstrual history

7.1. How many days does it last for? ______

7.2. Is this the regular cycle for you? YES/NO

7.3. Is it the normal flow for you? YES/NO

7.4. Please describe the level of flow (minimal; light; moderate; heavy; super heavy)

7.5. How many periods have you missed completely in the past 12 months? ______

7.6. How many periods have altered (for example their duration or flow level) over the past 12 months ______

7.7. What affects your regular cycle? Please describe ________________________________

7.8. Do you take any medication for your cycle? YES/NO

Please describe:

7.8.1. Name: __________________________

7.8.2. Dosage: _________________________

7.8.3. Frequency: __________________________

Section B: Training History

1. How many days do you do ballet training during the week? (days) ____
2. What is the duration of the average training session (1) in hours? ____
3. What is the TOTAL DURATION of ballet training sessions this week in hours? ____
4. Which number best represents the difficulty or intensity of your ballet training sessions on average? (According to the rate of perceived exertion RPE scale) ____

5. How many performances as part of a production, did you have this week? ____

6.1. How many sessions of other (non-ballet) training did you do in a week? Please describe. ____

6.2. What was the average duration of each of the other (non-ballet) training sessions this week in minutes/hours? Please describe. ____

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Section C: Injury History

PLEASE COMPLETE THIS FORM FOR EACH INDIVIDUAL PREVIOUS INJURY THAT OCCURRED WITHIN YOUR DANCING CAREER THAT RESULTED IN ALTERED OR TIME OFF FROM TRAINING– SHOULD YOU EXCEED 5 PREVIOUS INJURIES PLEASE ASK FOR ASSISTANCE FOR MORE FORMS.

Previous Injury #1:

1. Describe the injury: ____

   1.1. New (acute) YES/NO

   1.2. Ongoing (chronic) YES/NO

   1.3. Overuse or trauma (Please describe____

   1.4. Diagnosis ____

2. Location of injury (Please tick location)

Head	☐	Wrist
Face	☐	Hand
Neck	☐	Hip
Middle back	☐	Thigh
Lower back	☐	Knee
Shoulder	☐	Lower leg
Upper arm	☐	Ankle
Elbow	☐	Foot
Forearm	☐	Other:

3. The diagnosis of the abovementioned injury was made by?

   3.1. Self-diagnosed YES/NO

   3.2. Orthopaedic surgeon YES/NO

   3.3. GP YES/NO

   3.4. Physiotherapist YES/NO

3.5. Sports therapist / Biokinetics YES/NO

3.6. Diagnosis made ____

4. <u>Were any special investigations done?</u>

4.1. X-ray YES/NO

4.2. MRI YES/NO

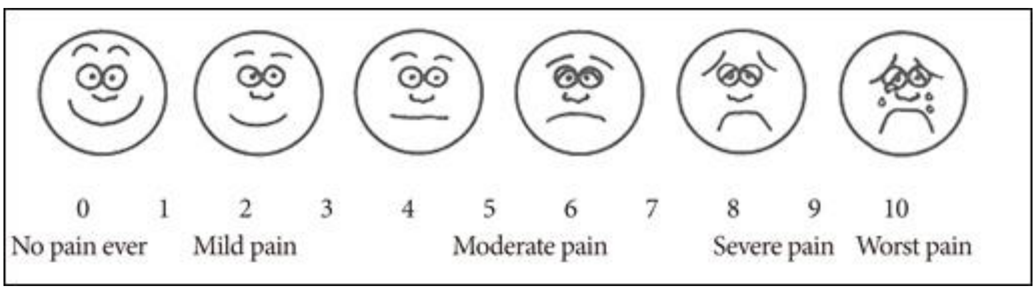
4.3. Bone scan YES/NO

4.4. Ultrasound YES/NO

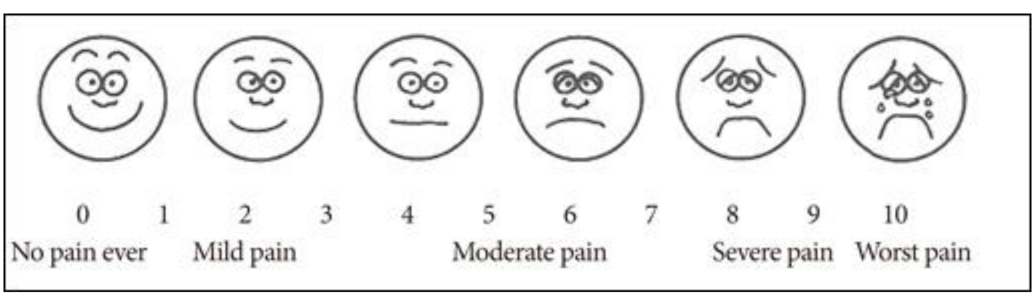
4.5. Blood tests YES/NO

4.6. Results (optional)____

5. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are at <u>REST</u>, with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



6. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are TRAINING (DANCING), with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



7. What were you doing when the injury occurred?

Ballet training YES/NO

Ballet performance YES/NO

Stretching YES/NO

Other (please specify)____

8. <u>What ballet movement or component were you doing when the injury occurred? Please describe.</u>

____

____

9. <u>What do you think caused the injury during your training? (You can select up to 3 options)</u>

9.1. Overuse YES/NO

9.2. Incorrect technique or execution of movement YES/NO

9.3. High intensity training session YES/NO

9.4. High training volume YES/NO

9.5. Sudden change in amount of training YES/NO

9.6. Sudden change in intensity of training YES/NO

9.7. Poor warm up YES/NO

9.8. Fatigue YES/NO

9.9. Repetition of the same movement YES/NO

9.10. I don’t know YES/NO

9.11. Other____

10. What movements increase or aggravate your pain while dancing?

____

____

____

____

11. What treatment did you have for your injury?

11.1.	None	YES/NO
11.2.	GP	YES/NO
11.3.	Physiotherapy	YES/NO
11.4.	Chiropractor	YES/NO
11.5.	Biokinetics	YES/NO
11.6.	Orthopaedic surgeon	YES/NO
11.7.	Massage	YES/NO
11.8.	Ice	YES/NO
11.9.	Rest	YES/NO
11.10.	Injections	YES/NO
11.11.	Acupuncture/dry needling	YES/NO
11.12.	Other (please specify) ____	
11.13.	Medication (please specify) ____	

12. How many training sessions did you MISS due to your injury? ______

13. How many sessions did you have to CHANGE OR ALTER due to your injury? ______

Previous Injury #2:

1. Describe the injury: ____
   1.1. New (acute) YES/NO
   1.2. Ongoing (chronic) YES/NO
   1.3. Overuse or trauma (Please describe____
   1.4. Diagnosis ____

2. Location of injury (Please tick location)

Head	☐	Wrist
Face	☐	Hand
Neck	☐	Hip
Middle back	☐	Thigh
Lower back	☐	Knee
Shoulder	☐	Lower leg
Upper arm	☐	Ankle
Elbow	☐	Foot
Forearm	☐	Other:

3. The diagnosis of the abovementioned injury was made by?
   3.1. Self-diagnosed YES/NO
   3.2. Orthopaedic surgeon YES/NO
   3.3. GP YES/NO
   3.4. Physiotherapist YES/NO
   3.5. Sports therapist / Biokinetics YES/NO
   3.6. Diagnosis made ____

4. <u>Were any special investigations done?</u>

   4.1. X-ray YES/NO

   4.2. MRI YES/NO

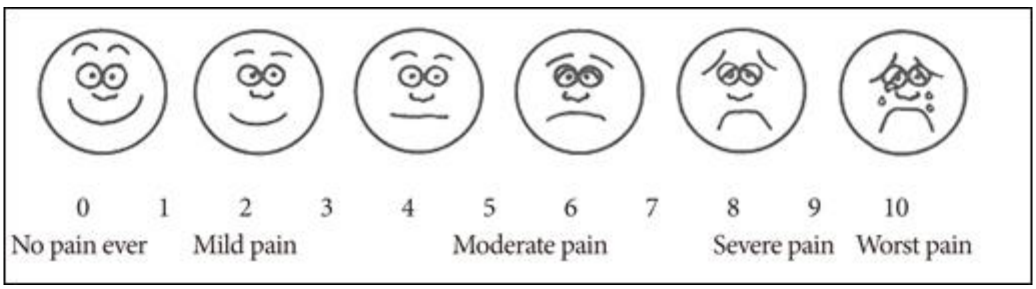
   4.3. Bone scan YES/NO

   4.4. Ultrasound YES/NO

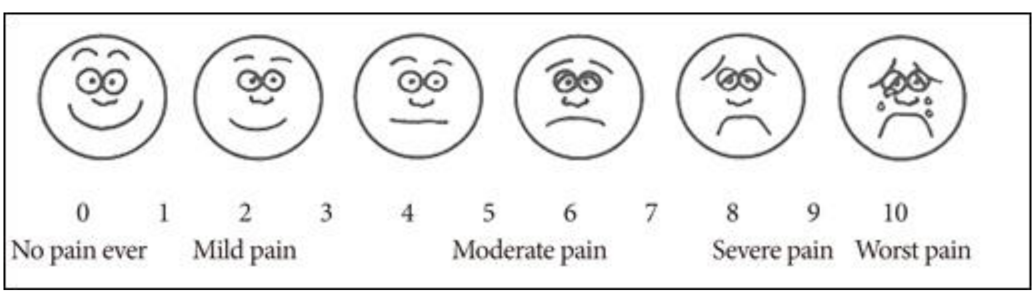
   4.5. Blood tests YES/NO

   4.6. Results (optional)____

5. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are at REST, with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



6. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are TRAINING (DANCING), with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



7. What were you doing when the injury occurred?

Ballet training	YES/NO
Ballet performance	YES/NO
Stretching	YES/NO

Other (please specify)____

8. <u>What ballet movement or component were you doing when the injury occurred? Please describe.</u>

____

____

9. <u>What do you think caused the injury during your training? (You can select up to 3 options)</u>

9.1. Overuse	YES/NO
9.2. Incorrect technique or execution of movement	YES/NO
9.3. High intensity training session	YES/NO
9.4. High training volume	YES/NO
9.5. Sudden change in amount of training	YES/NO
9.6. Sudden change in intensity of training	YES/NO
9.7. Poor warm up	YES/NO
9.8. Fatigue	YES/NO
9.9. Repetition of the same movement	YES/NO
9.10. I don't know	YES/NO

9.11. Other____

10. <u>What movements increase or aggravate your pain while dancing?</u>

____

____

____

____

11. What treatment did you have for your injury?

11.1.	None	YES/NO
11.2.	GP	YES/NO
11.3.	Physiotherapy	YES/NO
11.4.	Chiropractor	YES/NO
11.5.	Biokinetics	YES/NO
11.6.	Orthopaedic surgeon	YES/NO
11.7.	Massage	YES/NO
11.8.	Ice	YES/NO
11.9.	Rest	YES/NO
11.10.	Injections	YES/NO
11.11.	Acupuncture/dry needling	YES/NO
11.12.	Other (please specify) ____	
11.13.	Medication (please specify) ____	

12. How many training sessions did you MISS due to your injury? ______

13. How many sessions did you have to CHANGE OR ALTER due to your injury? ______

Previous Injury #3:

1. Describe the injury: ____
    1.1. New (acute) YES/NO
    1.2. Ongoing (chronic) YES/NO
    1.3. Overuse or trauma (Please describe____
    1.4. Diagnosis ____

2. Location of injury (Please tick location)

Head		Wrist
Face		Hand
Neck		Hip
Middle back		Thigh
Lower back		Knee
Shoulder		Lower leg
Upper arm		Ankle
Elbow		Foot
Forearm		Other:

3. The diagnosis of the abovementioned injury was made by?
    3.1. Self-diagnosed YES/NO
    3.2. Orthopaedic surgeon YES/NO
    3.3. GP YES/NO
    3.4. Physiotherapist YES/NO
    3.5. Sports therapist / Biokinetics YES/NO
    3.6. Diagnosis made ____

4. <u>Were any special investigations done?</u>

   4.1. X-ray YES/NO

   4.2. MRI YES/NO

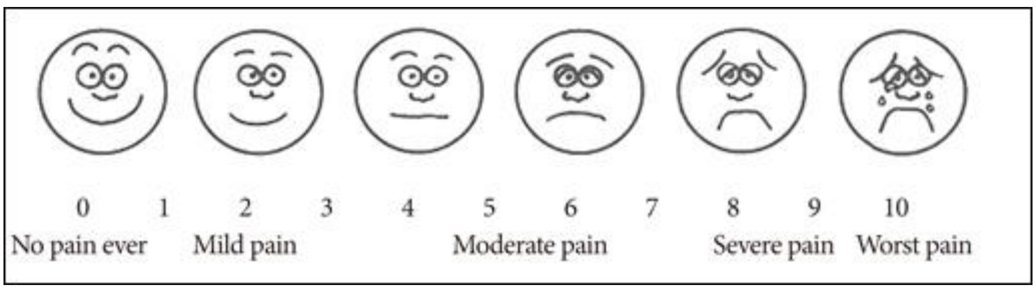
   4.3. Bone scan YES/NO

   4.4. Ultrasound YES/NO

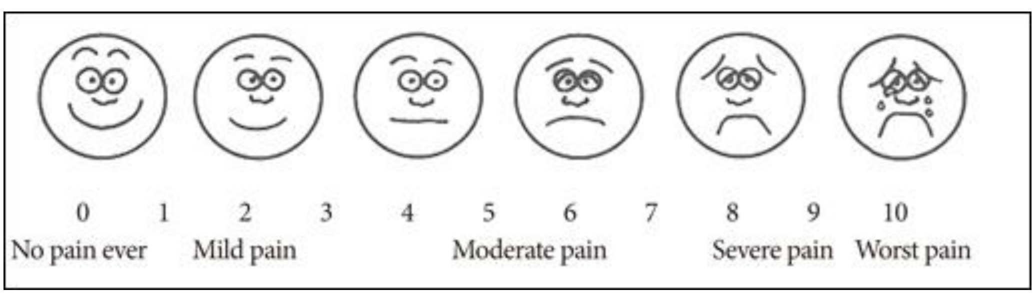
   4.5. Blood tests YES/NO

   4.6. Results (optional)____

5. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are at <u>REST</u>, with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



6. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are TRAINING (DANCING), with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



7. What were you doing when the injury occurred?

Ballet training	YES/NO
Ballet performance	YES/NO
Stretching	YES/NO

Other (please specify)____

8. <u>What ballet movement or component were you doing when the injury occurred? Please describe.</u>

____

____

9. <u>What do you think caused the injury during your training? (You can select up to 3 options)</u>

9.1. Overuse	YES/NO
9.2. Incorrect technique or execution of movement	YES/NO
9.3. High intensity training session	YES/NO
9.4. High training volume	YES/NO
9.5. Sudden change in amount of training	YES/NO
9.6. Sudden change in intensity of training	YES/NO
9.7. Poor warm up	YES/NO
9.8. Fatigue	YES/NO
9.9. Repetition of the same movement	YES/NO
9.10. I don't know	YES/NO

9.11. Other____

10. <u>What movements increase or aggravate your pain while dancing?</u>

____

____

____

____

11. What treatment did you have for your injury?

11.1.	None	YES/NO
11.2.	GP	YES/NO
11.3.	Physiotherapy	YES/NO
11.4.	Chiropractor	YES/NO
11.5.	Biokinetics	YES/NO
11.6.	Orthopaedic surgeon	YES/NO
11.7.	Massage	YES/NO
11.8.	Ice	YES/NO
11.9.	Rest	YES/NO
11.10.	Injections	YES/NO
11.11.	Acupuncture/dry needling	YES/NO
11.12.	Other (please specify) ____	
11.13.	Medication (please specify) ____	

12. How many training sessions did you MISS due to your injury? ______

13. How many sessions did you have to CHANGE OR ALTER due to your injury? ______

Previous Injury #4:

1. Describe the injury: ____
    - 1.1. New (acute) YES/NO
    - 1.2. Ongoing (chronic) YES/NO
    - 1.3. Overuse or trauma (Please describe____
    - 1.4. Diagnosis ____

2. Location of injury (Please tick location)

Location	Tick	Location
Head		Wrist
Face		Hand
Neck		Hip
Middle back		Thigh
Lower back		Knee
Shoulder		Lower leg
Upper arm		Ankle
Elbow		Foot
Forearm		Other:

3. The diagnosis of the abovementioned injury was made by?
    - 3.1. Self-diagnosed YES/NO
    - 3.2. Orthopaedic surgeon YES/NO
    - 3.3. GP YES/NO
    - 3.4. Physiotherapist YES/NO
    - 3.5. Sports therapist / Biokinetics YES/NO
    - 3.6. Diagnosis made ____

4. <u>Were any special investigations done?</u>

4.1. X-ray YES/NO

4.2. MRI YES/NO

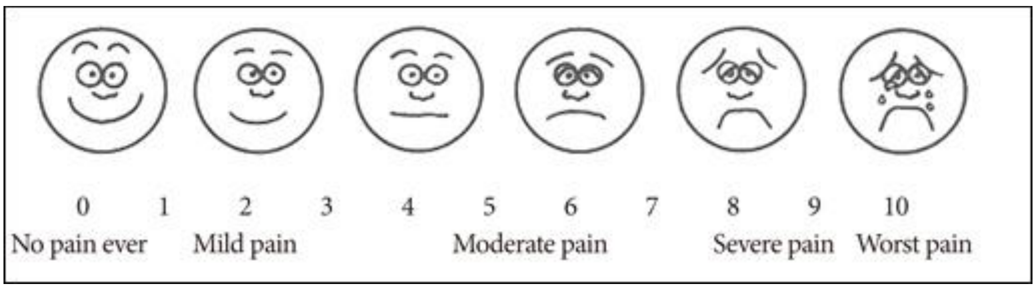
4.3. Bone scan YES/NO

4.4. Ultrasound YES/NO

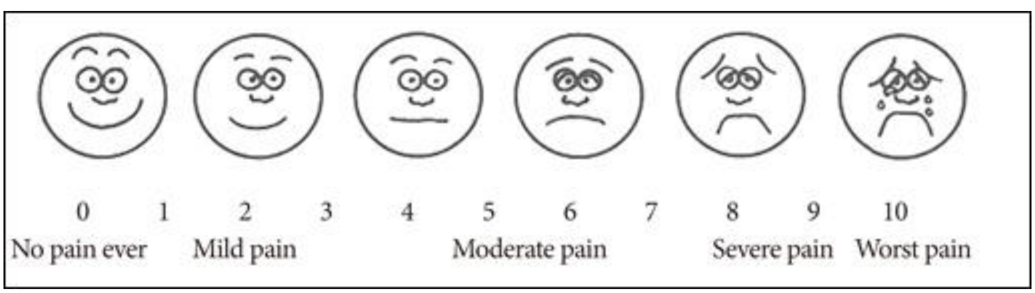
4.5. Blood tests YES/NO

4.6. Results (optional)____

5. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are at <u>REST</u>, with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



6. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are TRAINING (DANCING), with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



What were you doing when the injury occurred?

Ballet training YES/NO

Ballet performance YES/NO

Stretching YES/NO

Other (please specify)____

7. <u>What ballet movement or component were you doing when the injury occurred? Please describe.</u>

____

____

8. <u>What do you think caused the injury during your training? (You can select up to 3 options)</u>

8.1. Overuse YES/NO

8.2. Incorrect technique or execution of movement YES/NO

8.3. High intensity training session YES/NO

8.4. High training volume YES/NO

8.5. Sudden change in amount of training YES/NO

8.6. Sudden change in intensity of training YES/NO

8.7. Poor warm up YES/NO

8.8. Fatigue YES/NO

8.9. Repetition of the same movement YES/NO

8.10. I don't know YES/NO

8.11. Other____

9. <u>What movements increase or aggravate your pain while dancing?</u>

____

____

____

____

10. What treatment did you have for your injury?

10.1.	None	YES/NO
10.2.	GP	YES/NO
10.3.	Physiotherapy	YES/NO
10.4.	Chiropractor	YES/NO
10.5.	Biokinetics	YES/NO
10.6.	Orthopaedic surgeon	YES/NO
10.7.	Massage	YES/NO
10.8.	Ice	YES/NO
10.9.	Rest	YES/NO
10.10.	Injections	YES/NO
10.11.	Acupuncture/dry needling	YES/NO
10.12.	Other (please specify) ____	
10.13.	Medication (please specify) ____	

11. How many training sessions did you MISS due to your injury? ______

12. How many sessions did you have to CHANGE OR ALTER due to your injury? ______

Previous Injury #5:

1. Describe the injury: ____
   1.1. New (acute) YES/NO
   1.2. Ongoing (chronic) YES/NO
   1.3. Overuse or trauma (Please describe____
   1.4. Diagnosis ____

2. Location of injury (Please tick location)

Head		Wrist
Face		Hand
Neck		Hip
Middle back		Thigh
Lower back		Knee
Shoulder		Lower leg
Upper arm		Ankle
Elbow		Foot
Forearm		Other:

3. The diagnosis of the abovementioned injury was made by?
   3.1. Self-diagnosed YES/NO
   3.2. Orthopaedic surgeon YES/NO
   3.3. GP YES/NO
   3.4. Physiotherapist YES/NO
   3.5. Sports therapist / Biokinetics YES/NO
   3.6. Diagnosis made ____

4. Were any special investigations done?

   4.1. X-ray YES/NO

   4.2. MRI YES/NO

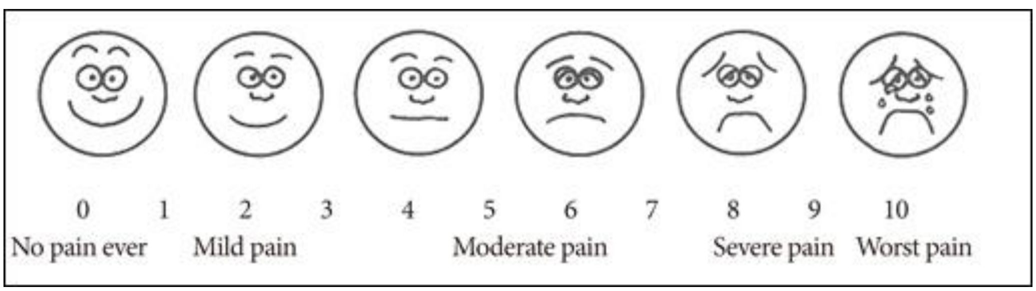
   4.3. Bone scan YES/NO

   4.4. Ultrasound YES/NO

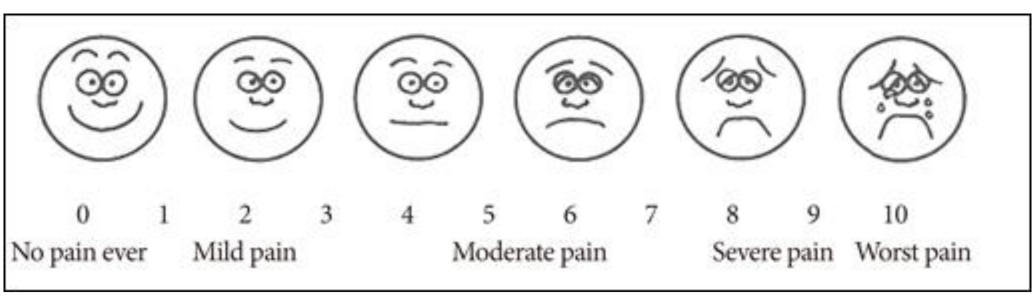
   4.5. Blood tests YES/NO

   4.6. Results (optional)____

5. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are at REST, with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



6. Please rank your pain from the abovementioned injury on a scale of 0-10 while you are TRAINING (DANCING), with 0 being the best (no pain at all) to 10 being the worst imaginable pain. If you answer 0, you are pain-free.



7. What were you doing when the injury occurred?

   Ballet training YES/NO

   Ballet performance YES/NO

   Stretching YES/NO

   Other (please specify)____

8. <u>What ballet movement or component were you doing when the injury occurred? Please describe.</u>

____

____

9. <u>What do you think caused the injury during your training? (You can select up to 3 options)</u>

   9.1. Overuse YES/NO

   9.2. Incorrect technique or execution of movement YES/NO

   9.3. High intensity training session YES/NO

   9.4. High training volume YES/NO

   9.5. Sudden change in amount of training YES/NO

   9.6. Sudden change in intensity of training YES/NO

   9.7. Poor warm up YES/NO

   9.8. Fatigue YES/NO

   9.9. Repetition of the same movement YES/NO

   9.10. I don't know YES/NO

   9.11. Other____

10. <u>What movements increase or aggravate your pain while dancing?</u>

____

____

____

____

11. What treatment did you have for your injury?

11.1.	None	YES/NO
11.2.	GP	YES/NO
11.3.	Physiotherapy	YES/NO
11.4.	Chiropractor	YES/NO
11.5.	Biokinetics	YES/NO
11.6.	Orthopaedic surgeon	YES/NO
11.7.	Massage	YES/NO
11.8.	Ice	YES/NO
11.9.	Rest	YES/NO
11.10.	Injections	YES/NO
11.11.	Acupuncture/dry needling	YES/NO
11.12.	Other (please specify) ____	
11.13.	Medication (please specify) ____	

12. How many training sessions did you MISS due to your injury? _______

13. How many sessions did you have to CHANGE OR ALTER due to your injury? _______

8.5 Appendix 5: Three-Day Nutrition Diary

Participant Name: Date:

Day number:

Weekday / Weekend

Meal	Food eaten	Serving size	Condiments	Amount/ quantity	Beverage	Amount
Breakfast **Time:**						
Snack **Time:**						
Lunch **Time:**						
Snack **Time:**						
Dinner **Time:**						
Snack **Time:**						

Serving sizes:

¼ cup – golf ball ½ cup – tennis ball 1 cup – fist size

Three-Day Nutrition Diary

Participant Name: Date:

Day number:

Weekday / Weekend

Meal	Food eaten	Serving size	Condiments	Amount/ quantity	Beverage	Amount
Breakfast **Time:**						
Snack **Time:**						
Lunch **Time:**						
Snack **Time:**						
Dinner **Time:**						
Snack **Time:**						

Serving sizes:

¼ cup – golf ball ½ cup – tennis ball 1 cup – fist size

<u>Three-Day Nutrition Diary</u>

Participant Name: Date:

Day number:

Weekday / Weekend

Meal	Food eaten	Serving size	Condiments	Amount/ quantity	Beverage	Amount
Breakfast **Time:**						
Snack **Time:**						
Lunch **Time:**						
Snack **Time:**						
Dinner **Time:**						
Snack **Time:**						

Serving sizes:

¼ cup – golf ball ½ cup – tennis ball 1 cup – fist size

8.6. **Appendix 6: Body Composition and Skinfold Measurements** (74)

- The measurements will be taken by a qualified Dietician trained in Skinfold Measurements.
- Measurements will be taken on the right side of the body.
- Each site will be marked with a non-permanent marker.
- Each reading will be rounded to the nearest 0.5mm.
- Readings will be repeated in the same order with a 15 second period in-between measurements. 3 measurements will be taken, and the averaged reading will be used to enhance accuracy.

Participants name:	Measurements (mm)		
	1	2	3
Biceps			
Triceps			
Subscapular			
Suprailiac			
Abdominal			
Thigh			
Medial calf			

Height	
Body mass	
BMI	

Sum of 7 skinfolds:

Predicted % body fat:

8.7. **Appendix 7: Functional Lower Extremity Evaluation (FLEE)**

Procedure:

- Participants will begin with a 5 minute of normal warmup routine.
- For tests performed on a single leg, participants will start with their dominant leg and repeat the test on the opposite leg.
- A metronome will be used to maintain the pace.

8 Test Battery

Control Sequence	1. Timed Lateral Step Down
	2. Lateral Leap and Catch
Hop Sequence	3. Single-Leg hops For Distance
	4. Single-Leg Timed Hop
	5. Single-Leg Triple Hop for Distance
	6. Crossover Hop for Distance
Endurance Sequence	7. Square Hop Test
	8. Lower Extremity Functional Test (Left)

1. Timed lateral step down
   - 1.1. Position the one leg on top of the step in a starting squat position
   - 1.2. Tap the opposite leg down to the floor or mat off the step whilst squatting the top leg.
   - 1.3. Alternate the step down in time to the metronome clicks (at 80bpm).
   - 1.4. Repeat on the opposite side.
   - 1.5. The test continues for 180 seconds

1.6. Strikes will be recorded for:

- discontinuation of the movement due to pain or inability to continue
- knee valgus
- loss of balance
- falling off pace
- hands coming off the hips

1.7. Once 3 strikes have been recorded the test is then stopped and the total time is the recorded measure prior to the 3 strikes.

2. The Lateral Leap and Catch

2.1. Jumping unilaterally continuously for 60 seconds with the metronome set to 40 bpm pace.

2.2. The participants jump from one foot to the other over lines set at 60% body height.

2.3. With each landing, the participant will need to ensure that correct landing biomechanics are achieved without a pelvic drop or knee valgus movements

2.4. The number of times the line is crossed in the 60 second time period, as well as the number of times it was not completely crossed, will be documented.

2.5. Strikes will be recorded for:

2.5.1. Faulty manoeuvres

2.5.2. Knee valgus

2.5.3. Pelvic drop

2.5.4. Significant loss of balance

2.6. The test will be terminated prior to the 60 second mark should the participant receive 3 strikes and the test time will be recorded.

3. The Hop test sequence

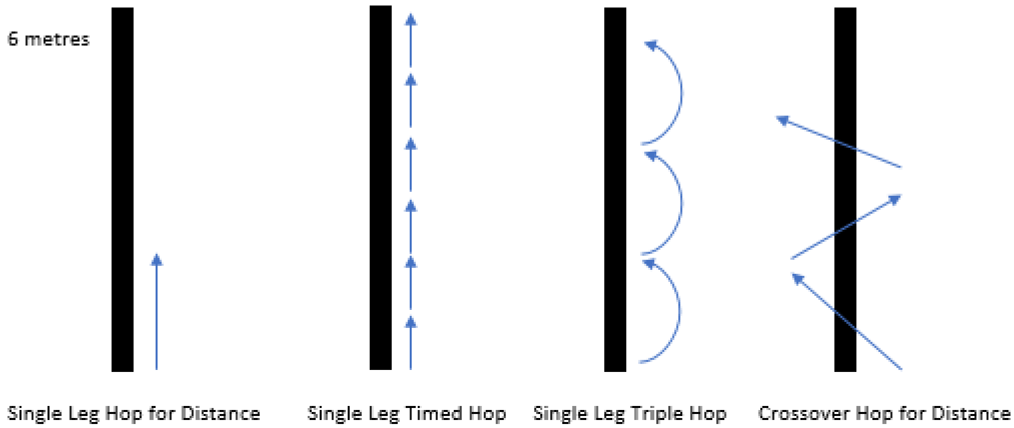
3.1. Used for the Single Leg Hop for distance, Single-Leg Timed Hop Test, Single-Leg Triple Hop of Distance, and Crossover Hop for Distance.

3.2. A 6m distance is measured out on the floor or mat.

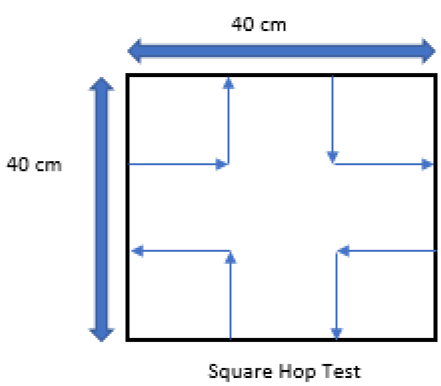
3.3. The distance is measured for the single, triple and crossover leg hop for distance.

3.4. Participants will be instructed to hold the landing for the Single Leg Hop, Triple Hop and Crossover Hop for 2 seconds, strikes will be given should hand move off hips or balance lost with the landing.

3.5. The average distance of the Hop test sequences will be used.



4. The Square Hop Test
   4.1. A square block measuring 40cm x 40 cm is indicated on the floor.
   4.2. The participant hops into the square, left and continues in a clockwise direction around the square.
   4.3. Participants will be allowed to practice the test prior.
   4.4. Touching the contralateral foot to the ground during the test is not permitted.
   4.5. Indicated ankle instability for functional performance deficits.
   4.6. The participant will stop the movement after 30 seconds at which the number of lines crossed minus the number of lines hit during the clockwise movement will be counted.



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5. The Lower Extremity Functional Test (LEFT)

5.1. Cones are placed in a diamond shape with 30 x 10 ft. cross-sections at spots indicated by A, B, C, and D.

5.2. The test is performed in the specific sequence:

5.2.1.Forward run from A-C-A.

5.2.2.Backwards run A-C-A.

5.2.3.Side shuffles around the perimeter A-D-C-B, and A-B-C-D.

5.2.4.Cariocas around the perimeter.

5.2.5.Figure 8 runs around the perimeter, looping around cones at C and A.

5.2.6.45-degree cuts around the perimeter cutting at B and D.

5.2.7.90-degree cuts from A-B-D and back from A-B-D.

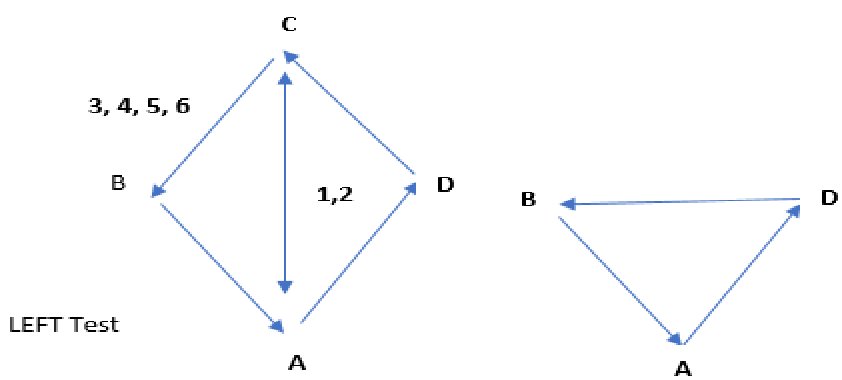
5.2.8.90-degree crossover cuts over the inside foot A-D-B and back A-B-D.

5.2.9.Forward run

5.2.10. Backward run

5.3. The score for the LEFT will be measured as the time taken to complete a full sequence using a stopwatch.

(Adapted from Tabor MA, et al. "A multicentre study of the test-retest reliability of the Lower Extremity Functional Test," Journal of Sport Rehabilitation 11(3): 2002)



8.8. Appendix 8: FLEE data collection form

Participant Name:	Time is taken to complete (seconds)	The distance achieved (m)	Strikes	Comments
1. Timed Lateral Step Down	Out of 180 seconds			
2. Lateral Leap and Catch	Out of 60 seconds	Lines crossed: Lines hit:		
3. Single-Leg hops For Distance		Distance:		
4. Single Leg Timed Hop		Distance:		
5. Single Leg Triple Hop for Distance		Distance:		
6. Crossover Hop for Distance		Distance:		
7. Square Hop Test	Out of 30 seconds	Lines crossed: Lines hit:		
8. Lower Extremity Functional Test (LEFT)	Time is taken to complete			

8.9. Appendix 9: Injury reporting form (to be completed by the participant)

Name:

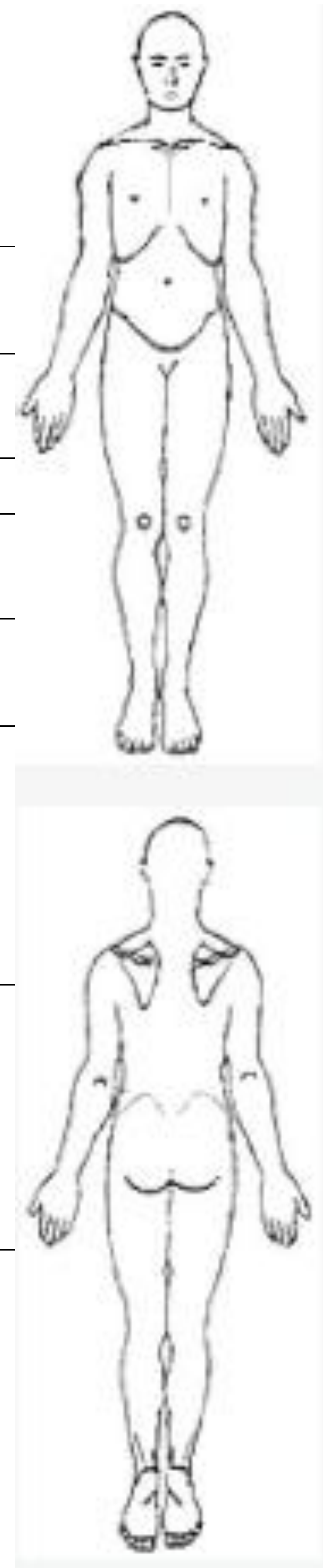
Date of birth:

Date of Injury:

Area of injury:

Date of form completion:

Describe the injury occurrence (exacerbation/first episode/recurrence)	
Were you able to continue training or performing? (Y/N)	
If not, reason (forced/precautionary)	
Please describe the specific side (bilateral/central/left/right/N/A)	
Please describe the specific areas injured	
What is your present stage of healing? (acute [3 weeks]/acute on chronic or subacute [3 to 8 weeks]/ chronic [greater than 10 weeks])	
Please describe the history of your present condition	



Where did the injury take place? (training/performing/gym/other)	
What activity were you performing? (stretching/jumping/training/rehearsal/weights/other)	
What movement were you performing? (arabesque/cannot recall/demi-pointe/large jumps/lifted/lifting/middle jumps/non-dance related/other/pirouette/plie/pointe/small jumps)	
What footwear were you wearing at the time of the injury? (ballet/barefoot/jazz/costume/pointe/trainers/other)	
Recovery strategy employed (combinations/exercise/ice or ice bath/hydration/meal/stretch/other)	

How many hours had you spent exercising on the day of the injury? (between 1 and 10)	
At what intensity were you training at? (minimum exertion) 1/2/3/4/5/6/7/8/9/10 (maximum exertion)	
How many hours did you spend exercising the previous day? (between 1 and 10)	
At what intensity? (minimum exertion) 1/2/3/4/5/6/7/8/9/10 (maximum exertion)	
Were you hydrated? (Y/N)	

If so, with what? (isotonic/water/other) Please describe	
How many hours since your last meal (1-12)	

Type of injury: OVERUSE (please describe possible extrinsic and intrinsic factors that may have contributed to the injury taking place)	
Extrinsic factors (environmental conditions/equipment/footwear/nutrition/other psychological factors/surface/training error/other)	
Intrinsic factors (lack of flexibility/ LLD/malalignment/muscle imbalance/muscle weakness/other)	
Type of injury: TRAUMATIC (please describe possible extrinsic and intrinsic factors that may have contributed to the injury taking place)	
Extrinsic factors (collision/accidental contact during partnering/props/other)	
Intrinsic factors (accelerated/jumping/lunge/side stepping/slip/sudden overload/twist/other)	
Injury grouping (if more than one area was affected by the injury taking place)	
Body part grouping (head-neck/shoulder/arm/forearm/wrist-hand/thoracic spine/rib/lumbar spine/pelvis/hip/upper leg/ knee/lower leg/ankle/foot)	
How long were you completely absent from any dance activities?	
What date did you return to full activities	

8.10. Appendix 10: Training Logbook (to be completed by the instructor)

Date: **13/02 to 19/02**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
E.g.: Jane Doe	Training Time 2hrs 15 mins	Training Time 3hrs 10 mins	Training Time Rest	Training Time 2hrs 15 mins	Training Time 3hrs 10 mins	Training Time Rest	Training Time
	Performance Time 35 mins	Performance Time	Performance Time 45 mins	Performance Time	Performance Time 1 hour 45 mins	Performance Time	Performance Time
	Training Time	Training Time	Training Time	Training Time	Training Time	Training Time	Training Time
	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time
	Training Time	Training Time	Training Time	Training Time	Training Time	Training Time	Training Time
	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time
	Training Time	Training Time	Training Time	Training Time	Training Time	Training Time	Training Time
	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time	Performance Time

8.11 Appendix 11: Informed Consent (Instructor)

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital

MSc Exercise and Sports Physiotherapy: Musculoskeletal Injuries in Ballet Dancers: A Prospective Study.

Informed Consent Form

Dear Instructor

I, Heather Brooker, am currently a Master's student in the Division of Physiotherapy at the University of Cape Town. The information obtained will be used to complete my mini-dissertation in partial fulfilment of the MPhil Exercise and Sports Physiotherapy programme. This study has obtained ethical approval from the Human Research Ethics Committee (HREC), Faculty of Health Sciences, University of Cape Town. (To be inserted).

I will be conducting a study to determine the incidence of overuse and traumatic musculoskeletal injuries in professional ballet dancers as well as screening for risk factors associated with the Female Athletic Triad.

You have been approached to assist with the study within your professional capacity as an instructor to record for each dancer taking part in the study their training and performing time, on an allocated timesheet. The timesheets will need to be submitted to me, the investigator, weekly. The timesheets will be used to determine the injury rate per 1000 dance hours and to assess the impact of training load on injury incidence within the professional ballet dancing population. Your participation in this study is voluntary, but vital for data collection, so is appreciated.

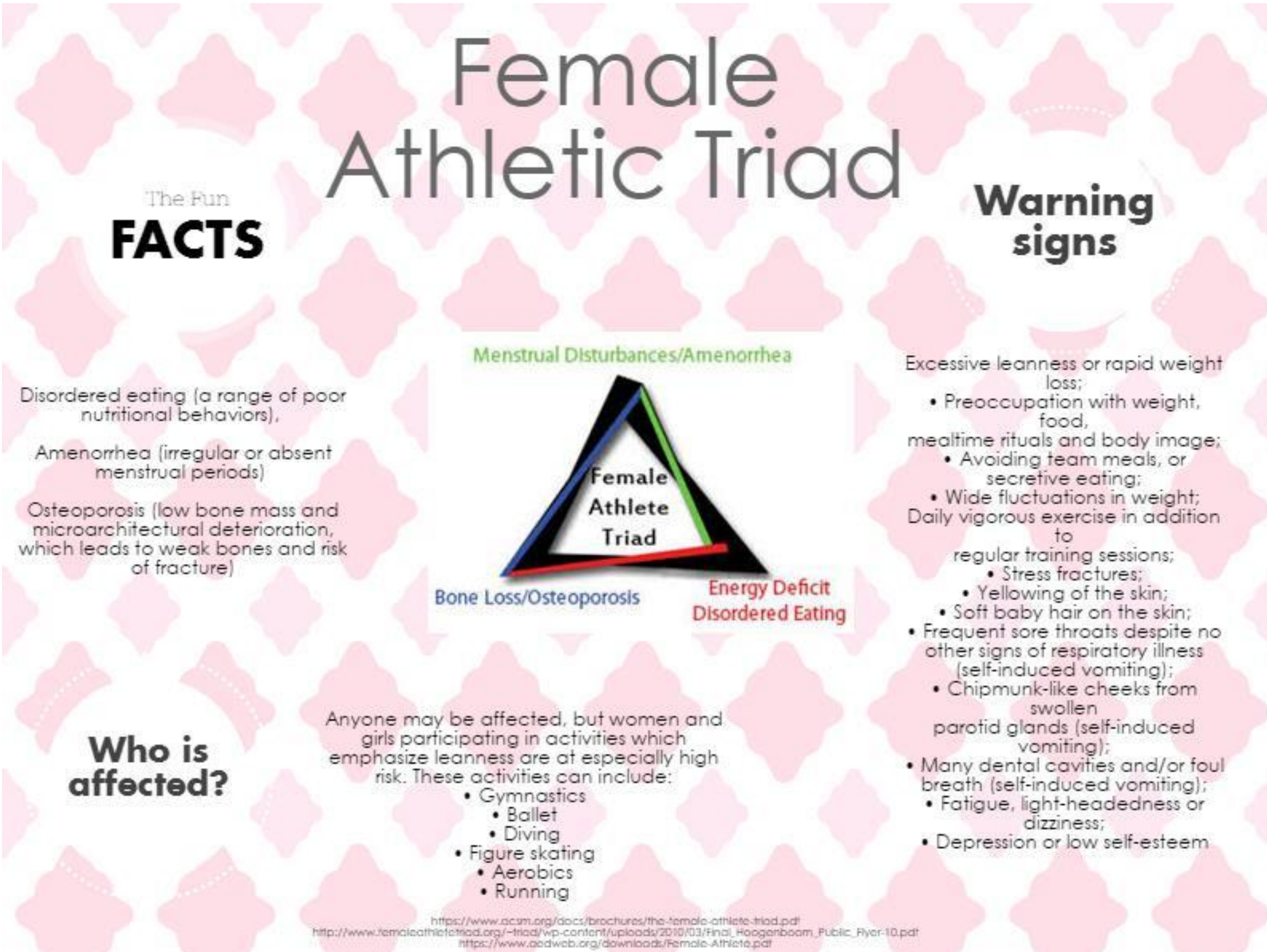
Should you have any questions with regards to the study and your role with the collection of data in this study, please do not hesitate to contact me.

Consent statement

By signing below, you are confirming that you have read and understood the informed consent form. You are welcome to ask questions at any time. All information collected during the process of this study is strictly confidential, and no participants will be identified in the event of a publication.

______________	______________	______________
Signature of Participant	Name (please print)	Date
______________	______________	______________
Signature of Investigator	Name (please print)	Date
______________	______________	______________
Signature of Witness	Name (please print)	Date

8.12. Appendix 12: Female Athletic Triad Information Booklet



Female Athletic Triad

Risks

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The Triad can affect every aspect of life. Nutrient deficiencies and fluid/electrolyte imbalance can lead to impaired performance, impaired growth, impaired mental functioning and increased risk of injury.
Long-term consequences may include loss of reproductive function
and serious medical conditions such as dehydration and starvation.
Ultimately, this condition could result in death.

Prevention and treatment

Treatment must address all possible causes of the Triad. Treatment should include medical, nutritional, and psychological intervention. Counseling and education regarding eating properly for the amount of energy expended as well as activity modification are integral parts of the recovery process. Normal menstruation should be a goal for the athlete.

Prevention should begin with nutritional, medical, and psychological education related to healthy eating and nutrition for a life-long healthy lifestyle.

She should keep track of her periods so she can monitor the number of days between cycles.

In addition, the athlete should not skip meals or snacks.Foods containing protein and fat (nuts, cheese, yogurt) as well as carbohydrate-containing foods (cereal, crackers, pretzels, fruit, vegetables) are healthy choices for the athlete.

The athlete should be encouraged to visit a dietitian if she needs meal and/or snack suggestions or recommendations.

https://www.acsm.org/docs/brochures/the-female-athlete-triad.pdf
http://www.femaleathletetriad.org/~triad/wp-content/uploads/2010/03/Final_Hoogenboom_Public_Flyer-10.pdf
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