# Associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers

By

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I, Kate Allison, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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# DEDICATION

I DEDICATE THIS DISSERTATION TO JESUS CHRIST, MY REASON FOR LIVING, AND IN WHOM ALL THINGS ARE FOUND.

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# ABSTRACT

**Background:** Classical ballet is an art form that seems graceful on the surface. However, beneath the disguise of beauty and ease lies an extremely physically demanding activity that calls for dedication, strength and perseverance. Ballet requires a specific body type and precise techniques, which predispose the dancer to musculoskeletal injury. Although a few studies have been conducted to investigate biomechanical factors as risk factors for injury in ballet dancers, few have included amateur ballet dancers and a range of biomechanical factors.

**Objectives:** This study aimed to determine characteristics of ballet-related injury in amateur ballet dancers in the greater Durban area; to measure and record lower limb biomechanical measurements of these dancers; and to identify associations between the biomechanical measurements and characteristics of injury in the population.

**Method:** A quantitative, questionnaire-based survey with biomechanical measurements was conducted on 21 amateur ballet dancers in the greater Durban area. Statistical analysis included the description of categorical variables using frequency and percentages in tables and bar charts. Continuous variables were summarised using mean, standard deviation and range, or median and range as appropriate. Independent Sample T-tests were used to compare biomechanical measurements between two independent groups. A $p$ value $<0.05$ was considered as statistically significant. Pearson's correlations and ANOVA testing were also used.

**Results:** The period prevalence of ballet-related injury over the last 2 years was found to be 62% and the point prevalence 38%. There were 37 total previous injuries, most of which occurred in the hamstring (24%). Most of the worst previous injuries were reported to have occurred in the low back (31%). Most of the worst previous (70%) and current (93%) injuries occurred over time. The worst previous injuries reported ranged from mild to severe in severity, while the worst current injuries reported ranged from mild to moderate.

Significant associations were found between right weight-bearing ankle dorsiflexion and previous injury; right weight-bearing ankle dorsiflexion and current injury; 'functional turnout' and onset of injury; right non weight-bearing ankle dorsiflexion and onset of injury; and 'compensated turnout' and onset of injury.

**Conclusion:** The results suggest a significant association between musculoskeletal ballet-related injury and reduced weight-bearing ankle dorsiflexion; between injuries that occur over time (overuse injuries) and decreased ‘functional turnout’; and between overuse injuries and decreased non weight-bearing ankle dorsiflexion. These findings may help identify risk factors for injury in ballet dancers and contribute towards preventing ballet-related injury.

**Keywords:** Ballet injury, musculoskeletal, biomechanical measurements

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| | |
|---|---|
| ANOVA | Analysis of Variance |
| ASIS | Anterior superior iliac spine |
| ASISs | Anterior superior iliac spines |
| IADMS | International Association for Dance Medicine and Science |
| ICC | Intra-class correlation |
| NWB | Non weight-bearing |
| PSISs | Posterior superior iliac spines |
| PSIS | Posterior superior iliac spine |
| Q-angle | Quadriceps angle |
| RAD | Royal Academy of Dance |
| SD | Standard Deviation |
| WB | Weight bearing |

# DEFINITION OF TERMS

**Acute Injury**

Also known as a 'traumatic' injury, an acute injury is a short-term injury that occurs due to a single traumatic event and is fairly severe (Dorland, 2007; Matava, 2008).

***Adage***

Derived from the Italian 'adagio', the French word 'adage' means 'at ease or leisure'. The 'adage' section of a ballet class occurs after the centre practice and consists of a series of steps made up of slow, graceful movements (Grant, 1982).

***Allégro***

Meaning 'brisk and lively', this term refers to steps that are bright and quick (Grant, 1982).

***Allégro, petit***

Small lively steps (Grant, 1982).

***Allégro, grande***

Large lively steps (Grant, 1982).

**Amateur ballet dancer**

An amateur ballet dancer is one who engages in ballet dancing on an unpaid basis and has not reached the professional level of dance expertise or experience. An amateur may dance for his/her own pleasure rather than as a career (National Arts Centre, 2014; Oxford Dictionaries, 2013).

***Arabesque***

One of the basic positions in ballet where the dancer is supported on one leg, with the other leg extended behind and at a right angle to it. The arms may be in various positions so that the longest possible line from the fingertips to the toes may be created (Grant, 1982).

**Ballet**

A theatrical form of dance, characterised by a structured technique (National Arts Centre, 2014).

**Ballet-Related Injury**

For the purposes of this study, any pain or dysfunction that had an effect on the dancers' ability to dance was recognized as an injury.

***Barre***

The horizontal wooden bar fastened to the walls of the ballet studio, which the dancer holds onto for support. The term also refers to a series of exercises at the beginning of every ballet class, *exercices á la barre* or *barre* work (Grant, 1982).

***Batterie***

Movements in which the legs beat together or one leg beats against the other (Grant, 1982).

**Biomechanical**

Pertaining to the application of mechanical principles to living structures (Dorland, 2007).

**Ceccheti Method, The**

This is the method of ballet that was established by Enrico Cecchetti, an outstanding teacher in the world's history of ballet. The method is strict with regard to its programme and includes specific set exercises for each day of the week (Grant, 1982).

**Centre practice**

The English term for *exercices au milieu*. This section of the ballet class is where the dancer performs steps similar to those of *barre* work, except in the centre of the room and without the support of the *barre* (Grant, 1982).

**Chronic Injury**

Injury that continues over a long time period (Dorland, 2007).

**Classical Ballet Positions, The**

Classical ballet involves five basic positions of the foot. Each step or movement begins in one of these positions and ends in one of these positions (Grant, 1982).

First position – the hips are externally rotated and adducted with the heels in contact with each other. The knees are aligned over the feet (Gilbert *et al*., 1998).

Second position – The alignment is the same as first position except the heels are away from each other with the hips abducted so that the feet are pelvis-width apart (Gilbert *et al*., 1998).

Third position – The hips are externally rotated with the knees aligned over the feet. The hips are adducted so that the thighs and legs are in contact with each other and the heel of the forward foot is in front of the middle of the longitudinal arch of the back foot (Gilbert *et al*., 1998).

Fourth position – The hips are externally rotated and adducted with the knees aligned over the feet. There is flexion at the hip joint of the forward leg and extension at the hip joint of the back leg, which causes the feet to be apart. The heel of the forward foot is directly in front of the head of the first metatarsal of the back foot. The heel of the back foot is directly behind the head of the fifth metatarsal of the forward leg foot (Gilbert *et al*., 1998).

Fifth position – The hips are externally rotated and adducted with the thighs and legs in contact with each other. The heel of the forward foot is directly in front of the head of the first metatarsal of the back foot. The heel of the back foot is directly behind the head of the fifth metatarsal of the forward foot (Gilbert *et al*., 1998).

**Class**

The lesson taken by dancers, which consists of *exercices á la barre*, *exercices au milieu*, *adage*, *pirouettes* and *allégro* sections (Grant, 1982).

***Demi-pointe***

When the dancer stands high up on the balls of the feet and under-parts of the toes (Grant, 1982).

***En pointe***

See *sur les pointes*.

**Extension**

The ability of a dancer to raise and hold her extended leg in the air. A dancer's extension is considered to be good when she is able to raise and hold her leg to the side at the level of the shoulder (Grant, 1982).

**Incidence**

This term describes the "occurrence of new cases of disease, injury, or other medical conditions over a specified time period, typically calculated as a rate or proportion" (Encyclopaedia Britannica, 2014).

**Musculoskeletal**

Pertaining to the skeleton and muscles (Dorland, 2007).

**Overuse Injury**

Overuse injury describes the damage of tissue as a result of repetitive demand and micro trauma over time. They are also referred to as a non-traumatic injury (Laker, 2014; Matava, 2008).

***Plié***

A movement in which the dancer bends the knee or both knees. In the execution of a *plié*, the legs are 'turned out' from the hips, the knees are open and aligned over the toes, and there is even weight distribution of the body weight on both feet (Grant, 1982).

***Plié, demi***

This is a *plié* that is performed without lifting the heels from the ground. It may be described as half-bending of the knees (Grant, 1982).

***Plié, grand***

This is a full *plié* in which there is full bending of the knees until the thighs become horizontal and the heels lift off the ground. The *plié* does not go far enough in second position to allow the heels lift off the ground (Grant, 1982).

**Pre-professional ballet dancer**

A pre-professional ballet dancer attends an intense pre-professional programme at a ballet school or company that is designed for students who intend to pursue a professional ballet career. These dancers take up to 5 hours of dance class each day, which includes classical ballet, jazz, contemporary, modern dance, character and repertory training (Atlanta Ballet Centre For Dance Education, 2014; Tulsa Ballet, 2014).

**Professional ballet dancer**

A professional ballet dancer has undergone pre-professional training and dances on a paid basis (National Arts Centre, 2014).

**Period Prevalence**

This term describes the percentage of a population with a particular disease or condition over a specified time period (Encyclopaedia Britannica, 2014).

**Point Prevalence**

This term describes the percentage of a population with a particular disease or condition at a certain point in time (Encyclopaedia Britannica, 2014).

***Relevé***

This refers to the elevating of the body up onto *demi-pointe* or *en pointe*, either as a smooth movement or as a springing movement (Grant, 1982).

**Rolling In**

Rolling in occurs when the dancer is 'turned out' and the weight of the foot is on the inside of the foot. This usually occurs with dancers who do not have sufficient 'turnout', and therefore force their 'turnout' instead of allowing it to come from the hips (Coplan, 2002; Grant, 1982).

**Rolling Out**

Rolling out occurs when the dancer is 'turned out' and the weight of the foot is on the outside of the foot (Grant, 1982).

**Royal Academy of Dance, The**

The Royal Academy of Dance (the RAD) is a worldwide dance education and training organisation (Royal Academy of Dance, 2011).

**Sickling**

This refers to a form of improper alignment, where the dancer rolls onto the lateral ray of the foot while rising up onto *demi-pointe*, causing a break in the line of the leg (Grant, 1982; Kadel, 2006).

***Sur les pointes***

This term, also known as *en pointe* refers to the raising of the body onto the tips of the toes with the ankles in maximal plantarflexion. The weight of the body is primarily carried in the ankle joint and the first and second toes (Grant, 1982; Kadel, 2006).

**Traumatic Injury**

See ‘Acute injury’.

**‘Turnout’**

This is an extreme position in ballet in which each leg is externally rotated so that the longitudinal axes of the feet are rotated, ideally, 180° away from each other (Gilbert *et al*., 1998). Sixty percent of ‘turnout’ is created by external rotation of the hips (IADMS *et al*., 2011). The term ‘turned out’ refers to the ballet dancer externally rotating their legs while dancing.

# CHAPTER ONE
# INTRODUCTION

## 1.1 INTRODUCTION

Although seemingly graceful, the art of classical ballet is considered one of the most physically challenging activities on the musculoskeletal system (Albisetti *et al*., 2010; Willis, 2008). This is due to the fact that the principle characteristics and precise techniques used in ballet exceed the normal range of a dancer's anatomical and physiological capabilities in terms of joint and muscle flexibility, placing unnecessary stress on muscles, joints and tendons and increasing the risk of injury (Motta-Valencia, 2006; Gupta *et al*., 2004). Dancers are also expected to display physical athletic attributes such as muscular strength and endurance, coordination, agility and swiftness (Russell, 2013). Those who cannot reach the standards of correct technique and attempt to exceed their own limits are predisposed to injury (International Association for Dance Medicine and Science *et al*., 2011; Motta-Valencia, 2006).

Classical ballet is defined as a method of dance based upon set positions and movements of the feet, arms and body, which are designed so that the dancer may move with the utmost agility, control, swiftness, weightlessness, and grace (Encyclopaedia Britannica, 2014).

Ballet dancers are divided into amateur dancers, pre-professional dancers and professional dancers. Amateur dancers engage in ballet dancing on an unpaid basis and have not reached the professional level of dance expertise or experience. An amateur may dance for his/her own pleasure rather than as a career (National Arts Centre, 2014; Oxford Dictionaries, 2013). This study revealed that amateur ballet dancers may dance between 2 and 11.5 hours per week. Pre-professional ballet dancers attend intense pre-professional programmes that are designed for students who intend to pursue a professional ballet career, where they take approximately 5 hours of dance class each day, which includes classical ballet, jazz, contemporary, modern dance, character and repertory training (Atlanta Ballet Centre For Dance Education, 2014; Tulsa Ballet, 2014). Professional ballet dancers have undergone pre-professional training and dance on a paid basis (National Arts Centre, 2014).

The principle characteristic of classical ballet is that of the 'turned out' position of the legs, which allows for greater mobility at the hip joint and creates an aesthetically pleasing line

of the extended leg (Encyclopaedia Britannica, 2014). It has been stated that the flexibility of the spine, hips and ankles is the 'hall-mark' of the ballet dancer (Grahame and Jenkins, 1972).

In addition to the physical demands of classical ballet, dancers are under psychological stress: they require determination, obedience and the utmost commitment to repetitively practise steps to perfection (Wan Nar Wong and William Wing Kee To, 2001).

Musculoskeletal injury is common among ballet dancers of all skill levels (Hincapie *et al*., 2008). Forty percent to 90% of professional ballet dancers and 26% to 63% of student ballet dancers sustain a dance-related injury some time in their ballet career (Coplan, 2002; Hincapie *et al*., 2008). Balding (2004) reported a 74% lifetime incidence and a 30% prevalence of ballet injury in an epidemiological study conducted on 5 male and 95 female amateur and professional dancers between the ages of 10 and 50 years in the greater Durban area. Negus *et al*. (2005) reported a period prevalence of 100% in a study performed on 5 male and 24 female pre-professional ballet dancers.

Chronic injuries and overuse injuries are the most common types of injuries found in ballet dancers (Hincapie, et al., 2008) and it has been said that the most commonly injured area of the ballet dancer's body is the lower limb, where 65% to 80% of all injuries occur (Milan, 1994). The most common traumatic injury sustained by ballet dancers is an acute lateral ankle sprain (Bauman *et al*., 1996; Kadel, 2006; Quirk, 1994; Balding, 2004), while the most common non-traumatic or overuse injury occurring in ballet dancers is a stress fracture, usually in the second metatarsal neck (Kadel, 2006; Motta-Valencia, 2006; Quirk, 1994).

Quirk (1994) outlined four main causes of ballet-related injury. The first cause, physique, includes factors such as anatomical causes and biomechanical factors, as well as assymetry. The second cause, technique, may include factors such as improper training, training errors, faulty technique, *en pointe* and extreme positions. The third cause, overuse, may include the factor of repetition, and the fourth cause is that of mishaps or accidents. Other contributors to injury are environmental factors, emotional factors and dietary factors (Milan, 1994; Balding, 2004; Motta-Valencia, 2006).

Frequent and repetitive movements during ballet dancing place dancers at greater risk for developing overuse injuries (Motta-Valencia, 2006). Ballet involves frequent and repetitive movements such as:

(Milan, 1994; Toledo *et al*., 2004; Bauman *et al*., 1996; Motta-Valencia, 2006; Marshall, 1988; Laible *et al*., 2013)

- jumping
- *relevé*
- dorsiflexion and plantarflexion
- *plies*
- flexion and hyperextension of the spine
- *demi-pointe*
- rising into and off of *pointe*
- hip flexion

Shrader (1996) suggests that physique injuries usually occur due to repetitive overload and microtrauma to tissues, superimposed on several biomechanical factors. These factors that may predispose a dancer to injury are identified as: lack of 'turnout' (Coplan, 2002; Gupta *et al*., 2004; Hamilton *et al*., 1992; Milan, 1994), femoral retroversion (IADMS *et al*., 2011), decreased ankle plantarflexion (Coplan, 2002; Gamboa *et al*., 2008; Marshall 1989; Motta-Valencia, 2006) and dorsiflexion (Ahonen, 2008; Milan, 1994), increased Q-angle, foot pronation and genu valgum (Motta-Valencia, 2006; Shrader, 1996). However, limited empirical research exists regarding the effect that these biomechanical factors have on the risk for injury in dance.

Although anecdotal information exists, and empirical studies correlating biomechanical measurements and injury have been performed on elite pre-professional ballet dancers, there is a paucity of empirical studies that have been performed on amateur ballet dancers (IADMS *et al*., 2011; Coplan, 2002; Milan, 1994; Motta-Valencia, 2006; Shrader, 1996; Gamboa *et al*., 2008; Negus *et al*., 2005).

There is also a lack of studies that observe associations between the above-named biomechanical factors and injury location, onset, frequency and severity, as well as a lack of quantitative and epidemiological research regarding potential risk factors for injury in amateur ballet dancers. Such research would be useful for the broadening of dance medicine (Angioi, 2012; Gamboa *et al*., 2008).

## 1.2 AIM

The aim of this study was to determine any associations between musculoskeletal injuries and selected lower limb biomechanical measurements in female amateur ballet dancers.

## 1.3 OBJECTIVES

- To collect data with regard to the demographics of female amateur ballet dancers in the greater Durban area; and the location, onset, frequency and severity (characteristics) of injury in this population.

- To measure and record selective lower limb biomechanical measurements in female amateur ballet dancers in the greater Durban area.

- To determine any associations between selected lower limb biomechanical measurements and the characteristics of injury in the population.

## 1.4 RATIONALE

Classical ballet is physically demanding (Albisetti *et al*., 2010; Willis, 2008) and musculoskeletal injury is common in ballet dancers, with 26% to 63% of student ballet dancers sustaining a dance-related injury some time in their ballet career (Coplan, 2002; Hincapie *et al*., 2008; Balding, 2004).

It has been suggested that variations in certain lower limb biomechanical measurements, specifically the degree of hip external rotation, Q-angle, femoral torsion, ankle plantarflexion and dorsiflexion, genu valgum and foot pronation, may increase the risk for injury in dance (Coplan, 2002; Motta-Valencia, 2006; IADMS *et al*., 2011; Milan, 1994). However, existing empirical research on biomechanical measurements and ballet-related injury have either been conducted on elite pre-professional ballet dancers (Gamboa *et al*., 2008) or has only focused on the measurement of 'turnout' (Coplan, 2002; Negus *et al*., 2005).

Twitchett (2009) stated that only a small amount of interest has been given to the effect of body structure and flexibility on ballet-related injury. There is a lack of epidemiological studies on amateur ballet dancers, which is important for the broadening of dance medicine (Angioi, 2012; Gamboa *et al*., 2008). Gamboa *et al*. (2008) pointed out that a paucity of quantitative research on the potential risk factors for ballet injury has been

published and Nguyen and Shultz (2009) stated that the association between lower extremity alignment and lower extremity injury risk in athletes continues to be poorly understood.

Schoene (2007) suggests that a thorough biomechanical evaluation should be carried out early in a dancer's ballet career, as such knowledge may prevent injury. In addition, Ahonen (2008) indicates that an understanding of the structure and biomechanics of the lower limb would help health care professionals, for example: to diagnose and evaluate injury; and that preventative exercises for foot injury should be based upon knowledge of lower limb biomechanics. Therefore, this study may provide valuable information to health care professionals in the musculoskeletal field, particularly chiropractors, for improved prevention, diagnosis and management of ballet injury.

## 1.5 OUTLINE OF CHAPTERS

This chapter introduced the research topic, as well as highlighting the aims, objectives and limitations of the study. Chapter Two will describe classical ballet, review the literature related to ballet injury, as well as create an understanding of the biomechanics involved in ballet dancing. Chapter Three will discuss the methodology that was used in the study. Chapter Four will present the results and discussion. Chapter Five will conclude the research, as well as outline recommendations.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter aims to describe the art of ballet, review literature related to ballet injury, including risk factors; as well as create an understanding of the biomechanics involved in ballet dancing.

## 2.2 THE ART OF BALLET

### 2.2.1 Definition

Dance is the rhythmical movement of the body, typically to music and in a particular space. The purpose of dance is to express ideas or feelings, to release energy, or merely to enjoy movement (Encyclopaedia Britannica, 2014). Classical ballet is a form of dance that is specifically characterized by pointing of the toes, turning out of the legs at the hip, high extensions, *pointe* work and ethereal qualities (Au, 2012).

### 2.2.2 Class Structure

Ballet class may be carried out in preparation for a performance or for general practice in working toward an examination (Balding, 2004).

Each ballet class is approximately 60 to 90 minutes long (Balding, 2004) and follows a specific format as follows: (Balding, 2004; Grant, 1982; Kadel, 2006)

Warm Up

These are exercises performed a few minutes before class that consist of stretching and limbering, often at the *barre*. This is important for preparing the muscles and tendons before class in order to prevent injury and ensure that the body is pliable.

*Exercices á la barre*

The ballet class begins at the *barre*, where a dancer (holding onto the *barre* with one hand) executes steps that are a foundation to steps that will be carried out later away from the *barre* during *exercices au milieu*. The dancer obtains their most important training during *barre* work, throughout which the correct development of muscle strength, ‘turnout’, balance, control and flexibility occurs.

*Exercices au Milieu*

Also known as 'centre practice', this section of the ballet class is when the dancer performs steps similar to those of *barre* work, except in the centre of the room and without the support of the *barre*. These exercises promote development of the dancer's stability and posture.

*Adage*

Derived from the French word 'adagio', which means 'at ease or leisure', this section of the class consists of a series of steps made up of slow, graceful movements. Regardless of their simplicity or complexity, these flowing movements are performed with apparent ease. They are carried out to develop poise and balance so that the dancer may dance majestically and gracefully.

*Pirouettes*

This section includes turns of the body on one leg.

*Allégro*

This French term means 'brisk' or 'lively' and describes the nature of the steps practised in this section of the ballet class. The section is further broken up into *petit allégro*, *batterie* and *grand allégro*.

*Temps de Pointe*s

Also known as *pointe* work or *sur les pointes*, this term refers to the use of *pointe* shoes for dancing on the tips of the toes with the ankles in maximal plantarflexion.

## 2.3 THE BIOMECHANICS OF BALLET

Ballet dancers are expected to adopt an aesthetically pleasing, but biomechanically unnatural, posture. It includes dancing in extreme body positions, for example: with the legs 'turned out' (Balding, 2004; Gupta *et al*., 2004), pelvic alignment altered (Deckert, 2009; Wightman, 2005), and dancing *en pointe* (Motta-Valencia, 2006) and *demi-pointe* with maximal ankle plantarflexion (Kadel, 2006; Motta-Valencia, 2006). Extreme flexibility of the muscles and joints, particularly of the back and legs, is also required (Grahame and Jenkins, 1972).

### 2.3.1 'Turnout'

This is an extreme position in ballet in which each leg is externally rotated so that the longitudinal axes of the feet are, ideally, rotated 180° away from each other (Gilbert *et al*., 1998). Movement in the joints of the foot, ankle, knee, hip, pelvis and spine all contribute to 'turnout' (Grossman *et al*., 2005), with approximately 60% of 'turnout' being created by external rotation of the hips (IADMS *et al*., 2011).

Ideal 'turnout' requires a minimum of 70° of hip external rotation bilaterally, 15° of external rotation at the foot bilaterally, and 5° of tibial external rotation. Femoral torsion, the degree to which the femoral neck projects forward or backward from the coronal plane of the femoral shaft (Magee, 2002), also plays a role in 'turnout'.

Femoral anteversion describes forward torsion of the femoral neck from the coronal plane of the femoral shaft, while femoral retroversion describes backward torsion of the femoral neck from the coronal plane of the femoral shaft (Magee, 2002). Ballet dancers with femoral anteversion have a decreased ability to 'turn out', while those with femoral retroversion have an increased ability to 'turn out' (IADMS *et al*., 2011). Ballet dancers who lack adequate 'turnout' due to anatomical limitations may begin to compensate in the areas of the foot, knee and spine in order to maximise their 'turnout' (Thomasen, 1982).

Compensation may occur at the spine and pelvic levels. For example, the dancer will anteriorly tilt the pelvis, causing an increased lumbar lordosis to allow for increased external rotation at the hips (Thomasen, 1982). The dancer may compensate at the knees by 'screwing' the knee joints, which means that she maximally externally rotates the feet while the knees are in a flexed position (*demi-plié*) and then, without moving her feet, forcefully straightens her knees. 'Rolling in' of the feet is a compensation characterised by the dancer forcing her feet into pronation in order to acquire an increased 'turnout' (Coplan, 2002; IADMS *et al*., 2011).

### 2.3.2 Pelvic Alignment

Ballet training emphasizes the importance of correct pelvic alignment for optimal technique and aesthetic appeal (Deckert, 2009). A neutral pelvic position is expected to be assumed, without excessive anterior or posterior pelvic tilting (Deckert, 2009). Acceptable guidelines for ensuring correct pelvic alignment are: a) vertically aligning the anterior superior iliac spines (ASISs) with the pubic symphysis and b) horizontally aligning the ASISs within a few degrees of the posterior superior iliac spines (PSISs), with the lumbar spine in neutral (Deckert *et al*., 2007; Deckert, 2009).

### 2.3.3 Maximal Ankle Plantarflexion

Ballet dancers are required to have an extreme range of motion of ankle plantarflexion in order to achieve the positions of *demi-pointe* and *en pointe* (Russell *et al*., 2010). In *demi-pointe*, a dancer balances on the plantar aspect of the toes, with the metatarsophalangeal joint fully flexed (Khan *et al*., 1995). *En pointe* refers to the position of the foot in the *pointe* shoe, where the ankle is maximally plantarflexed in full equinus with the dancer on the tips of her toes (Hamilton *et al*., 1992; Khan *et al*., 1995).

Extreme ranges of ankle dorsiflexion are also required by ballet dancers in order for the achievement of the *demi-plié*, in which the dancer bends her knees, with the feet in the 'turned out' position, to the point where the heels would have to be raised in order to continue bending the knees (Khan *et al*., 1995).

### 2.3.4 Flexibility

Ballet requires joint flexibility (Hamilton *et al*., 1992) and Grahame and Jenkins (1972) state that the flexibility of the spine, hips and ankles is the 'hall-mark' of the ballet dancer.

## 2.4 BALLET-RELATED INJURY

### 2.4.1 Definition of a Ballet Injury

Ballet injury has been defined in previous international studies as 'any pain or dysfunction of the low back or lower extremities that impacted the dancer's ability to practice or perform' (Coplan, 2002); or 'any pain, discomfort, or other musculoskeletal problem, which required modification of, or time away from, dance training, examinations, or performance' (Negus *et al*., 2005); or 'a musculoskeletal complaint that required at least 1 physical therapy treatment session' (Gamboa *et al*., 2008). For the purposes of this study, any pain or dysfunction that had an effect on the dancers' ability to dance was recognized as an injury.

### 2.4.2 Prevalence and Incidence

Literature on injury among ballet dancers suggests a moderate to high prevalence of injury among ballet dancers. Wiesler *et al*. (1996) reported a prevalence of 64% in a study conducted in North Carolina, USA on 101 male and female student ballet dancers and 47 male and female student modern dancers over a 1 year period. Coplan (2002) reported a prevalence of 57% in a study conducted in Baltimore, USA on 3 male and 27 female college-level ballet dancers and instructors. Negus *et al*. (2005) reported a prevalence of

93% in a study conducted in Perth, Australia on 5 male and 24 female ballet dancers from a pre-professional programme and Gamboa *et al*. (2008) reported an injury prevalence of 32% to 51% per year in a five-year study in Washington, USA on 71 male and 288 female elite pre-professional ballet dancers.

Literature also suggests a moderate to high incidence and period prevalence of injury among ballet dancers. Coplan (2002) reported a lifetime incidence of 47% in a study conducted in Baltimore, USA on 3 male and 27 female college-level ballet dancers and instructors, and Negus *et al*. (2005) reported a period prevalence of injury of 100% in a study conducted in Perth, Australia on 5 male and 24 female ballet dancers from a pre-professional programme.

### 2.4.3 Injury Type

Two main types of injury exist: non-traumatic or overuse injuries and traumatic or acute injuries (Macintyre and Joy, 2000). Non-traumatic injuries or overuse injuries are the most common types of injuries found in ballet dancers (Hincapie, et al., 2008). They are most often soft tissue injuries such as strains, sprains and tendinopathy (Hincapie *et al*., 2008), and are not often caused by a single traumatic or physical factor, but rather due to repetitive stress and microtrauma to tissue combined with a number of biomechanical factors (Shrader, 1996).

### 2.4.4 Injury Location

According to Coplan (2002) and Milan (1994), the most commonly injured area of the ballet dancer's body is the lower limb, where 60% to 80% of all injuries occur. This is followed by low back injuries, which account for 10% to 17% of all injuries, and then upper limb injuries which account for the remaining 5% to 15%.

The injuries stated from 2.4.4.1 to 2.4.4.6 commonly occur in the following areas of the lower limb and low to middle spine:

#### 2.4.4.1 Foot Injuries

Stress fracture – This is the most common non-traumatic or overuse injury occurring in ballet dancers (Kadel, 2006; Motta-Valencia, 2006). It occurs due to an increased load on the bone that is too rapid for adequate bone remodelling, resulting in bone weakness (Kadel, 2006). A common site for stress fracture is the second metatarsal neck, due to this metatarsal being longer than the others (Quirk, 1994).

Metatarsal fractures – Spiral fracture of the fifth metatarsal, also known as 'dancer's fracture', is a commonly occurring traumatic injury that may be caused in part by the continuous action of the *relevé* carried out by ballet dancers, as well as by improper landings from jumps (Russell, 2012; Bauman *et al*., 1996; Kadel, 2006).

Plantar fasciitis – During dorsiflexion of the metatarsophalangeal joints, the plantar fascia becomes taut and the metatarsal heads become depressed, aiding in the elevation of the medial arch of the foot (Milan, 1994). Therefore, continuous *demi-pointe* contributes to the development of plantar fasciitis, an injury that occurs frequently among ballet dancers (Milan, 1994). Forced 'turnout' and 'rolling' of the feet have also been suggested as contributors towards plantar fasciitis (Johnson, 1983; Marshall, 1988; Milan, 1994).

Sesamoiditis – This condition occurs more commonly in the medial sesamoid and is often due to dancers landing jumps incorrectly without sufficient deceleration (Quirk, 1994). Contributing factors may include forcing 'turnout' and 'rolling in' of the feet (Kadel, 2006; Macintyre and Joy, 2000).

Cuboid subluxation – Subluxation of the cuboid occurs frequently in ballet dancers (Marshall and Hamilton, 1992). Acute subluxations may occur with traumatic ankle sprains, while overuse cuboid subluxations may occur due to the repetitive movements of rising onto and off of *pointe* (Kadel, 2006; Marshall and Hamilton, 1992).

Hallux rigidus – This significantly disabling condition involves arthritic changes of the first metatarsophalangeal joint that begin to limit the ability of the dancer to achieve proper *demi-pointe* and *pointe* positions (Kadel, 2006; Quirk, 1994). It may even lead to a dancer having to give up dancing (Quirk, 1994).

#### 2.4.4.2 Ankle Injuries

Ankle sprain – The most common traumatic injury sustained by ballet dancers is an acute lateral ankle sprain involving the anterior talofibular ligament, which often occurs with the ankle in an inverted and plantarflexed position on the landing of a jump (Bauman *et al*., 1996; Kadel, 2006; Quirk, 1994).

Posterior impingement syndrome – This condition involves impingement of the posterior talus on the tibia during maximal plantarflexion, a frequently assumed position when the dancer dances on *pointe* and *demi-pointe* (Bauman *et al*., 1996; Quirk, 1994).

Anterior impingement syndrome – This condition is caused by the frequent position of or movement into maximal dorsiflexion in classical ballet (Bauman *et al*., 1996). It often involves a loss or limitation of *demi-plié* (Kadel, 2006).

Achilles tendinitis or tendinopathy – This overuse injury occurs frequently in ballet dancers (Russell, 2012) and is due to the excessive stress often placed on the Achilles tendon, particularly during *en pointe* and *demi-pointe* when the gastrocnemius and soleus are being forcefully contracted (Malone and Hardaker, 1990; Milan, 1994).

Flexor hallucis longus tendinitis or tendinopathy ('dancer's tendinopathy) – This overuse injury occurs commonly in ballet dancers (Russell, 2012), mostly due to the flexor hallucis longus being under excessive strain and from continual *demi-pointe*, *pointe* and *plié* movements (Milan, 1994), as well as continual plantarflexion of the foot and toes (Bauman *et al*., 1996; Kadel, 2006).

2.4.4.3 Leg Injuries

Shin splints – When the lower leg muscles are put under strain from excessive 'rolling in' or pronation of the foot, shin splints may become a problem for dancers (Milan, 1994) and may produce pain in the posterolateral leg (Motta-Valencia, 2006).

2.4.4.4 Knee Injuries

Peri-patellar pain – It has been said that peri-patellar pain is the most common knee condition found in ballet dancers (Milan, 1994). Included in this group is chondromalacia patella, synovial plica syndrome, patella stress fractures, laterally subluxating patella, knee bursitis and lateral pressure syndrome (Milan, 1994; Reid, 1988).

Patellar tendinitis – The overuse injury of patellar tendinitis occurs commonly in ballet dancers, most probably due to repetitive jumping and *pliés* (Bauman *et al*., 1996).

Patellofemoral pain syndrome – this is also common and has said be perpetuated in ballet dancers by malalignment, repetitive *pliés* and forced 'turnout' (Bauman *et al*., 1996). It has been shown to be perpetuated by iliotibial band tightness and excessive tibial external rotation (Winslow and Yoder, 1995).

2.4.4.5 Hip Injuries

Snapping hip syndrome – This condition involves audible clicking or snapping in the hip during movements of the thigh (Garry and Jenkins, 2012). External snapping is caused by the ilitotibial band sliding over the greater trochanter, while internal snapping is caused by the iliopsoas tendon sliding over the iliopectineal eminence (Garry and Jenkins, 2012). The condition may be painful or painless, and may be caused by intra-articular loose bodies or acetabular labral tears (Garry and Jenkins, 2012; Motta-Valencia, 2006).

Iliopsoas syndrome – When snapping hip syndrome with an internal cause is accompanied by pain and weakness, the condition is referred to iliopsoas syndrome (Laible, et al., 2013). Ballet dancers are at risk for developing this syndrome due to the repetitive hip flexion movements that they carry out (Laible *et al*., 2013).

Acetabular labral tear – This type of injury occurs in ballet dancers due to the continuous external rotation movement (Lewis and Sahrmann, 2006).

2.4.4.6 Spinal Injuries

Spondylolysis – The constant hyperextension and hyperlordosis of the spine in female ballet dancers increases the risk for the development of spinal injuries such as spondylolysis (Milan, 1994) due to the excessive stress placed on the posterior parts of the spine (Motta-Valencia, 2006).

### 2.4.5 Contributors to Injury

Quirk (1994) suggested four main causes of ballet-related injury, namely physique, technique, overuse and mishaps. Physique may include anatomical causes and biomechanical factors, as well as assymetry. Technique may include factors such as improper training, training errors, faulty technique, *en pointe* and extreme positions. Overuse may include the factor of repetition. Other contributors to injury are environmental factors, emotional factors and dietary factors. These main causes and factors are explained below:

2.4.5.1 Physique

Anatomical Causes and Biomechanical Factors – Female ballet dancers are expected to be thin with very flexible joints (Quirk, 1994). According to Nolan (2011), the ideal ballet

body is said to be slender, with a lengthy neck, short to medium length trunk, long legs with long arms and high foot arches.

Certain anatomical and biomechanical factors have anecdotally been said to play a role in the development of ballet-related injuries. Biomechanical factors that have been suggested as factors for predisposition to a ballet-related injury are lack of 'turnout' (Gupta *et al*., 2004; Milan, 1994), femoral anteversion (IADMS *et al*., 2011; Micheli, 1989), decreased ankle plantarflexion (Coplan, 2002; Gamboa *et al*., 2008; Motta-Valencia, 2006) and dorsiflexion (Ahonen, 2008; Milan, 1994), increased Q-angle, foot pronation and genu valgum (Micheli, 1989; Motta-Valencia, 2006).

Certain studies have found associations between biomechanical factors and ballet-related injury:

In a retrospective cohort study conducted in Washington, USA on 71 male and 188 female elite pre-professional adolescent ballet dancers where hip range of motion, ankle range of motion, femoral torsion, foot position, and 'functional turnout' were measured (Gamboa *et al*., 2008), a statistically significant higher prevalence of foot pronation and reduced ankle plantar flexion were found in injured dancers.

Wiesler *et al*. (1996) found no correlation between future injury and ankle range of motion abnormalities in a study conducted in North Carolina, USA on 101 male and female student ballet dancers and 47 male and female student modern dancers, where ankle range of motion was compared with injury history.

Coplan (2002) conducted a retrospective cohort study in Baltimore, USA on 3 male and 27 female college-level ballet dancers and instructors, and found that ballet dancers with a greater 'functional turnout' than their available bilateral hip range of motion are at a higher risk of injury.

In a descriptive, correlation study conducted in Perth, Australia on 5 male and 24 female pre-professional ballet dancers where hip range of motion and 'functional turnout' were measured, it was found that the number and severity of non-traumatic injuries were associated with decreased 'functional turnout', but not with hip range of motion (Negus *et al*., 2005).

The following biomechanical factors are said to contribute to injury in the following ways:

Hip External Rotation: Hip external rotation is a component of 'turnout'. The normal range of hip external rotation is 40 - 60° (Magee, 2002).

'Functional and Compensated Turnout': 'Functional turnout' consists primarily of hip external rotation, with turnout at the knee, tibia and ankle making up for the rest (IADMS *et al*., 2011). A range of 100 - 131° of 'functional turnout' has been reported in previous studies (Coplan, 2002; Negus et al., 2005).

'Compensated turnout' is calculated as the total hip external rotation measurement subtracted from the functional turnout measurement (Coplan, 2002; Negus *et al*., 2005).

The persistent attempt of female ballet dancers who have an inadequate degree of hip external rotation in achieving an improved 'functional turnout' beyond their available hip range of motion contributes to injury, particularly of the low back and lower limb (Coplan, 2002; Milan, 1994; Negus *et al*., 2005). Lack of adequate 'turnout' may lead to compensations such as increasing the lumbar lordosis through tilting the pelvis anteriorly, 'screwing' of the knees and 'rolling in' of the feet or pronation (Coplan, 2002; Milan, 1994). Inadequate 'turnout' and the emphasis placed on attaining extreme hip external rotation in the 'turned out' position may cause injury in the kinetic chain (Gupta *et al*., 2004).

Femoral Torsion: The femoral torsion angle is the degree of forward or backward projection of the femoral neck from the coronal plane of the femoral shaft (Magee, 2002). The normal range of femoral torsion is 8 - 15° (Magee, 2002).

Femoral anteversion describes forward torsion of the femoral neck from the coronal plane of the femoral shaft, while femoral retroversion describes backward torsion of the femoral neck from the coronal plane of the femoral shaft (Magee, 2002).

Dancers with femoral anteversion have a decreased ability to 'turn out', while those with femoral retroversion have an increased ability to 'turn out' (IADMS *et al*., 2011). This means that dancers with femoral anteversion may force their 'turnout' beyond their natural limitations, increasing the risk of injury (Gilbert *et al*., 1998).

Ankle Range of Motion: The normal range of ankle plantarflexion is 0 - 50° (Clarkson, 2005; Magee, 2002), while the normal range of ankle dorsiflexion is 8 - 26° (Rome, 1996).

Decreased range of motion in the ankles has been identified as a factor that contributes to injury. Inadequate ankle plantarflexion in a dancer may cause compensational 'sickling' of the foot (Gamboa *et al*., 2008; Motta-Valencia, 2006), increasing the stress on the involved joints (Coplan, 2002). Dancers with inadequate ankle dorsiflexion are susceptible to ankle inversion sprains and malalignment syndromes when the foot compensates by rocking onto the lateral rays in *demi-pointe* (Milan, 1994). Inadequate ankle dorsiflexion during deep *pliés* while landing may lead to a compensatory 'rolling in' of the foot (Ahonen, 2008).

Quadriceps-Angle (Q-angle): The Q-angle is the angle between the quadriceps muscles and the patellar tendon. It represents the angle of muscle force of the quadriceps muscle (Magee, 2002). The angle is found at the intersection of two lines drawn from the anterior superior iliac spine (ASIS) to the centre of the patella and from the centre of the patellar to the tibial tuberosity (Rahimi *et al*., 2012). The normal range of Q-angle is 18 - 22° (Magee, 2002).

Motta-Valencia (2006) suggests that an increased Q-angle may contribute to overuse injuries such as patellar dysfunction; and Shrader (1996) suggests that an increased Q-angle may contribute to overuse injuries such as patellofemoral joint syndrome. With an increased Q-angle, additional biomechanical stress is added to the knee during repetitive activity, such as ballet. An abnormality in the movement of the patella develops (lateral patella tracking) and leads to patellofemoral pain syndrome (Charette, 2003; Motta-Valencia, 2006).

Pronation: Ballet dancers with inadequate 'turnout' at the hips often compensate by 'rolling in' their feet. This is also called 'pronation' (Coplan, 2002; Milan, 1994). The amount of foot 'pronation' or 'rolling in' may be measured using the Navicular Drop Test (Magee, 2002).

Hyper-pronation has been suggested as another type of anatomical malalignment that may contribute to injury (Micheli, 1989). It increases torsional stress on the Achilles tendon (Toledo *et al*., 2004; Macintyre and Joy, 2000) and joints of the lower limb, predisposing dancers to overuse injury at the medial foot, ankle and knee (Motta-Valencia, 2006). Cuboid subluxation is seen to occur in dancers who land a jump with the foot in a pronated position (Milan, 1994).

Knee Alignment: Misalignment of the knee may occur in the form of 'genu valgum' or 'genu varum'. Genu valgum deformity is also known as 'knock knees'; and genu varum deformity is also known as 'bow-leggedness' (Magee, 2002).

Increased patellofemoral pain has been found to be strongly related to mechanical and anatomical limitations in ballet dancers (Winslow and Yoder, 1995). A combination of anatomical malalignments that increase valgus stress on the knee, such as an increased Q-angle, hyper-pronation and genu valgum, contribute to patellofemoral pain syndrome and patellar tendinitis (Micheli, 1989).

Other: Other biomechanical imbalances have been suggested as contributors to ballet-related injury, such as poor core strength, imbalance of the pelvic muscles, tight Achilles tendons or weak eccentric leg muscle strength (Toledo *et al*., 2004).

Assymetry – Gupta *et al*. (2004) found that differences in strength on the right and left sides of the body may contribute to the risk of injury in the kinetic chain.

2.4.5.2 Technique

Improper training – Lack of warm up and poor body weight alignment may contribute to ballet-related injury (Toledo *et al*., 2004). Milan (1994) suggests that the risk for injury of the spine and lower limb may be increased by the persistence of ballet instructors who expect correct 'turnout' beyond the ballet dancer's personal limitation.

Training errors – According to Kadel (2006), most dance footwear does not allow for any shock absorbance. Improper footwear may lead to overuse injury (Micheli, 1989) and *pointe* shoes that are poor-fitting or too worn out may also contribute to injury (Kadel, 2006) and the tying of ribbons too tight around the ankle may lead to or aggravate Achilles tendinitis (Quirk, 1994; Kadel, 2006; Motta-Valencia, 2006).

Faulty technique – The forcing of 'turnout' beyond a ballet dancer's physiological hip range of motion is said to directly cause non-traumatic ballet-related injury due to tissue overload (Negus *et al*., 2005). This involves the ballet dancer compensating by 'rolling in' or over-pronating their feet, increasing their lumbar lordosis or 'screwing' the knees in external rotation of the tibia (Coplan, 2002; Thomasen, 1982).

Coplan (2002) found that the forcing of 'turnout' is associated specifically with injuries of the low back and lower extremities. This also contributes to the development of stress fractures of the foot (Johnson, 1983) and tendinitis (Quirk, 1994).

Over-pronation has been pointed out to increases the risk for the development of Achilles tendinitis (Kadel, 2006), shin splints (Milan, 1994), and dysfunctions at the medial foot, ankle and knee (Motta-Valencia, 2006).

Hyper-lordosis during *arabesque* movements adds excessive pressure to the posterior spinal components (Motta-Valencia, 2006) and may result in spinal injury (Milan, 1994).

'Screwing' of the knees places excessive strain on the medial aspects of the knees, resulting in injuries, such as medial collateral ligament sprain and patellofemoral pain syndrome (Milan, 1994; Winslow and Yoder, 1995).

*En Pointe* – Dancing *en pointe* on the tips of the toes with the foot and ankle in maximal plantarflexion places excessive stress on muscles, joints and tendons of the lower limb, which increases the risk of injury in this area (Motta-Valencia, 2006; Khan *et al*., 1995). Such excessive stress also adds to the development of posterior impingement syndrome, flexor hallucis longus tendinitis and Achilles tendinitis (Malone and Hardaker, 1990; Milan, 1994).

Extreme positions – Bronner *et al*. (2003) states that the maximum flexibility of the joints required by ballet dancers puts them at risk for a muscular injury, as the muscles are at an extreme mechanical disadvantage at the end of their ranges.

In addition to the extreme position of *en pointe* mentioned above, the maximal ankle dorsiflexion required for *pliés* places the dancer at risk for developing anterior impingement syndrome (Bauman *et al*., 1996).

#### 2.4.5.3 Overuse

Repetition – Ballet training involves a number of repetitive movements that lead to repetitive microtrauma (Gamboa *et al*., 2008; Bauman *et al*., 1996; Shrader, 1996). Regions of the body that are particularly predisposed to injury from repetitive movements are the tendons, especially those of the ankle (Quirk, 1994).

Repetitive jumping (Milan, 1994; Toledo *et al*., 2004), *relevé* (Bauman *et al*., 1996), dorsiflexion and plantarflexion (Milan, 1994), *pliés* (Bauman *et al*., 1996; Motta-Valencia, 2006), flexion and extension of the spine (Milan, 1994), *demi-pointe* (Marshall, 1988; Milan, 1994) and rising into and off of *pointe* contributes to the occurrence of patella-related pain (Bauman *et al*., 1996), metatarsal fractures (Russell, 2012; Bauman *et al*., 1996), anterior and posterior impingement syndrome (Bauman *et al*., 1996), spinal injury (Milan, 1994), plantar fasciitis (Marshall, 1988; Milan, 1994), cuboid subluxation (Marshall and Hamilton, 1992) and flexor hallucis longus and Achilles tendinitis (Quirk, 1994).

2.4.5.4 Mishaps

Acute or traumatic injuries occur in a single event, potentially due to fatigue, loss of balance, incorrect execution of steps, tiredness or sudden stress on a tissue (Macintyre and Joy, 2000; Motta-Valencia, 2006).

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2.4.5.5 Other

Environmental Hazards – The floor of a ballet studio or stage may often play a role in injury, as floors are required to be resilient, shock absorbent and have surface friction (Milan, 1994).

Emotional Factors – Most ballet dancers are exceptionally dedicated people who are persevering and goal oriented; and this type of 'over achiever' personality may contribute towards injury (Balding, 2004; Hamilton *et al*., 1989).

Dietary Factors – Diet plays a role in contributing to ballet-related injury and ballet dancers are constantly under stress regarding their diet as they are expected to maintain a lean and slim physique, which may mean that they are required to diet aggressively (Motta-Valencia, 2006). A limited diet may cause hormonal and metabolic imbalances, amenorrhoea and an increased risk for developing osteoporosis, which lead to a higher risk for injury, such as stress fractures (Motta-Valencia, 2006). A poor diet may also lead to early fatigue in ballet dancers, predisposing them to musculoskeletal injury, as well as slower healing of injuries (Balding, 2004).

## 2.5 CONCLUSION

Although ballet dancers are expected to have a certain body type, very few people have given any consideration on how such a body type may have an impact on injury (Twitchett, 2009).

The training required to achieve the precise techniques in ballet increases the risk of injury in dancers, as these techniques exceed the normal ranges of a dancer's anatomical and physiological capabilities (Gupta *et al*., 2004; Motta-Valencia, 2006). Dancers who cannot reach the standards of correct technique and attempt to exceed their own limits are predisposed to injury (IADMS *et al*., 2011; Motta-Valencia, 2006).

Limited empirical research exists regarding the effect that variation in the degree of: hip external rotation, Q-angle, femoral torsion, ankle planterflexion and dorsiflexion, genu valgum and foot pronation have on the risk for injury in dance. Although anecdotal information exists (Coplan, 2002; Motta-Valencia, 2006; IADMS *et al*., 2011; Milan, 1994), and empirical studies correlating biomechanical measurements and injury have been performed on pre-professional and student ballet dancers (Coplan, 2002; Gamboa *et al*., 2008; Negus *et al*., 2005; Wiesler *et al*., 1996), there is a paucity of empirical studies that have been performed on amateur ballet dancers to observe associations between all of the above mentioned biomechanical measurements and injury location, onset, frequency and severity.

Thorough biomechanical evaluation carried out early in a dancer's ballet career may prevent injury (Schoene, 2007); understanding structure and biomechanics of the lower limb helps to diagnose and evaluate injury; and preventative exercises for foot injury should be based upon knowledge of lower limb biomechanics (Ahonen, 2008).

Gamboa *et al*. (2008) states that only a few studies have been carried out to investigate any relationship between dance injury and measureable intrinsic characteristics. The sum of all these factors indicate that there is a lack of quantitative and epidemiological research regarding potential risk factors for injury in amateur ballet dancers. Reducing such a lack of quantitative research is important for promoting knowledge of dance and dance related injuries (Angioi, 2012; Gamboa *et al*., 2008).

# CHAPTER THREE
# MATERIALS AND METHODS

## 3.1 INTRODUCTION

This chapter contains details on the procedures carried out for the conduction of the study, including study design, subject recruitment, data collection and analysis.

## 3.2 STUDY DESIGN

The study was a quantitative, descriptive, observational, questionnaire-based survey with the use of biomechanical measurements (Fink & Kosekoff, 1985). The questionnaire was put through an Expert Group process, as well as a Pilot study to ensure the correct context for the study. Data collection was carried out at the Durban University of Technology by means of a structured questionnaire (Salant & Dillman, 1994); the recording of physical biomechanical measurements; and the correlation of the biomechanical measurements against the anthropometric factors.

## 3.3 RESEARCH TOOLS

### 3.3.1 Development of the Questionnaire

The questionnaire used in this study was adapted, with permission (Appendix D), from that of a previous epidemiological study on dancers in the greater Durban area by Balding (2004). The questionnaire was used as it included foundational questions regarding participant demographics, ballet history and history of ballet-related injury. The researcher adapted it by changing certain questions and introducing additional questions to suit the requirements for this study. The questionnaire underwent face validity testing prior to the study by means of an Expert Group and Pilot Study.

### 3.3.2. Expert Group

3.3.2.1 Purpose of the Expert Group

An Expert Group (or Focus Group) is a group of people who have a similar type of experience in common, but do not exist naturally as a social group (Terre Blanche *et al*., 2006). The purpose of the Expert Group was to determine validity of the questionnaire (Bernard, 2000). 'Validity' is a term that describes 'the degree to which the measurement

process measures the variable that it claims to measure' (Gravetter and Forzano, 2012). The types of validity that were addressed in the Expert Group are as follows:

*Face validity* refers to the extent to which a measurement appears to measure what it claims to measure (Terre Blanche *et al*., 2006). It was determined by the Expert Group members agreeing that the tool seems valid on 'the face of it' (Bernard, 2000).

*Content validity* is the extent to which a measure covers a specific domain or field of content (Terre Blanche *et al*., 2006). This was determined by the Expert Group members giving their subjective opinions on the questionnaire, and critically analyzing and discussing the content of it (Litwin, 1995).

*Construct validity* involves determining how a measure of construct is empirically related to other measures with which it is theoretically associated (Terre Blanche *et al*., 2006). It is determined by the Expert Group members agreeing that there is congruency between the aims and objectives of the study and the measurement tool (questionnaire) (Bernard, 2000).

3.3.2.2 Expert Group Members and Procedure

The Expert Group consisted of ten people, who were recruited by purposive sampling and were recruited to meet the requirements as outlined in the guidelines for an Expert Group (Salant and Dillman, 1994; Morgan, 1998 (a); Morgan, 1998 (b); Morgan, 1998 (c)):

- the researcher
- the supervisor of the study
- a chiropractor who is familiar with ballet dancers
- a supervisor of research
- a Master's student who had completed the expert group stage of their questionnaire study
- a Master's student who had not reached the expert group stage of their questionnaire study
- two ballet dancers
- a ballet teacher
- an individual to record the meeting

Once the researcher had completed the construction of the questionnaire (Appendix A3 – Pre Expert Group Questionnaire), these individuals were either approached personally or telephonically contacted to ascertain whether they would agree to consider attending the Expert Group meeting. As soon as the Expert Group members were established, a meeting time and place was set and the booking of a venue was made. Refreshments, the appropriate stationary and audiovisual equipment were also organised.

On the arrival at the venue at the arranged time, the Expert Group members were welcomed to the meeting by the researcher. The purpose and procedure of the meeting was explained. A Letter of Information and Consent Form (Appendix A1) and Confidentiality and Code of Conduct Form (Appendix A2) was given to each member, which they were required to read and sign. The members were able to ask the researcher any questions relating to the study during this time.

Once the members of the Expert Group were content, they each received a questionnaire (Appendix A3 - Pre Expert Group Questionnaire). The questionnaire was discussed one question at a time, and changes were made to questions based upon the opinions and knowledge of the Expert Group members. Group consensus was required before changes to the questionnaire were made (Morgan, 1998 (a); Morgan, 1998 (b); Morgan, 1998 (c)).

The appropriate changes were made to the questionnaire in order to produce the questionnaire to be used for the study (Appendix C5 – Post Expert Group Questionnaire). The Expert Group Transcript may be found as Appendix A4.

### 3.3.3 Pilot Study

3.3.3.1 Purpose of the Pilot study

A Pilot study was conducted as a trial run prior to the conduction of the main study (Fink & Kosekoff, 1985). It aimed to highlight any problems with the questionnaire or study design (Fink & Kosekoff, 1985).

3.3.3.2 Pilot Population, Sampling and Recruitment

The Pilot study included 6 participants who were female ballet dancers above the age of 18 years in the greater Durban area. Non-probability purposive sampling was used to select participants from ballet studios in the greater Durban area (Terre Blanche et al., 2006).

The Cecchetti Society of Southern Africa was contacted to obtain the freely available contact details of all of the Cecchetti method dance studios and teachers in the greater Durban area.

The list of contact details of all of the Royal Academy of Dance (RAD) method studios and teachers in the greater Durban area was sourced from the RAD South Africa website, www.rad.org.za, from which this information is freely available.

The owner or principal of each studio was contacted and an appointment was made to visit them at their studio when their senior dancers were present. A Principal's Letter of Information and Consent Form (Appendix B1) was emailed to the owner or principal in advance, in order for them to read over it prior to the researcher's visit.

On the researcher's arrival at each studio, the principal or owner was again given the Principal's Letter of Information and Consent (Appendix B1), which they were asked to read and sign if they agreed to giving permission for recruitment for the study to take place in their studio. They were allowed to ask any questions before signing this document, which served to request their permission for the recruitment of research participants at their studio through: a) the placing of an advert in the form of a poster at the ballet studio; and b) the researcher verbally informing the ballet students of the study. The researcher then gave the owner or principal an Advertisement (Appendix B2 – Pilot study) to place in the studio and verbally informed the senior dancers of the research study.

All of the ballet dancers at each studio who responded immediately to the verbal invitation to participate in the study were asked to add their name and contact details to a recruitment list. The recruitment process at the studio took approximately 30 minutes.

Each dancer who responded, either during the researcher's visit to the studio or via the advertisement, was telephonically contacted within a couple of days to determine whether they were eligible for the study (Appendix B3 – Telephonic Screening).

#### 3.3.3.3 Pilot Study Procedure

For those participants who met the requirements for the study, an appointment was made at the Durban University of Technology Chiropractic Day Clinic. Each participant's

appointment took place in the professional environment of a private room at the Chiropractic Day Clinic at the Durban University of Technology, under the supervision of a qualified clinician. Each participant was given a Participant's Letter of Information and Consent Form (Appendix B4), which they were asked to read and sign. They were allowed to ask any questions before signing the document. The participant had her height and weight measured, and the researcher then interviewed the participant in order to complete the questionnaire (Appendix B5). After the interview, the selected objective biomechanical measurements were taken and recorded on the Measurement Data Sheet (Appendix B6).

## 3.4 STUDY POPULATION

The study included 21 participants who were 18 to 25-year-old White amateur female ballet dancers at the intermediate or advanced level in the greater Durban area. All of the dancers who participated were at the advanced level, as no intermediate dancers responded who fulfilled the inclusion criteria. The sample for the study was similar to the sample used in a study by Valenti *et al*. (2011), where 10 non-professional, female dancers between the ages of 16 and 23 years were recruited.

## 3.5 SAMPLING AND RECRUITMENT

Non-probability purposive sampling was used to select participants from ballet studios in the greater Durban area for the main study and pilot study (Terre Blanche et al., 2006). Although it is not possible to determine the number of ballet dancers in the greater Durban area who fit the research criteria, the researcher was able to estimate that there were approximately 31. This would mean that an estimated 68% of the population participated in the main study.

The Cecchetti Society of Southern Africa was contacted to obtain the freely available contact details of all of the Cecchetti method dance studios and teachers in the greater Durban area.

The list of contact details of all of the Royal Academy of Dance (RAD) method studios and teachers in the greater Durban area was sourced from the RAD South Africa website, www.rad.org.za, from which this information is freely available.

The owner or principal of each studio was contacted and an appointment was made to visit them at their studio when their senior dancers were present. A Principal's Letter of

Information and Consent Form (Appendix C1) was emailed to the owner or principal in advance, in order for them to read over it prior to the researcher's visit.

On the researcher's arrival at each studio, the principal or owner was again given the Principal's Letter of Information and Consent (Appendix C1), which they were asked to read and sign if they agreed to giving permission for recruitment for the study to take place in their studio. They were allowed to ask any questions before signing this document, which served to request their permission for the recruitment of research participants at their studio through: a) the placing of an advert in the form of a poster at the ballet studio; and b) the researcher verbally informing the ballet students of the study. The researcher then gave the owner or principal an Advertisement (Appendix C2) to place in the studio and verbally informed the senior dancers of the research study.

All of the ballet dancers at each studio who responded immediately to the verbal invitation to participate in the study were asked to add their name and contact details to a recruitment list. The recruitment process at the studio took approximately 30 minutes.

Each dancer who responded, either during the researcher's visit to the studio or via the advertisement, was telephonically contacted within a couple of days to determine whether they were eligible for the study (Appendix C3 – Telephonic Screening).

## 3.6 CRITERIA FOR PARTICIPATION IN THE STUDY

During the Telephonic Interview (Appendix C3) it was determined whether the ballet dancers met the Inclusion Criteria and therefore was eligible to participate in the study. The criteria were as follows:

### 3.6.1 Inclusion Criteria

- Participants must be female.
- Participants must be White to ensure that differences in skeletal anatomy between ethnic groups do not affect the outcomes of the research (Gerace *et al*., 1994).
- Participants must be 18 to 25 years of age.
- Ballet must be the participants' main form of dance, making up for at least 80% of their dance activity.
- Participants must be at the intermediate or advanced level in ballet (amateur ballet dancers dance at graded levels, with the highest levels being intermediate and advanced).

- Participants must have a minimum of two years ballet experience.
- Participants must attend at least two hours of ballet class per week.

### 3.6.2 Exclusion Criteria

- Participants who reported serious musculoskeletal injuries (not related to ballet), which required casting or bracing, were not permitted to take part in the study due to the possible effect their injuries may have on the biomechanical measurements that were required of this study.
- Participants reporting a history of surgery to their musculoskeletal system, for injuries not related to ballet, were excluded from the study due to the possible effect of the surgery on biomechanical measurements to be taken.
- Participants with any musculoskeletal congenital anomaly affecting their lower limb/s were not permitted to take part in the study.
- Participants who were not willing to sign the Participant's Letter of Information and Consent Form (Appendix B4 – Expert Group; Appendix C4 – main study) were not permitted to take part in the study.
- Professional, paid or beginner ballet dancers were excluded from participation in the study, as only Intermediate or Advanced amateur dancers were required.
- Those who were members of the Expert Group were not permitted to take part in the Pilot study or main study.

## 3.7 ALLOCATION

For those participants who met the requirements for the study, an appointment was made at the Durban University of Technology Chiropractic Day Clinic for them to complete a structured questionnaire in the form of an interview (Appendix C5 – Post Expert Group Questionnaire) and to undertake a physical assessment (Appendix C6 – Measurement Data Sheet) by a supervised 6$^{th}$ year student (the researcher), under the guidance of a clinician. All of the participants formed one group with subgroup analysis related to the presence or absence of injury.

## 3.8 MEASURING TOOLS

### 3.8.1 Biomechanical Measurements

*Reliability* refers to how dependable a measuring instrument is (Terre Blanche *et al*., 2006).

A c*orrelation* refers to the extent of association, or the strength of the relationship between two variables. A *correlation coefficient* ranges from -1 to 1 and represents a correlation. At 0, no relationship exists between the variables. As the value approaches -1, the strength of a negative association increases, and as the value approaches 1, the strength of a positive association increases (Terre Blanche *et al*., 2006). Intra-class correlation (ICC) was used in the study to describe the reliability of measurements.

3.8.1.1 Universal Goniometer

The universal goniometer is a protractor (180° or 360°) that has one axis that joins two arms. One of these arms is stationary, while the other is movable around the axis of the protractor (Clarkson, 2005). This study made use of the Baseline® 12-inch 360° plastic goniometer 12-1000.

The universal goniometer is a cost-effective and accessible tool for the use of measuring joint range of motion and biomechanical measurements (Clarkson, 2005).

Reliability studies have indicated that the universal goniometer is more reliable than visual estimation of joint range of motion and that intra-tester reliability is superior to inter-tester reliability (Clarkson, 2005).

Radiography is the most accurate method of assessing joint motion and biomechanical measurements (Smith *et al*., 2008). However, this is costly and less easily accessible, and it would be inappropriate to unnecessarily expose female participants to x-ray radiation in their reproductive years.

3.8.1.2 Measurements

**3.8.1.2.1 Hip external rotation (active and passive)**

Hip external rotation is a component of 'turnout'. Active and passive hip external rotation may be measured using a goniometer (Bennell *et al*., 1999; Bennell *et al*., 2001; Clarkson, 2005; Gilbert *et al*., 1998; Negus *et al*., 2005). A universal goniometer was used in similar studies (Negus *et al*., 2005; Coplan, 2002) for measuring hip external rotation. The normal range of hip external rotation is 40 - 60° (Magee, 2002)

Nussbaumer *et al*. (2010) found the intra-tester reliability of goniometry for measuring hip external rotation to be higher than 0.90 ICC. Clapper and Wolf (1988) found an ICC of 0.80 for the reliability of this measurement.

#### 3.8.1.2.2 Quadriceps angle (Q-angle)

The Q-angle is the angle between the quadriceps muscles and the patellar tendon. It represents the angle of muscle force of the quadriceps muscle (Magee, 2002). The angle is found at the intersection of two lines drawn from the anterior superior iliac spine (ASIS) to the centre of the patella and from the centre of the patellar to the tibial tuberosity (Rahimi *et al*., 2012). The normal range for the Q-angle is 18 - 22° (Magee, 2002)

The 'gold standard' for measuring the Q-angle is by the use of radiography, magnetic resonance imaging or computed tomography (Smith *et al*., 2008). However, these methods are expensive and not easily accessible, and radiography and tomography exposes the participant to radiation.

The Q-angle may also be measured using a universal goniometer (Rahimi *et al*., 2012), which is more easily accessible and less costly. Piva *et al*. (2006) found goniometry for the measurement of the Q-angle to have moderate values of reliability, stating the inter-tester reliability to be 0.70 (ICC). Shultz *et al*. (2006) reported the intra-tester reliability of this method of Q-angle assessment to be 0.89 to 0.98 (ICC). Emami *et al*. (2007) found the Q-angle to be a useful clinical measurement in the evaluation of knee injury.

#### 3.8.1.2.3 Femoral torsion angle (Craig's Test)

The femoral torsion angle is the degree of forward or backward projection of the femoral neck from the coronal plane of the femoral shaft (Magee, 2002). The normal range is 8 - 15° (Magee, 2002).

This angle is measured clinically using Craig's test (Magee, 2002). Other methods include radiography, computed tomography and ultrasound. However, it has been stated by Gulan *et al*. (2000) that these methods of measurement are expensive, involve unnecessary exposure to radiation and are not much more accurate than clinical methods.

Ruwe *et al*. (1992) found that the Craig's test measurement of the femoral torsion angle is superior to radiography in some instances, and Shultz *et al*. (2006) has stated that the intra-tester reliability of this method is 0.77 to 0.97 (ICC).

#### 3.8.1.2.4 Ankle plantarflexion and dorsiflexion

A universal goniometer may be used for the measurement of ankle plantarflexion and dorsiflexion (Clarkson, 2005). The normal range for ankle motion is 0 - 50° for plantarflexion (Clarkson, 2005; Magee, 2002) and 8 - 26° for dorsiflexion (Rome, 1996).

Venturni *et al*. (2006) found intra-session reliability to be high for measurements with the universal goniometer and inter-session reliability to be moderate (0.65 0 0.77). Inter-examiner reliability was found to be moderate (0.72). Youdas *et al*. (1993) found the intra-tester reliability of the measurement of ankle dorsiflexion with the use of a universal goniometer to be 0.87 (ICC). The same measurement for plantarflexion had an intra-tester reliability of 0.82 (ICC). Russell *et al*. (2010) found an intra-examiner reliability of 0.99 (ICC) for goniometric measurements of ankle range of motion.

#### 3.8.1.2.5 'Functional Turnout' and 'Compensated Turnout'

'Functional turnout' consists primarily of hip external rotation, with 'turnout' at the knee, tibia and ankle making up for the rest (IADMS *et al*., 2011).

'Functional turnout' can be measured by asking the participant to stand on a large sheet of white paper and assume their best 'first position'. The outlines of the participant's feet are then traced. At a later stage, the 'functional turnout' angle is calculated by measuring the angle of bisection of the longitudinal axes of the 2 feet with a goniometer. The longitudinal axis lines are drawn from the midpoint of the heel to the midpoint of the tip of the second toe (Coplan, 2002; Negus *et al*., 2005).

No normal range of 'functional turnout' has been established, but a range of 100 - 131° has been reported in previous studies (Coplan, 2002; Negus *et al*., 2005).

'Compensated turnout' is calculated as the total hip external rotation measurement subtracted from the 'functional turnout' measurement (Coplan, 2002; Negus *et al*., 2005).
Gilbert *et al*. (1998) found the test-retest reliability of this measurement of 'functional turnout' in first position to be 0.86 (ICC), while Negus *et al*. (2005) found an intra-tester reliability of 0.91 (ICC).
No normal range of 'compensated turnout' has been established, but a range of 5 – 68.9° has been reported in previous studies (Coplan, 2002; Negus *et al*., 2005). This range is wide, as 'compensated turnout' from the ankle, tibia and knee may form up to 40% of the total 'turnout' (IADMS *et al*., 2011).

#### 3.8.1.2.6 'Rolling in' or pronation of the foot

Ballet dancers with inadequate 'turnout' at the hips often compensate by 'rolling in' their feet (Milan, 1994). This is also called pronation (Coplan, 2002; Milan, 1994). The amount of foot pronation or 'rolling in' may be measured using the Navicular Drop Test (Magee, 2002).

Shrader *et al*. (2005) found inter-rater reliability for the Navicular Drop Test to be 0.67 to 0.92 (ICC) and 0.85 to 0.97 (ICC). Intra-rater reliability was found to be 0.73 to 0.95 (ICC) and 0.90 to 0.98 (ICC). Shultz *et al*. (2006) found the intra-tester reliability of this test to be 0.91 to 0.97 (ICC).

#### 3.8.1.2.7 Knee Alignment

The evaluation of knee alignment for genu varum or valgum may be carried out by measuring the inter-condylar and inter-malleoli distances (Arazi *et al*., 2001) (Magee, 2002).

Cheng *et al*. (1991) stated that the inter-condylar and inter-malleoli measurements for knee alignment are easier to apply clinically and are as reliable as goniometry of the tibiofemoral angle. Thijs *et al*. (2012) found the intra-tester reliability of the measurement of inter-condylar and inter-malleoli distance to be 0.96 (ICC) and the inter-tester reliability to be 0.95 (ICC).

## 3.9 STUDY PROCEDURE

Each participant's appointment took place in the professional environment of a private room at the Chiropractic Day Clinic at the Durban University of Technology, under the supervision of a qualified clinician. Each participant was given a Participant's Letter of Information and Consent Form (Appendix C4), which they were asked to read and sign. They were allowed to ask any questions before signing the document. The participant had her height and weight measured, and the researcher then interviewed the participant in order to complete the questionnaire (Appendix C5). After the interview, the selected objective biomechanical measurements were taken.

The following biomechanical measurements were measured bilaterally as explained below. Each biomechanical measurement was repeated three times and the average was calculated (Negus *et al*., 2005; Gamboa *et al*., 2008). All figures were recorded on the Measurements Data Sheet (see Appendix F):

### 3.9.1 Hip external rotation (active and passive)

Active hip external rotation was measured as follows:

The participant was positioned supine with both knees flexed and hanging over the edge of the examination table. The hip being tested was in the neutral position, with the thigh secured to the table with a belt to prevent any active or passive movement other than hip external rotation. The axis of the goniometer was placed over the centre of the patella and the stationary arm was positioned perpendicular to the floor. The participant was then asked to actively move the leg as far medially as possible, without the pelvis moving. The moving arm of the goniometer was aligned with the anterior midline of the tibia and the angle between the two arms was recorded (Clarkson, 2005; Negus *et al*., 2005).

Passive hip external rotation was measured as follows:

The participant was positioned supine with both knees flexed and hanging over the edge of the examination table. The hip being tested was in the neutral position, with the thigh secured to the table with a belt to prevent any active or passive movement other than hip external rotation. The axis of the goniometer was placed over the centre of the patella and the stationary arm was positioned perpendicular to the floor. The researcher then passively moved the leg as far medially as possible, without the pelvis moving. The moving arm of the goniometer was aligned with the anterior midline of the tibia and the angle between the two arms was read (Clarkson, 2005; Negus *et al*., 2005).

### 3.9.2 Quadriceps angle (Q-angle)

The Q-angle was measured as follows:

With the participant in the standing position, with the hips and knees extended and the quadriceps muscle relaxed, the axis of a universal goniometer was placed over the centre of the patella. The stationary arm was pointed in the direction of the anterior superior iliac spine (ASIS), while the moving arm was placed in line with the patella tendon over the centre of the tibial tubercle. The angle formed by the two arms was read and recorded as the Q-angle (Magee, 2002; Rahimi *et al*., 2012).

### 3.9.3 Femoral torsion angle

The femoral torsion angle was measured as follows:

The patient was positioned prone on the examination table with the knee flexed to 90°. Standing on the contralateral side, the researcher internally and externally rotated the participant's hip on the side being tested, while palpating the greater trochanter on the side being tested. When the greater trochanter was parallel to the table and at its most

lateral position, a goniometer was used to measure the angle between the true vertical and the long axis of the tibia (Magee, 2002).

### 3.9.4 Ankle plantarflexion (Weight-bearing and non weight-bearing)

Ankle plantarflexion in the weight-bearing position was measured as follows:
With the participant standing on a platform with their feet parallel, the axis of the goniometer was placed inferior to the lateral malleolus. The stationary arm of the goniometer was positioned parallel to the longitudinal axis of the fibula, pointing towards the fibula head. The movable arm was positioned parallel to the fifth metatarsal. A reading was taken and recorded as 0°. The participant was then asked to extend their ankle and rise up onto *demi-pointe* as far as possible. The movable arm was positioned parallel to the fifth metatarsal again and a reading was taken. The difference between the 2 readings was recorded as the degree of weight-bearing ankle plantarflexion (Clarkson, 2005; Russell *et al*., 2010).

Ankle plantarflexion in the non weight-bearing position was measured as follows:
The participant was positioned supine on the examination table with the ankle in the anatomical position of 0°. The axis of the goniometer was placed inferior to the lateral malleolus. The stationary arm of the goniometer was positioned parallel to the longitudinal axis of the fibula, pointing towards the fibula head. The movable arm was positioned parallel to the fifth metatarsal. The participant was then asked to extend the ankle into maximal plantarflexion and the researcher adjusted the movable arm so that it was parallel to the fifth metatarsal again. The reading was taken and recorded as the degree of non weight-bearing ankle plantarflexion (Clarkson, 2005; Russell *et al*., 2010).

### 3.9.5 Ankle dorsiflexion (Weight-bearing and non weight-bearing)

Ankle dorsiflexion in the weight-bearing position was measured as follows:
With the participant standing on a platform with their feet parallel, the axis of the goniometer was placed inferior to the lateral malleolus. The stationary arm of the goniometer was positioned parallel to the longitudinal axis of the fibula, pointing towards the fibula head. The movable arm was positioned parallel to the fifth metatarsal. A reading was taken and recorded as 0°. The participant was then asked to flex their ankle as far as possible, keeping their foot flat on the platform. The movable arm was positioned parallel to the fifth metatarsal again and a reading was taken. The difference between the 2 readings was recorded as the degree of weight-bearing ankle dorsiflexion (Clarkson, 2005; Russell *et al*., 2010).

Ankle dorsiflexion in the non weight-bearing position was measured as follows:
The participant was positioned supine on the examination table, with a towel placed under the knee to relax the gastrocnemius and the ankle in the anatomical position of 0°. The axis of the goniometer was placed inferior to the lateral malleolus. The stationary arm of the goniometer was positioned parallel to the longitudinal axis of the fibula, pointing towards the fibula head. The movable arm was positioned parallel to the fifth metatarsal. The participant was then asked to flex the ankle into maximal dorsiflexion and the researcher adjusted the movable arm so that it was parallel to the fifth metatarsal again. The reading was taken and recorded as the degree of non weight-bearing ankle dorsiflexion (Clarkson, 2005; Russell *et al*., 2010).

### 3.9.6 'Functional turnout' and 'Compensated Turnout'

'Functional turnout' was measured as follows:
The participant was asked to stand on a large sheet of white paper and assume their best 'first position'. The researcher traced the outline of the participant's feet. At a later stage, the 'functional turnout' angle was calculated by measuring the angle of bisection of the longitudinal axes of the 2 feet with a goniometer. The longitudinal axis lines were drawn from the midpoint of the heel to the midpoint of the tip of the second toe (Coplan, 2002; Negus *et al*., 2005).

'Compensated turnout' was calculated by subtracting the total (bilateral) active hip external rotation measurement from the 'functional turnout' measurement (Negus *et al*., 2005; Coplan, 2002).

### 3.9.7 'Rolling in' or Pronation of the Foot

The amount of 'rolling in' or foot pronation was measured using the Navicular Drop Test as follows:
The researcher first asked the participant to stand with the feet in the anatomical position. A measurement was taken from the most prominent part of the navicular to the floor with a ruler. The researcher then palpated the talar head on the dorsal foot with the thumb and index finger of one hand while asking the participant to slowly rotate their trunk from side to side. The subtalar joint was considered to be in the neutral position when the talar head does not bulge on either side. The height of the navicular was taken again with the foot in this subtalar neutral position. The difference between the two measurements was recorded as the amount of 'rolling in' or foot pronation (Magee, 2002).

A difference in the two measurements of more than 10mm was considered abnormal and excessive pronation (Brody, 1982).

### 3.9.8 Knee Alignment

Knee alignment was observed for genu valgum deformity, also known as 'knock knees'; and genu varum deformity, also known as 'bow-leggedness' (Magee, 2002).

If present, the researcher measured these deformities as follows:
The participant was asked to stand up straight with their ankles (medial malleoli) as close together as possible and the medial aspects of their knees as close together as possible. If the knees touched and the ankles did not, with a space of 9 – 10cm between the ankles, it was recorded that the participant had genu valgum. If the ankles touched and the knees did not, with a space of 4cm or more between the knees, it was recorded that the participant had genu varum (Magee, 2002).

The participants were thanked for their time and participation, and were free to leave.

## 3.10 DATA ANALYSIS

Categorical variables were described using frequency and percentages in tables and bar charts. Continuous variables were summarised using mean, standard deviation and range, or median and range as appropriate. Independent samples t-tests were used to compare biomechanical measurements between two independent groups. A $p$ value $<0.05$ was considered as statistically significant. Pearson's correlations were done between biomechanical measurements and severity ratings. ANOVA testing was used where there were more than three independent group means being compared.

## 3.11 ETHICS

Ethical clearance was given by the Durban University of Technology's Institutional Research and Ethics Committee (Appendix E). This clearance indicated that the study was approved and complied with the principles outlined in the Declarations of Helsinki, Nuremburg and Belmont of 1975.

Informed Consent was obtained from the owner or principal of each studio, granting permission for the recruitment of research participants at their studio through the placing of an advert in the form of a poster and through the researcher verbally informing the

students of the study. It also served to request the permission of the principal or owner for the canvassing of their students.

Informed Consent was obtained from the participants prior to them participating in the study, and privacy and confidentiality was maintained throughout the study. The participants had the right to withdraw from the study at any time. Injured participants were made aware of the Chiropractic Day Clinic during their appointment so that they could seek treatment if they so wished.

Permission was obtained from the Clinic Director of the Chiropractic Day Clinic.

Feedback on the study will be given to the participants once the research process is complete.

# CHAPTER FOUR
# RESULTS AND DISCUSSION

## 4.1 INTRODUCTION

This chapter includes a review of the objectives of the study, a section on the response rate, and the types of data used in the study.

The results and discussion of the statistical analysis of the data collected during the study are also presented in this chapter. The demographic characteristics; period prevalence, point prevalence and characteristics of ballet-related injury; biomechanical measurements; and associations between biomechanical measurements and characteristics of injury are presented and discussed using tables and figures.

The results and discussion were combined into a single chapter in order to reduce repetition and to facilitate ease of understanding the tables and figures presented.

## 4.2 REVIEW OF THE OBJECTIVES

- To collect data with regard to the demographics of female amateur ballet dancers in the greater Durban area; and the location, onset, frequency and severity (characteristics) of injury in this population.

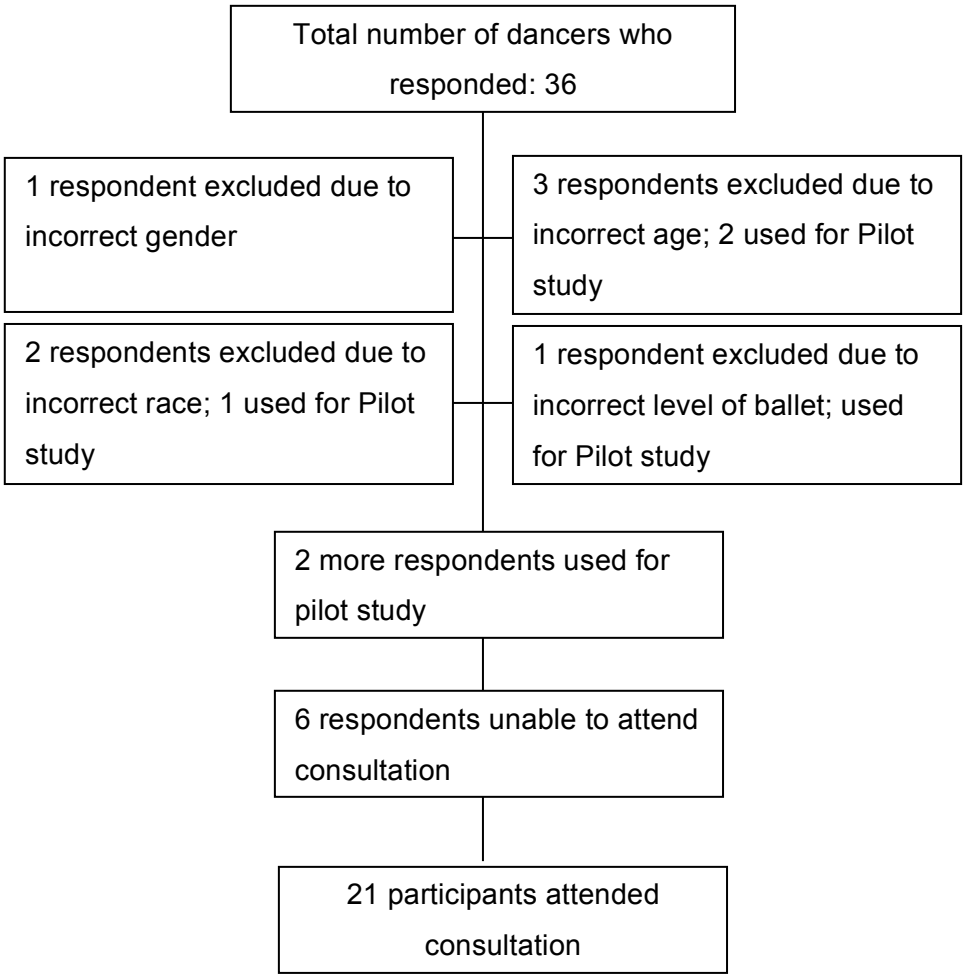
- To measure and record selective lower limb biomechanical measurements in female amateur ballet dancers in the greater Durban area.

- To determine any associations between selected lower limb biomechanical measurements and the characteristics of injury in the population.

## 4.3 RESPONSE RATE

A total of 36 dancers responded to the recruitment process. One of these was excluded due to not fulfilling the gender criteria, 3 were excluded due to not fulfilling the age criteria and 2 were excluded due to not fulfilling the race criteria. Two respondents were used for the pilot study and 6 were unable to attend the consultation. A total of 21 participants were

therefore recruited for the study. The following consort diagram illustrates the participant recruitment of the research process:



## 4.4 DEMOGRAPHIC CHARACTERISTICS

The First Objective was to collect data with regard to the demographics of female amateur ballet dancers in the greater Durban area; and the location, onset, frequency and severity (characteristics) of injury in this population.

### 4.4.1 Age Distribution

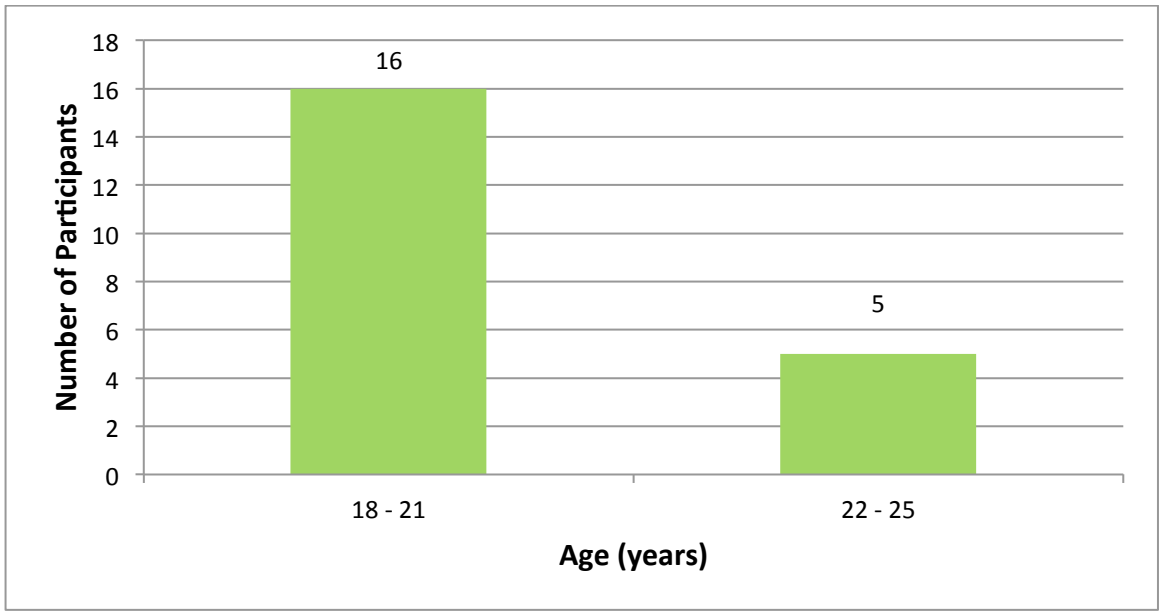



**Figure 4.1 Age distribution of the sample population (N=21)**

The majority of the participants (76%) were between the ages of 18 and 21 years old. The youngest participant was 18 years old and the oldest was 25 years old. The mean age was 20 years old (SD = 2.7).

Eighteen to 25-year-old dancers were permitted to participate in the study, as per the inclusion criteria. More than two thirds of the participants (76%) in this study were between the ages of 18 and 21 years old. The mean age of 20 years old is similar to that of the mean age found in studies by Negus *et al*. (2005), Russell *et al*. (2010) and Coplan (2002), who had mean ages of 18 years, 20 years and 22 years, respectively.

### 4.4.2 Height Distribution

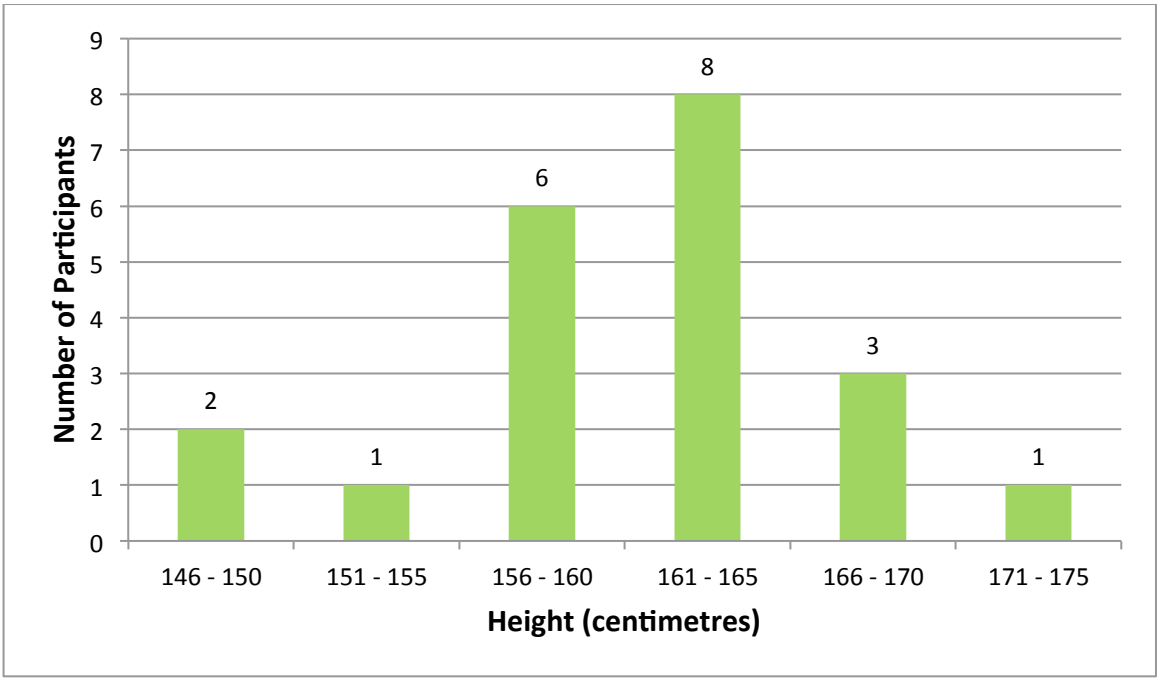



**Figure 4.2 Height Distribution of the sample population (N=21)**

Most of the participants (38%) were between 161cm and 165cm in height. The shortest participant measured 146cm and the tallest measured 175cm. The mean height was 161cm (SD = 6.8).

The mean height of 161cm is similar to that of Coplan (2002) and Valenti's *et al*. (2011) studies, in which the participants had a mean height of 163cm and 160cm for females, respectively.

### 4.4.3 Weight Distribution

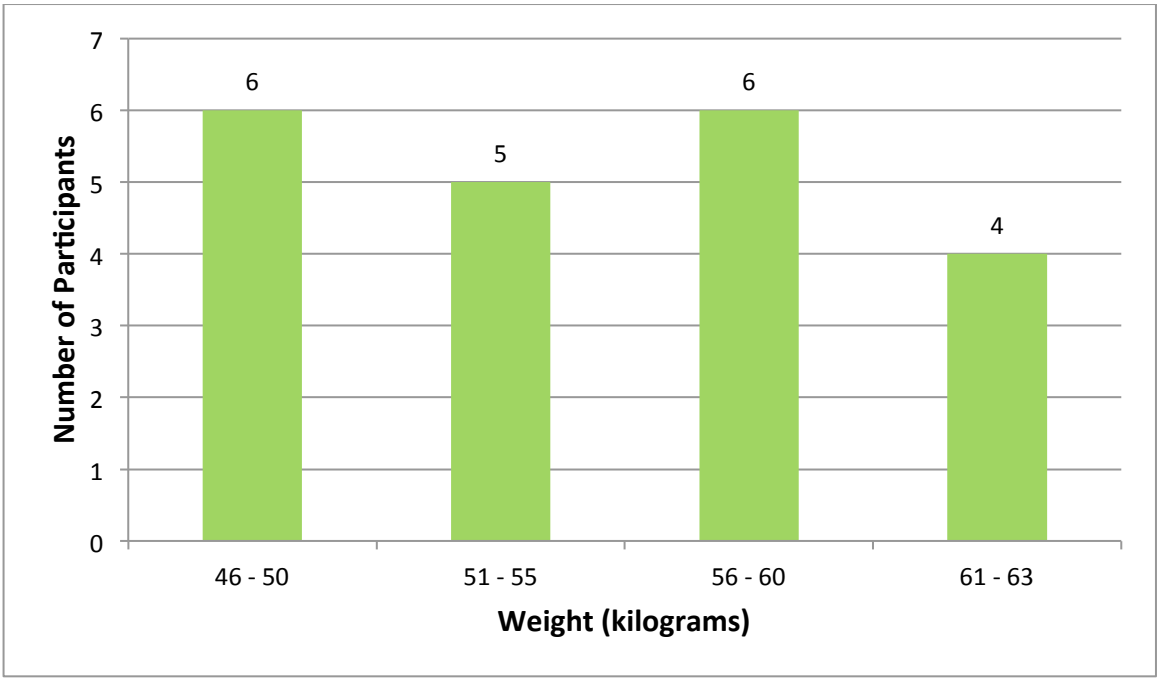



**Figure 4.3 Weight Distribution of the sample population (N=21)**

Most of the participants weighed between 46kg and 50kg (29%) or between 56kg and 60kg (29%). The lightest participant was 46kg and the heaviest was 63kg. The mean weight was 54.5kg (SD = 5.6).

The mean weight of 54.5kg in this study is similar to that of Coplan (2002) and Valenti's *et al*. (2011) studies, which reported a mean weight of 53kg and 54kg for females, respectively.

### 4.4.4 Ballet Experience

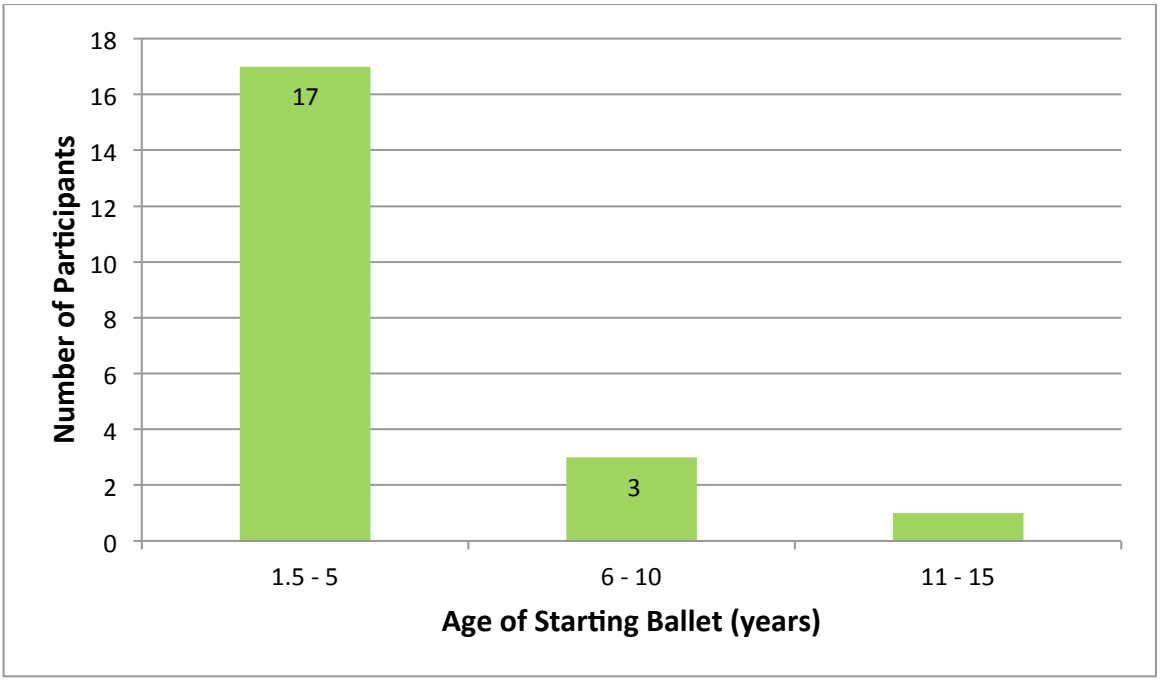



**Figure 4.4 Ballet experience of the sample population (N=21)**

The majority (81%) of the participants started ballet between the ages of 1.5 years and 5 years. The youngest age of starting ballet was 1.5 years, while the oldest was 15 years. The mean (SD = 3.4) age of starting ballet was 5 years, which is similar to that of an epidemiological study performed in the greater Durban area by Balding (2004), where a mean of 5 years was reported.

The dancers in this study highlighted that their experience of ballet ranged from 5 years to 23 years, with a mean (SD = 4.3) of 15 years, which is similar to that of Russell's *et al*. (2010) study, who stated that their dancers reported a mean of 15 years of dance experience in the university level dancers in their study.

The number of classes attended by the participants per week ranged from 1 to 6, with 33% of the participants attending 3 classes per week. The mean (SD= 1.4) number of classes attended per week was 3. Sixty-seven percent of the dancers in this study attended less than 4 classes per week. This is in contrast to Balding's (2004) study, in which it was highlighted that 52% attended less than 4 classes per week. This difference may be due to the fact that Balding recruited dancers who were between the ages of 10 years and 50 years.

The number of hours of ballet attended by the participants per week varied greatly and ranged from 2 to 12. The mean (SD = 2.6) number of hours of ballet attended per week was 5.

### 4.4.5 Period Prevalence and Frequency

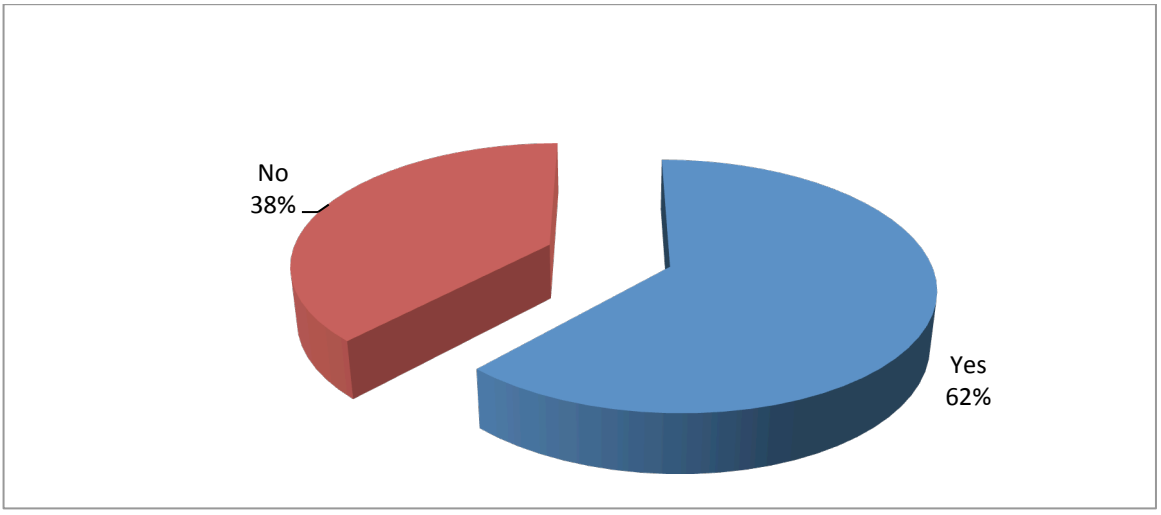



**Figure 4.5** **Period prevalence of ballet-related injuries in the sample population over 2 years (n=13)**

Nearly two-thirds (62% (n=13)) of the sample population had sustained at least one injury in the previous 2 years. The number of injuries sustained by each participant ranged from 1 to 10, and the median number of injuries was 2. These results concur with similar studies such as that of Negus *et al*. (2005), who reported 100% period prevalence of injuries over the previous 2 years, which may be due to the fact that pre-professional dancers were used in the study.

Regarding frequency of injury, the number of injuries sustained by each participant ranged from 1 to 10, and the median number of injuries was 2. This is similar to the findings of Negus *et al*. (2005), who reported a median number of 2 non-traumatic injuries in 93% of the sample.

### 4.4.6 Point Prevalence

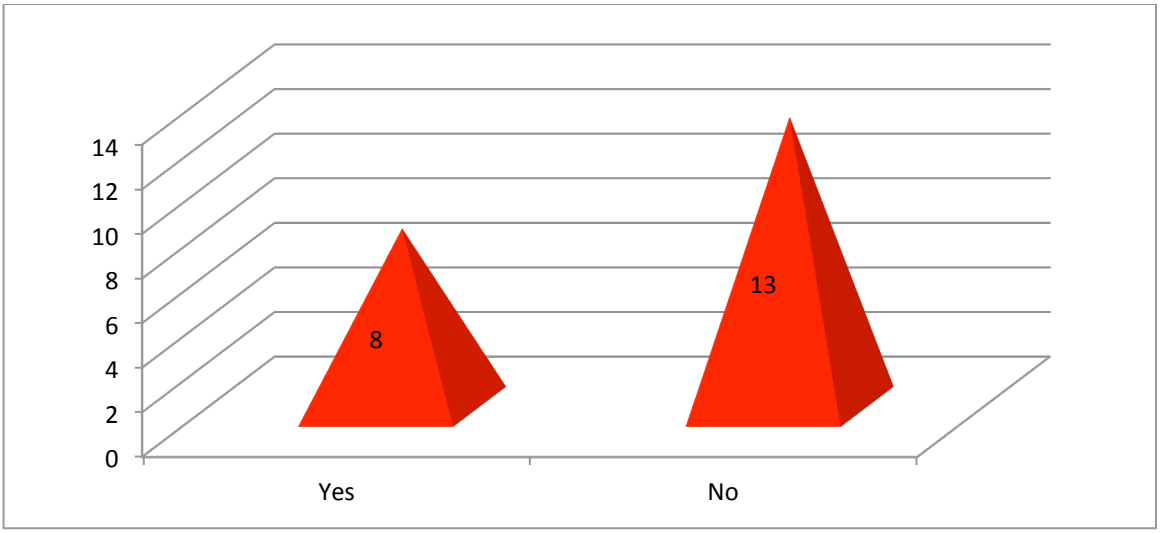



**Figure 4.6 Point prevalence of ballet-related injury in the sample population (n=8)**

The point prevalence of injury in the sample population was 38% (n=8). This is lower than the figures in similar studies, where a prevalence of 57% (Coplan, 2002) and 93% (Negus *et al*., 2005) were found. The difference between the results of this study and the study conducted by Negus *et al*. (2005) may be due to the fact that pre-professional dancers were used by Negus *et al*. (2005), whereas this study recruited amateur dancers.

### 4.4.7 Location

#### 4.4.7.1 Location of Previous Injuries

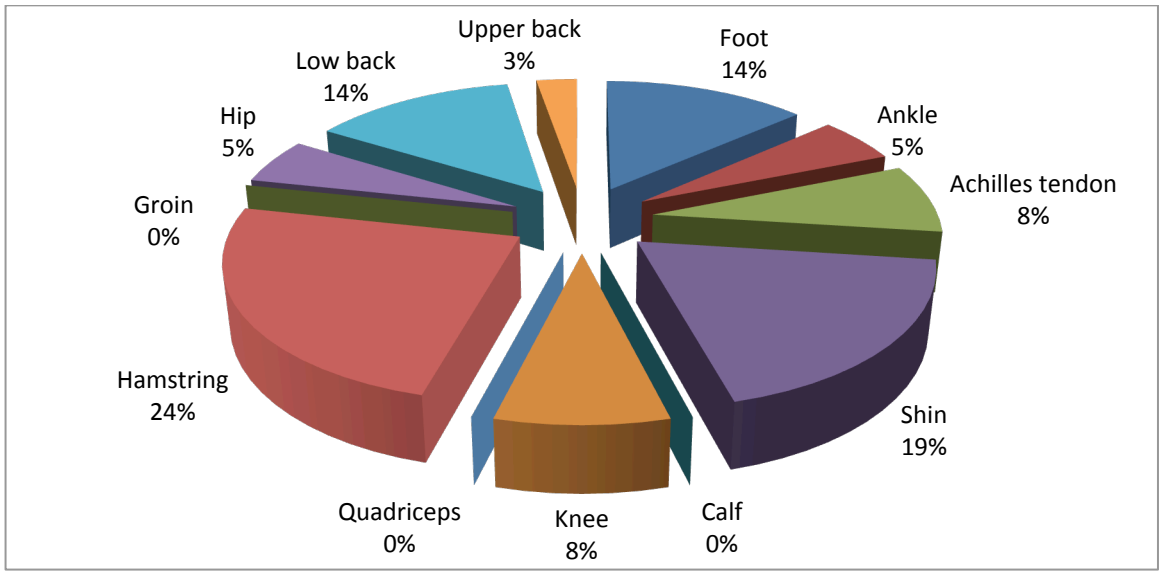



**Figure 4.7 Location of previous ballet-related injuries in the sample population (n=37)**

There were a total of 37 injuries sustained between the 13 participants who had previous injuries. The majority of these occurred in the hamstring (24%), followed by the shin (19%), the foot (14%) and low back (14%) (n=37).

#### 4.4.7.2 Location of Worst Previous Injuries

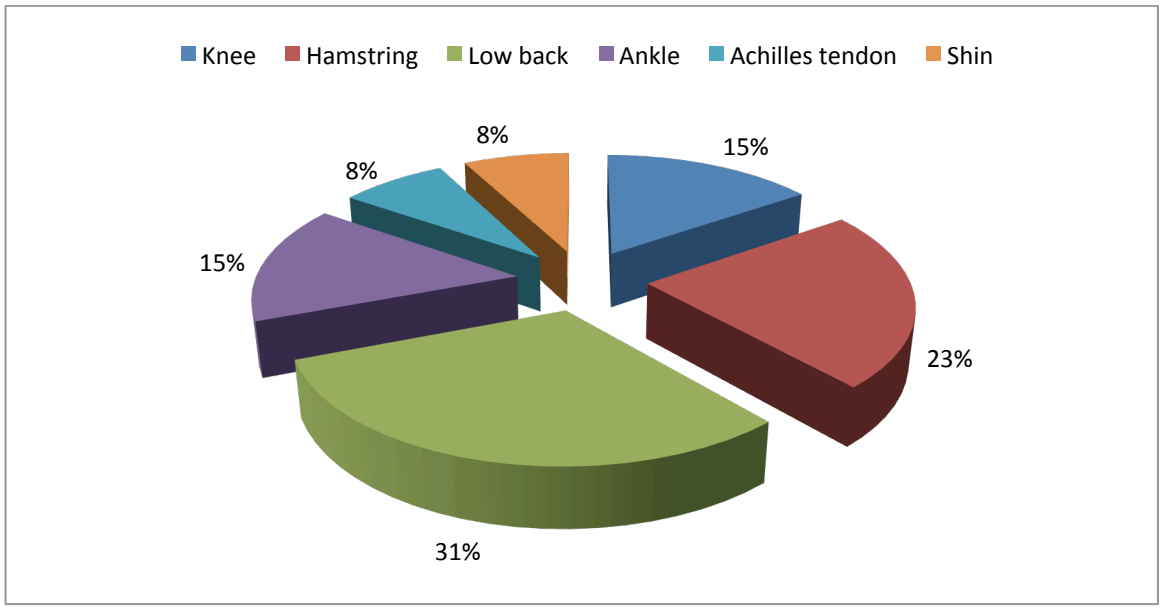



**Figure 4.8 Location of worst previous ballet-related injuries in the subgroup/ sample with previous injury (n=13)**

Just under a third (31%) of the worst previous injuries reported by the dancers occurred in the low back, followed by the hamstring with 23%.

4.4.7.3 Location of Worst Current Injuries

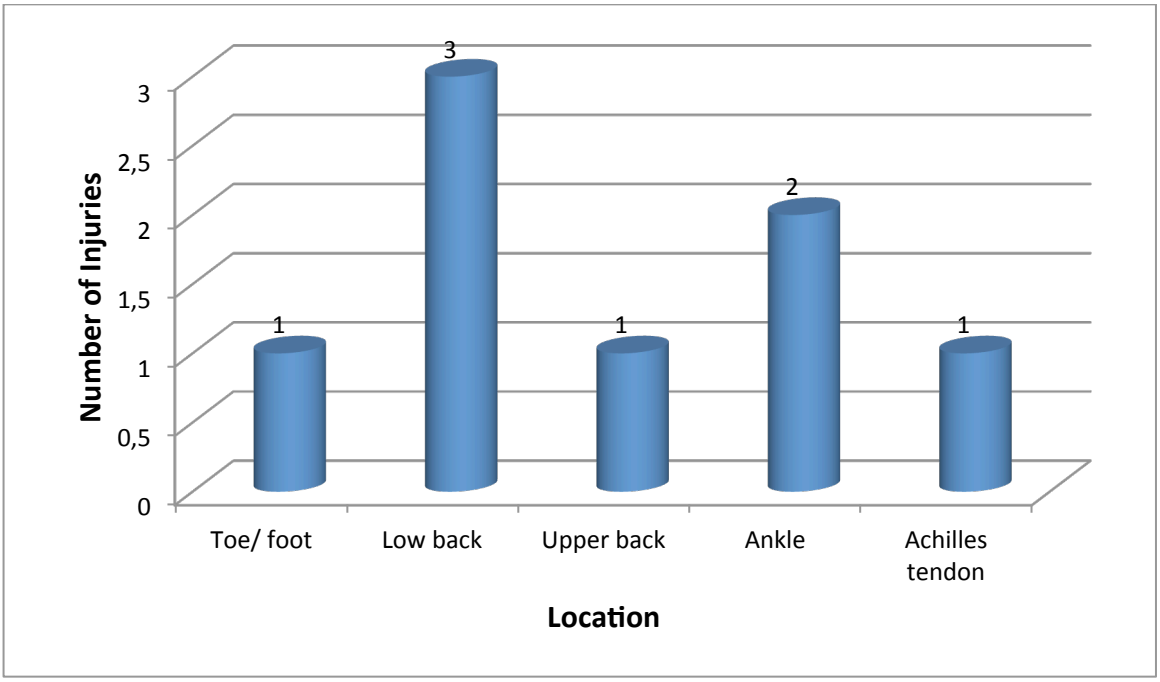



**Figure 4.9** **Location of worst current ballet-related injuries in the sample population (n=8)**

Over a third (38%) of the worst current injuries were located at the low back, followed by the ankle (25%).

4.4.7.4 Discussion of Location of Previous and Current Injuries

The location of previous and current injury are comparable to the findings in other studies. Coplan (2002) reported similar findings of 36% of injuries in the knee, 23% in the shin, 14% in the low back, 14% in the ankle, 5% in the hip and 5% in the foot. Gamboa *et al*. (2008) reported 53% of injuries in the foot/ankle, 22% in the hip, 16% in the knee and 9% in the back. Negus *et al*. (2005) reported a distribution of injuries in the hip (26%), the ankle (26%), the lower leg (20%), the foot (11%), the low back (10%), the knee (7%) and the thigh (1%).

## 4.4.8 Onset

4.4.8.1 Onset of Worst Previous Injuries

**Table 4.1 Onset of Worst Previous Ballet-Related Injuries in the Sample Population according to Occurrence Over Time or During a Single Traumatic Event**

| | Over Time | | Single Event | | N/A | |
|---|---|---|---|---|---|---|
| | Count | Row N % | Count | Row N % | Count | Row N % |
| Injury 1 | 7 | 33.3% | 6 | 28.6% | 8 | 38.1% |
| Injury 2 | 9 | 42.9% | 0 | 0.0% | 12 | 57.1% |
| Injury 3 | 3 | 14.3% | 2 | 9.5% | 16 | 76.2% |
| Injury 4 | 2 | 9.5% | 1 | 4.8% | 18 | 85.7% |

More than two-thirds of the participants' four worst previous injuries were reported to have occurred over time, and were therefore overuse injuries (70%) (n=30).

4.4.8.2 Onset of Worst Current Injuries

**Table 4.2 Onset of Worst Current Ballet-Related Injuries in the Sample Population according to Occurrence Over Time or During a Single Traumatic Event**

| | Over time | | Single Event | | N/A | |
|---|---|---|---|---|---|---|
| | Count | Row N % | Count | Row N % | Count | Row N % |
| Injury 1 | 7 | 33.3% | 1 | 4.8% | 13 | 61.9% |
| Injury 2 | 3 | 14.3% | 0 | 0.0% | 18 | 85.7% |
| Injury 3 | 2 | 9.5% | 0 | 0.0% | 19 | 90.5% |
| Injury 4 | 1 | 4.8% | 0 | 0.0% | 20 | 95.2% |

Ninety-three percent of the participants' four worst current injuries were reported to have occurred over time, and were therefore overuse injuries (n=14).

4.4.8.3 Discussion of Onset of Injuries

These findings were expected, as overuse injuries are the most common types of ballet-related injuries. Other studies reported similar findings to this study in that most injuries were non-traumatic and due to overuse (Gamboa *et al*., 2008; Negus *et al*., 2005).

### 4.4.9 Severity

The participants were asked to rate the severity of their injury from a scale of 0 to 10, with 0 being the least severe and 10 being the most severe. This type of severity rating is

subjective. Mild severity was classified as 0 to 4; moderate severity was classified as 5 to 7; and severe severity was classified as 8 to 10.

4.4.9.1 Severity of Worst Previous Injuries

**Table 4.3 Severity of Worst Previous Ballet-Related Injuries in the Sample Population**

| | Injury 1 | Injury 2 | Injury 3 | Injury 4 |
|---|---|---|---|---|
| N | 13 | 9 | 5 | 3 |
| Mean | 6.31 | 4.00 | 4.10 | 1.33 |
| Std. Deviation | 1.974 | 2.236 | 3.681 | .577 |
| Minimum | 3 | 1 | 1 | 1 |
| Maximum | 10 | 8 | 8 | 2 |

The severity of the worst injuries reported ranged from mild (3/10) to severe (10/10), with a mean (SD =2.0) of 6/10. The second and third worst injuries reported scored a mean of 4/10 on the severity scale (SD = 2.2 and 3.7), while the fourth worst injuries reported scored a 1/10 (SD =0.6).

4.4.9.2 Severity of Worst Current Injuries

**Table 4.4 Severity of Worst Current Ballet-Related Injuries in the Sample Population**

| | Injury 1 | Injury 2 | Injury 3 | Injury 4 |
|---|---|---|---|---|
| N | 8 | 3 | 2 | 1 |
| Mean | 3.31 | 1.50 | 0.50 | 1.00 |
| Std. Deviation | 1.624 | 1.323 | 0.000 | |
| Minimum | 1 | 1 | 1 | 1 |
| Maximum | 6 | 3 | 1 | 1 |

The severity of the worst injuries reported ranged from mild (1/10) to moderate (6/10), with a mean of a mild 3/10 (SD = 1.6). The second, third and fourth worst injuries reported were mild, ranging from 1/10 to 3/10 on the severity scale.

4.4.9.3 Discussion of Severity of Injuries

Current injuries were milder than the dancers' previous injuries. However, quantifying severity was subjective as it relied on each dancer's memory and judgement.

### 4.4.10 Duration

4.4.10.1 Duration of Worst Previous Injuries

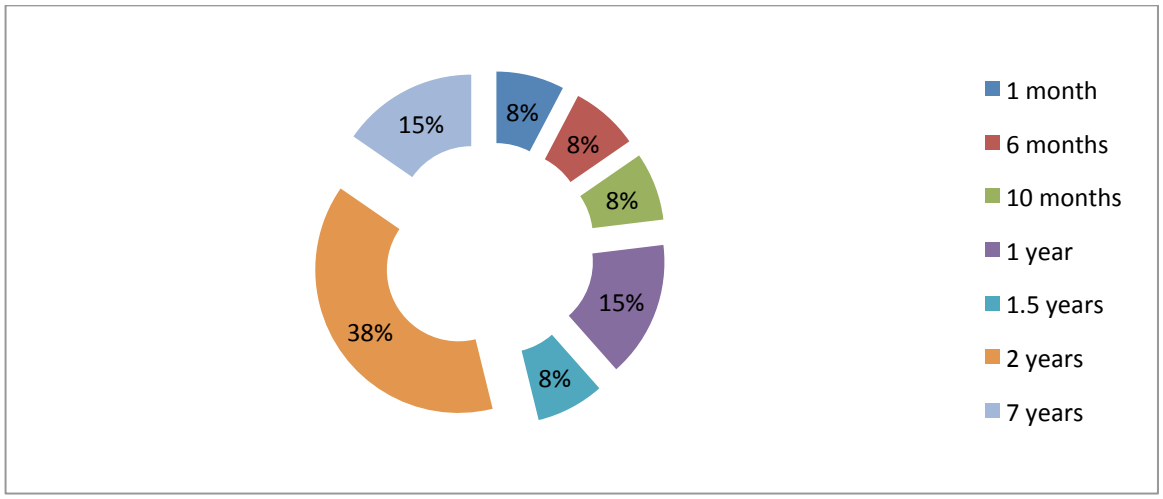



**Figure 4.10 Duration of worst previous ballet-related injuries in sample population (n=13)**

Of the worst previous injuries sustained by the dancers, 38% lasted for 2 years (n=13).

4.4.10.2 Duration of Worst Current Injuries

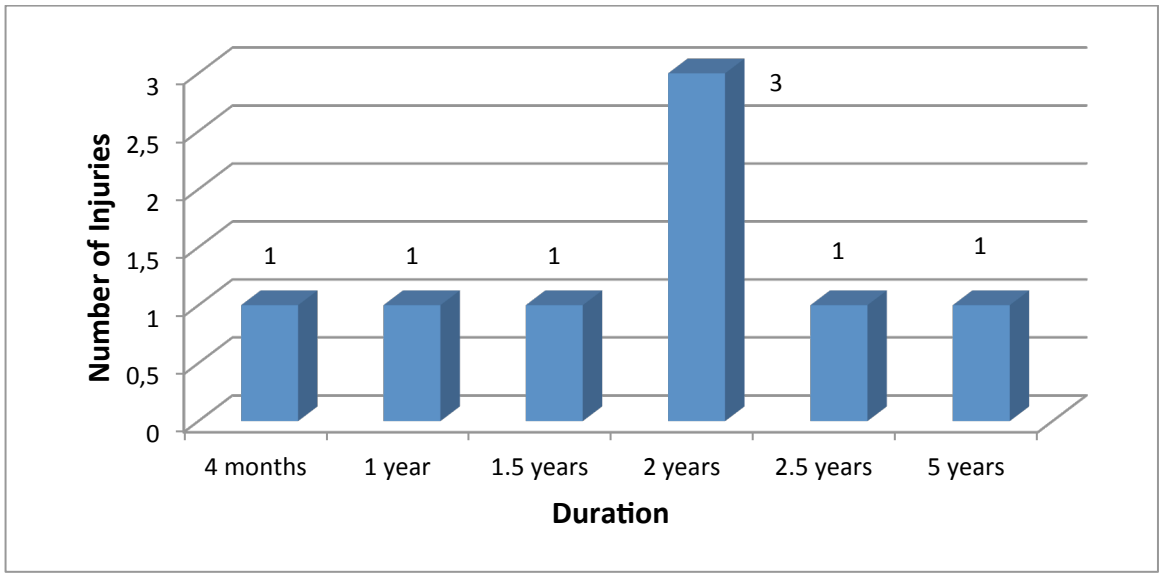



**Figure 4.11 Duration of worst current ballet-related injuries in the sample population (n=8)**

Similar to the duration of the worst previous injuries, 38% of the worst current injuries sustained by the participants lasted for 2 years (n=8).

4.4.10.3 Discussion of Duration of Injuries

In both the worst previous and worst current injury groups, 38% of injuries last for 2 years. This may be due to the fact that most of the dancers did not stop dancing due to their injuries, which may have exacerbated the injury and prolonged the healing process.

## 4.4.11 Effect of Injuries on Dancing

4.4.11.1 Effect of Worst Previous Injuries on Dancing

**Table 4.5 Effect of Worst Previous Ballet-Related Injuries on Dancing according to Whether the Injuries Stopped the Participant From Dancing**

| | Yes, totally stopped dancing | | Yes, had to modify classes | | No | |
|---|---|---|---|---|---|---|
| | Count | N % | Count | N % | Count | N % |
| Did injury 1 stop you from dancing? | 5 | 41.7% | 4 | 33.3% | 3 | 25.0% |
| Did injury 2 stop you from dancing? | 1 | 12.5% | 4 | 50.0% | 3 | 37.5% |
| Did injury 3 stop you from dancing? | 0 | 0.0% | 3 | 60.0% | 2 | 40.0% |
| Did injury 4 stop you from dancing? | 0 | 0.0% | 1 | 33.3% | 2 | 66.7% |

Most injuries did not prevent the dancers from dancing, but rather caused them to modify their classes.

4.4.11.2 Effect of Worst Current Injuries on Dancing

**Table 4.6 Effect of Worst Current Ballet-Related Injuries on Dancing according to Whether the Injuries Were Stopping the Participant From Dancing**

| | | Count | Column N % |
|---|---|---|---|
| Is injury 1 stopping you from dancing? | Yes, I modify classes | 1 | 12.5% |
| | No | 7 | 87.5% |
| Is injury 2 stopping you from dancing? | No | 3 | 100.0% |
| Is injury 3 stopping you from dancing? | No | 2 | 100.0% |

| | | | |
|---|---|---|---|
| Is injury 4 stopping you from dancing? | No | 1 | 100.0% |

Most of the participants' four worst injuries (88%) were not preventing them from dancing (n=14).

4.4.11.3 Discussion of the Effect of Worst Injuries on Dancing

Most of the participants in this study did not sustain injuries that prevented them from dancing. The worst previous injuries were mild to severe in severity, which means that some dancers were dancing through severe injuries. This could be due to the fact that they feel under pressure from ballet teachers or themselves to continue dancing and excel. The worst current injuries ranged from mild to moderate in severity, which means that some dancers may have felt that it was not harmful to dance through their injuries.

## 4.5 BIOMECHANICAL MEASUREMENTS

The Second Objective was to measure and record selective lower limb biomechanical measurements in female amateur ballet dancers in the greater Durban area.

**Table 4.7 Biomechanical Measurements of the Sample Population**

| Biomechanical Measurement | Mean | Standard Deviation |
|---|---|---|
| Right Hip External Rotation (Active) | 46.8 | 7.9 |
| Left Hip External Rotation (Active) | 42.2 | 8.0 |
| Right Hip External Rotation (Passive) | 51.2 | 7.3 |
| Left Hip External Rotation (Passive) | 46.5 | 10.1 |
| Right Q-Angle | 13.3 | 3.6 |
| Left Q-Angle | 12.0 | 4.1 |
| Right Femoral Torsion Angle | 10.9 | 3.9 |
| Left Femoral Torsion Angle | 10.8 | 3.5 |
| Right Ankle Plantarflexion (WB) | 67.1 | 6.4 |
| Left Ankle Plantarflexion (WB) | 72.4 | 7.5 |
| Right Ankle Plantarflexion (NWB) | 77.0 | 6.8 |
| Left Ankle Plantarflexion (NWB) | 76.1 | 7.7 |
| Right Ankle Dorsiflexion (WB) | 29.0 | 6.5 |
| Left Ankle Dorsiflexion (WB) | 30.0 | 7.4 |
| Right Ankle Dorsiflexion (NWB) | 8.6 | 4.7 |
| Left Ankle Dorsiflexion (NWB) | 8.0 | 4.6 |
| Functional Turnout | 139.3 | 14.9 |
| Compensated Turnout | 50.3 | 14.9 |

### 4.5.1 Q-Angle

The mean (SD = 4.1 and 3.6) for both the right and left Q-angle measurements (13.3° and 12°, respectively) were recorded below the normal range of 18-22°. This may be due to the fact that goniometry is not the gold standard of measuring this angle.

### 4.5.2 Ankle Range of Motion

The means (SD = 6.4; 7.5; 6.8; 7.7) for the right and left ankle plantarflexion (weight-bearing and non weight-bearing) measurements (67.1°, 72.4°, 77° and 76.1°, respectively) were recorded well above the normal value of 50°. These are similar to the findings of Russell *et al*. (2010), who reported a mean of 74° for weight-bearing plantarflexion and a mean of 70° for non weight-bearing for ankle plantarflexion, using gonometric measurements in university level dancers. These measurements are expected, as ballet dancers require extreme range of motion at the ankle, especially for *demi-pointe* and *en pointe*.

The mean (SD = 6.5 and 7.4) for both the right and left ankle dorsiflexion (weight-bearing) measurements (29° and 30°, respectively) were recorded above the normal range of 8-26°. This is similar to the findings of Russell *et al*. (2010), who reported a mean of 35° with the use of a similar goniometric tool in university level dancers. These measurements are not surprising, as ballet dancers require extreme ankle joint range of motion for dancing, especially for *pliés*.

### 4.5.3 'Functional Turnout'

The mean (SD = 14.9) for the 'functional turnout' measurement (139.3°) was recorded above the mean values of 131°, 96° and 109° reported in previous studies (Negus *et al*., 2005; Gilbert *et al*., 1998; Coplan, 2002). This may be due to the dancers being given different instructions on assuming their first position. In this study, each participant was instructed to assume their 'best first position', without the researcher correcting their technique. In the study conducted by Gilbert *et al*. (1998), the dancers were asked to assume a 'turnout' that was technically correct. Coplan (2002) has suggested that dancers may achieve an improved 'turnout' when technique is not emphasised.

## 4.6 BIOMECHANICAL MEASUREMENTS AND CHARACTERISTICS OF INJURY

The Third Objective was to interpret the data in order to determine any associations between selected lower limb biomechanical measurements and the characteristics of injury in the population.

### 4.6.1 Biomechanical Measurements and Period Prevalence and Point Prevalence

4.6.1.1 Biomechanical Measurements and Period Prevalence

**Table 4.8 Biomechanical Measurements and Period Prevalence**

| Biomechanical Measurement | Have you sustained an injury from ballet dancing in the last 2 years? | N | Mean | Std. Deviation | Std. Error Mean | *P* value |
|---|---|---|---|---|---|---|
| Right Hip External Rotation (Active) | Yes | 13 | 47.154 | 9.6510 | 2.6767 | 0.807 |
| | No | 8 | 46.250 | 4.4641 | 1.5783 | |
| Region of body injured | Have you sustained an injury from ballet dancing in the last 2 years? | N | Mean | Std. Deviation | Std. Error Mean | *P* value |
| | No | 8 | 44.250 | 6.4087 | 2.2658 | |
| Right Hip External Rotation (Passive) | Yes | 13 | 50.692 | 7.7286 | 2.1435 | 0.701 |
| | No | 8 | 52.000 | 7.0102 | 2.4785 | |
| Left Hip External Rotation (Passive) | Yes | 13 | 44.462 | 9.9550 | 2.7610 | 0.244 |
| | No | 8 | 49.875 | 10.1480 | 3.5879 | |
| Right Q-Angle | Yes | 13 | 13.000 | 3.0551 | 0.8473 | 0.600 |
| | No | 8 | 13.875 | 4.4861 | 1.5861 | |
| Left Q-Angle | Yes | 13 | 11.231 | 2.6506 | 0.7351 | 0.249 |
| | No | 8 | 13.375 | 5.6300 | 1.9905 | |
| Right Femoral Torsion Angle | Yes | 13 | 10.846 | 4.1200 | 1.1427 | 0.932 |
| | No | 8 | 11.000 | 3.7033 | 1.3093 | |
| Left Femoral Torsion Angle | Yes | 13 | 10.308 | 3.1986 | 0.8871 | 0.461 |
| | No | 8 | 11.500 | 4.0356 | 1.4268 | |
| Right Ankle Plantarflexion (WB) | Yes | 13 | 66.000 | 7.1181 | 1.9742 | 0.330 |
| | No | 8 | 68.875 | 4.9407 | 1.7468 | |
| Left Ankle Plantarflexion (WB) | Yes | 13 | 71.923 | 6.7511 | 1.8724 | 0.732 |
| | No | 8 | 73.125 | 9.0623 | 3.2040 | |
| Right Ankle Plantarflexion | Yes | 13 | 76.769 | 8.2174 | 2.2791 | 0.880 |
| | No | 8 | 77.250 | 3.9911 | 1.4111 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| (NWB) | | | | | | |
| Left Ankle Plantarflexion (NWB) | Yes | 13 | 76.000 | 9.2556 | 2.5670 | 0.917 |
| | No | 8 | 76.375 | 4.9552 | 1.7519 | |
| Right Ankle Dorsiflexion (WB) | Yes | 13 | 26.846 | 6.4011 | 1.7754 | 0.046* |
| | No | 8 | 32.625 | 5.3168 | 1.8798 | |
| Left Ankle Dorsiflexion (WB) | Yes | 13 | 27.692 | 6.8725 | 1.9061 | 0.067 |
| | No | 8 | 33.750 | 7.0458 | 2.4911 | |
| Right Ankle Dorsiflexion (NWB) | Yes | 13 | 7.538 | 4.1556 | 1.1526 | 0.182 |
| | No | 8 | 10.375 | 5.1807 | 1.8316 | |
| Left Ankle Dorsiflexion (NWB) | Yes | 13 | 7.077 | 3.9468 | 1.0946 | 0.224 |
| | No | 8 | 9.625 | 5.3436 | 1.8892 | |
| Functional Turnout | Yes | 13 | 136.923 | 15.2996 | 4.2433 | 0.369 |
| | No | 8 | 143.125 | 14.4364 | 5.1041 | |
| Compensated Turnout | Yes | 13 | 48.846 | 14.8876 | 4.1291 | 0.586 |
| | No | 8 | 52.625 | 15.6929 | 5.5483 | |

*A statistically significant ($p$=0.046) association was identified between limited weight bearing dorsiflexion of the right ankle and a history of previous injury.

### 4.6.1.2 Biomechanical Measurements and Point Prevalence

**Table 4.9 Biomechanical Measurements and Point Prevalence**

| Biomechanical Measurement | Are you presently suffering from any injuries due to ballet? | N | Mean | Std. Deviation | Std. Error Mean | *P* value |
|---|---|---|---|---|---|---|
| Right Hip External Rotation (Active) | Yes | 8 | 45.250 | 7.3436 | 2.5964 | 0.494 |
| | No | 13 | 47.769 | 8.4277 | 2.3374 | |
| Left Hip External Rotation (Active) | Yes | 8 | 40.000 | 9.3656 | 3.3112 | 0.328 |
| | No | 13 | 43.615 | 7.1126 | 1.9727 | |
| Right Hip External Rotation (Passive) | Yes | 8 | 47.500 | 4.9281 | 1.7423 | 0.068 |
| | No | 13 | 53.462 | 7.7633 | 2.1532 | |
| Left Hip External Rotation (Passive) | Yes | 8 | 42.750 | 9.6177 | 3.4004 | 0.188 |
| | No | 13 | 48.846 | 10.0982 | 2.8007 | |
| Right Q-Angle | Yes | 8 | 12.500 | 2.5635 | 0.9063 | 0.417 |
| | No | 13 | 13.846 | 4.0997 | 1.1371 | |
| Left Q-Angle | Yes | 8 | 10.750 | 2.2520 | 0.7962 | 0.260 |
| | No | 13 | 12.846 | 4.7583 | 1.3197 | |
| Right Femoral Torsion Angle | Yes | 8 | 10.000 | 2.2678 | 0.8018 | 0.415 |
| | No | 13 | 11.462 | 4.5938 | 1.2741 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Left Femoral Torsion Angle | Yes | 8 | 9.875 | 2.6959 | 0.9531 | 0.375 |
| | No | 13 | 11.308 | 3.9027 | 1.0824 | |
| Right Ankle Plantarflexion (WB) | Yes | 8 | 64.750 | 8.7953 | 3.1096 | 0.195 |
| | No | 13 | 68.538 | 4.1556 | 1.1526 | |
| Left Ankle Plantarflexion (WB) | Yes | 8 | 71.875 | 7.5676 | 2.6755 | 0.816 |
| | No | 13 | 72.692 | 7.7716 | 2.1554 | |
| Right Ankle Plantarflexion (NWB) | Yes | 8 | 74.875 | 8.1493 | 2.8812 | 0.283 |
| | No | 13 | 78.231 | 5.7901 | 1.6059 | |
| Left Ankle Plantarflexion (NWB) | Yes | 8 | 76.000 | 10.2817 | 3.6351 | 0.949 |
| | No | 13 | 76.231 | 6.1935 | 1.7178 | |
| Right Ankle Dorsiflexion (WB) | Yes | 8 | 25.000 | 5.4772 | 1.9365 | 0.022* |
| | No | 13 | 31.538 | 6.0085 | 1.6665 | |
| Left Ankle Dorsiflexion (WB) | Yes | 8 | 26.250 | 6.4752 | 2.2893 | 0.067 |
| | No | 13 | 32.308 | 7.1924 | 1.9948 | |
| Right Ankle Dorsiflexion (NWB) | Yes | 8 | 7.125 | 3.1820 | 1.1250 | 0.260 |
| | No | 13 | 9.538 | 5.2854 | 1.4659 | |
| Left Ankle Dorsiflexion (NWB) | Yes | 8 | 7.000 | 3.3381 | 1.1802 | 0.425 |
| | No | 13 | 8.692 | 5.2183 | 1.4473 | |
| Functional Turnout | Yes | 8 | 134.375 | 16.1151 | 5.6975 | 0.247 |
| | No | 13 | 142.308 | 13.9307 | 3.8637 | |
| Compensated Turnout | Yes | 8 | 49.250 | 8.0667 | 2.8520 | 0.810 |
| | No | 13 | 50.923 | 18.2230 | 5.0541 | |

*A statistically significant ($p$=0.022) association was identified between limited weight bearing dorsiflexion of the right ankle and the presence of injury.

Most of the biomechanical measurements were lower in injured dancers, but the difference was not statistically significant.

#### 4.6.1.3 Discussion of Biomechanical Measurements and Injury Period Prevalence and Point Prevalence

In the present study, all of the biomechanical measurements (except for right active hip external rotation in previously injured dancers) were lower in injured dancers and dancers

with a history of injury, but the difference was not statistically significant. This is supported by Coplan (2002), who found a decrease in the degrees of hip external rotation and hip internal rotation in injured dancers. Negus *et al*. (2005) found an association between reduced 'functional turnout' and injury point prevalence.

Right weight-bearing ankle dorsiflexion was significantly lower in currently injured dancers than in currently non-injured dancers, as well as significantly lower in those participants with previous injury than without previous injury. A similar study by Gamboa *et al*. (2008) did not report significant differences in ankle dorsiflexion between injured and non-injured dancers, but rather found insufficient ankle plantarflexion in injured dancers compared to non-injured dancers. Wiesler *et al*. (1996) found significantly lower dorsiflexion measurements in previously self-reportedly injured dancers, which concurs with this study. The results of this study and those of Wiesler *et al*. (1996) may therefore suggest that, either decreased ankle dorsiflexion may be a risk factor for the development of injury, or that injury leads to a reduced range of motion in the ankle joint. Therefore, causality may not be determined.

## 4.6.2 Biomechanical Measurements and Location

4.6.2.1 Biomechanical Measurements and Location of Worst Previous Injury

**Table 4.10 Biomechanical Measurements and Location of Worst Previous Injury**

| Biomechanical Measurement | Injury 1 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | right knee | left knee | right hamstring | left hamstring | low back | Right ankle | Left ankle | Right Achilles | Right shin | Not Applicable |
| | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean |
| Right Hip External Rotation (Active) | 47.0 | 46.0 | 55.0 | 48.5 | 45.0 | 37.0 | 43.0 | 40.0 | 68.0 | 46.3 |
| Left Hip External Rotation (Active) | 39.0 | 38.0 | 41.0 | 41.5 | 42.8 | 30.0 | 33.0 | 46.0 | 52.0 | 44.3 |
| Right Hip External Rotation (Passive) | 53.0 | 49.0 | 52.0 | 54.5 | 49.3 | 41.0 | 42.0 | 46.0 | 70.0 | 52.0 |
| Left Hip | 35.0 | 46.0 | 42.0 | 43.0 | 48.0 | 33.0 | 34.0 | 50.0 | 60.0 | 49.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| External Rotation (Passive) | | | | | | | | | | |
| Right Q-Angle | 16.0 | 12.0 | 16.0 | 13.0 | 11.3 | 16.0 | 12.0 | 8.0 | 18.0 | 13.9 |
| Left Q-Angle | 17.0 | 12.0 | 10.0 | 11.0 | 12.3 | 10.0 | 8.0 | 7.0 | 11.0 | 13.4 |
| Right Femoral Torsion Angle | 8.0 | 12.0 | 11.0 | 9.5 | 10.8 | 10.0 | 8.0 | 8.0 | 22.0 | 11.0 |
| Left Femoral Torsion Angle | 6.0 | 12.0 | 12.0 | 10.0 | 11.0 | 8.0 | 7.0 | 10.0 | 15.0 | 11.5 |
| Right Ankle Plantarflexion (WB) | 73.0 | 71.0 | 53.0 | 66.0 | 66.8 | 61.0 | 63.0 | 67.0 | 71.0 | 68.9 |
| Left Ankle Plantarflexion (WB) | 77.0 | 75.0 | 72.0 | 69.0 | 71.3 | 78.0 | 61.0 | 67.0 | 82.0 | 73.1 |
| Right Ankle Plantarflexion (NWB) | 78.0 | 90.0 | 60.0 | 72.5 | 78.5 | 77.0 | 70.0 | 87.0 | 77.0 | 77.3 |
| Biomechanical Measurement | Injury 1 | | | | | | | | | |
| | right knee | left knee | right hamstring | left hamstring | low back | Right ankle | Left ankle | Right Achilles | Right shin | Not Applicable |
| | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean |
| Left Ankle Plantarflexion (NWB) | 82.0 | 87.0 | 66.0 | 68.0 | 80.8 | 86.0 | 57.0 | 76.0 | 75.0 | 76.4 |
| Right Ankle Dorsiflexion (WB) | 26.0 | 19.0 | 28.0 | 29.0 | 25.5 | 24.0 | 22.0 | 40.0 | 30.0 | 32.6 |
| Left Ankle Dorsiflexion (WB) | 28.0 | 19.0 | 28.0 | 28.5 | 26.8 | 19.0 | 29.0 | 40.0 | 33.0 | 33.8 |
| Right Ankle Dorsiflexion (NWB) | 18.0 | 2.0 | 9.0 | 8.0 | 5.8 | 4.0 | 8.0 | 12.0 | 6.0 | 10.4 |
| Left Ankle Dorsiflexion (NWB) | 14.0 | 2.0 | 9.0 | 6.0 | 5.8 | 3.0 | 11.0 | 13.0 | 5.0 | 9.6 |
| Functional Turnout | 136.0 | 146.0 | 142.0 | 150.5 | 141.5 | 113.0 | 128.0 | 116.0 | 132.0 | 143.1 |
| Compensated Turnout | 50.0 | 62.0 | 46.0 | 60.5 | 54.0 | 46.0 | 52.0 | 30.0 | 12.0 | 52.6 |

Statistical comparisons were not possible due to the low number of injuries in most groups.

4.6.2.2 Biomechanical Measurements and Location of Worst Current Injury

**Table 4.11 Biomechanical Measurements and Location of Worst Current Injury**

| Biomechanical Measurement | Injury 1 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Left toe/ foot | low back | Upper back | Right ankle | Left ankle | Right Achilles | N/A – not injured |
| | Mean | Mean | Mean | Mean | Mean | Mean | Mean |
| Right Hip External Rotation (Active) | 47.0 | 43.7 | 49.0 | 37.0 | 43.0 | 55.0 | 47.8 |
| Left Hip External Rotation (Active) | 45.0 | 41.7 | 46.0 | 30.0 | 33.0 | 41.0 | 43.6 |
| Biomechanical Measurements | Injury 1 | | | | | | |
| | Left toe/ foot | low back | Upper back | Right ankle | Left ankle | Right Achilles | N/A – not injured |
| | Mean | Mean | Mean | Mean | Mean | Mean | Mean |
| Right Hip External Rotation (Passive) | 48.0 | 48.7 | 51.0 | 41.0 | 42.0 | 52.0 | 53.5 |
| Left Hip External Rotation (Passive) | 41.0 | 46.0 | 54.0 | 33.0 | 34.0 | 42.0 | 48.8 |
| Right Q-Angle | 11.0 | 11.3 | 11.0 | 16.0 | 12.0 | 16.0 | 13.8 |
| Left Q-Angle | 9.0 | 12.0 | 13.0 | 10.0 | 8.0 | 10.0 | 12.8 |
| Right Femoral Torsion Angle | 8.0 | 11.3 | 9.0 | 10.0 | 8.0 | 11.0 | 11.5 |
| Left Femoral Torsion Angle | 8.0 | 11.0 | 11.0 | 8.0 | 7.0 | 12.0 | 11.3 |
| Right Ankle Plantarflexion (WB) | 74.0 | 69.0 | 60.0 | 61.0 | 63.0 | 53.0 | 68.5 |
| Left Ankle Plantarflexion (WB) | 79.0 | 72.0 | 69.0 | 78.0 | 61.0 | 72.0 | 72.7 |
| Right Ankle Plantarflexion (NWB) | 78.0 | 80.0 | 74.0 | 77.0 | 70.0 | 60.0 | 78.2 |
| Left Ankle Plantarflexion (NWB) | 76.0 | 79.3 | 85.0 | 86.0 | 57.0 | 66.0 | 76.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Right Ankle Dorsiflexion (WB) | 24.0 | 22.0 | 36.0 | 24.0 | 22.0 | 28.0 | 31.5 |
| Left Ankle Dorsiflexion (WB) | 27.0 | 23.3 | 37.0 | 19.0 | 29.0 | 28.0 | 32.3 |
| Right Ankle Dorsiflexion (NWB) | 13.0 | 5.3 | 7.0 | 4.0 | 8.0 | 9.0 | 9.5 |
| Left Ankle Dorsiflexion (NWB) | 10.0 | 6.0 | 5.0 | 3.0 | 11.0 | 9.0 | 8.7 |
| Functional Turnout | 126.0 | 137.0 | 155.0 | 113.0 | 128.0 | 142.0 | 142.3 |
| Compensated Turnout | 34.0 | 52.0 | 60.0 | 46.0 | 52.0 | 46.0 | 50.9 |

Statistical comparisons were not possible due to the low number of injuries in most groups.

### 4.6.3 Biomechanical Measurements and Onset

#### 4.6.3.1 Biomechanical Measurements and Onset of Worst Previous Injury

**Table 4.12 Biomechanical Measurements and Onset of Worst Previous Injury**

| Biomechanical Measurement | Injury 1 | | | *P* value (for comparison between over time and single event) |
|---|---|---|---|---|
| | over time | single event | N/A | |
| | Mean | Mean | Mean | |
| Right Hip External Rotation (Active) | 45.6 | 49.0 | 46.3 | 0.547 |
| Left Hip External Rotation (Active) | 40.9 | 41.2 | 44.3 | 0.953 |
| Right Hip External Rotation (Passive) | 49.3 | 52.3 | 52.0 | 0.503 |
| Left Hip External Rotation (Passive) | 45.0 | 43.8 | 49.9 | 0.844 |
| Right Q-Angle | 12.6 | 13.5 | 13.9 | 0.607 |
| Left Q-Angle | 10.3 | 12.3 | 13.4 | 0.175 |
| Right Femoral Torsion Angle | 11.7 | 9.8 | 11.0 | 0.436 |
| Left Femoral Torsion Angle | 10.4 | 10.2 | 11.5 | 0.890 |
| Right Ankle Plantarflexion (WB) | 67.0 | 64.8 | 68.9 | 0.606 |

| | | | | |
|---|---|---|---|---|
| Left Ankle Plantarflexion (WB) | 72.0 | 71.8 | 73.1 | 0.967 |
| Right Ankle Plantarflexion (NWB) | 78.7 | 74.5 | 77.3 | 0.380 |
| Left Ankle Plantarflexion (NWB) | 76.0 | 76.0 | 76.4 | 1.000 |
| Right Ankle Dorsiflexion (WB) | 26.0 | 27.8 | 32.6 | 0.628 |
| Left Ankle Dorsiflexion (WB) | 27.3 | 28.2 | 33.8 | 0.829 |
| Right Ankle Dorsiflexion (NWB) | 6.6 | 8.7 | 10.4 | 0.388 |
| Left Ankle Dorsiflexion (NWB) | 7.1 | 7.0 | 9.6 | 0.951 |
| Functional Turnout | 128.6 | 146.7 | 143.1 | 0.026* |
| Compensated Turnout | 42.3 | 56.5 | 52.6 | 0.085 |

*A statistically significant ($p$=0.026) association was identified between functional turnout and the nature of onset of injury, where dancers with lower functional turnout were more likely to have developed their worst past injury over time and those with higher functional turnout were more likely to attribute the onset of their injury to a single event.

### 4.6.3.2 Biomechanical Measurements and Onset of Worst Current Injury

**Table 4.13 Biomechanical Measurements and Onset of Worst Current Injury**

| Biomechanical Measurement | Injury 1 | | | |
|---|---|---|---|---|
| | Over time | Single event | N/A | |
| | Mean | Mean | Mean | P value (for comparison between over time and single event) |
| Right Hip External Rotation (Active) | 45.6 | 49.0 | 46.3 | 0.821 |
| Left Hip External Rotation (Active) | 40.9 | 41.2 | 44.3 | 0.608 |
| Right Hip External Rotation Passive) | 49.3 | 52.3 | 52.0 | 0.923 |
| Left Hip External Rotation (Passive) | 45.0 | 43.8 | 49.9 | 0.863 |
| Right Q-Angle | 12.6 | 13.5 | 13.9 | 0.573 |
| Left Q-Angle | 10.3 | 12.3 | 13.4 | 0.449 |

| | | | | |
|---|---|---|---|---|
| Right Femoral Torsion Angle | 11.7 | 9.8 | 11.0 | 0.386 |
| Left Femoral Torsion Angle | 10.4 | 10.2 | 11.5 | 0.500 |
| Right Ankle Plantarflexion (WB) | 67.0 | 64.8 | 68.9 | 0.294 |
| Left Ankle Plantarflexion (WB) | 72.0 | 71.8 | 73.1 | 0.353 |
| Right Ankle Plantarflexion (NWB) | 78.7 | 74.5 | 77.3 | 0.714 |
| Left Ankle Plantarflexion (NWB) | 76.0 | 76.0 | 76.4 | 1.00 |
| Right Ankle Dorsiflexion (WB) | 26.0 | 27.8 | 32.6 | 0.862 |
| Left Ankle Dorsiflexion (WB) | 27.3 | 28.2 | 33.8 | 0.912 |
| Right Ankle Dorsiflexion (NWB) | 6.6 | 8.7 | 10.4 | 0.034* |
| Left Ankle Dorsiflexion (NWB) | 7.1 | 7.0 | 9.6 | 0.377 |
| Functional Turnout | 128.6 | 146.7 | 143.1 | 0.618 |
| Compensated Turnout | 42.3 | 56.5 | 52.6 | 0.027* |

*Right ankle dorsiflexion and 'compensated turnout' were significantly lower in participants whose onset of injury was over time compared to a single event. It must be noted that there was only one case where the onset of injury was a single event.

4.6.3.3 Discussion of Biomechanical Measurements and Onset of Injury

Right ankle dorsiflexion was significantly lower in the participants of this study whose onset of their worst current injury was over time compared to a single event. This may suggest that, either decreased dorsiflexion is a risk factor for the development of overuse injury, or that the development of an overuse injury may result in decreased ankle range of motion. Therefore, causality cannot be determined.

'Compensated turnout' was significantly lower in participants whose onset of their worst current injury was over time compared to a single event. In contrast, Coplan (2002) found significantly ($P$ = 0.006) higher 'compensated turnout' values in injured dancers compared to non-injured dancers.

A significant difference in the 'functional turnout' of the participants in this study was found between the worst previous injuries that occurred over time and those that occurred in a single event. 'Functional turnout' values were significantly lower in those whose onset of their worst previous injury was over time compared to a single event. This finding is similar to that of the findings in the study conducted by Negus *et al*. (2005), where decreased 'functional turnout' was found to be associated with the number and severity of non-traumatic injuries. This suggests an association between decreased 'functional turnout' and the development of overuse injuries. Either decreased 'functional turnout' is a risk

factor for the development of overuse injury, or overuse injury development predisposes ballet dancers to reduced 'functional turnout'. The causality cannot be determined.

### 4.6.4 Biomechanical Measurements and Severity

4.6.4.1 Biomechanical Measurements and Severity of Worst Previous Injury

**Table 4.14 Biomechanical Measurements and Severity of Worst Previous Injury**

| | | Injury 1 |
|---|---|---|
| Right Hip External Rotation (Active) | Pearson Correlation | -.038 |
| | Sig. (2-tailed) | .903 |
| | N | 13 |
| Left Hip External Rotation (Active) | Pearson Correlation | -.162 |
| | Sig. (2-tailed) | .598 |
| | N | 13 |
| Right Hip External Rotation (Passive) | Pearson Correlation | -.053 |
| | Sig. (2-tailed) | .863 |
| | N | 13 |
| Left Hip External Rotation (Passive) | Pearson Correlation | -0.033 |
| | Sig. (2-tailed) | 0.914 |
| | N | 13 |
| Right Q-Angle | Pearson Correlation | 0.193 |
| | Sig. (2-tailed) | 0.527 |
| | N | 13 |
| Left Q-Angle | Pearson Correlation | 0.447 |
| | Sig. (2-tailed) | 0.126 |
| | N | 13 |
| Right Femoral Torsion Angle | Pearson Correlation | 0.293 |
| | Sig. (2-tailed) | 0.331 |
| | N | 13 |
| Left Femoral Torsion Angle | Pearson Correlation | 0.327 |
| | Sig. (2-tailed) | 0.276 |
| | N | 13 |
| Right Ankle Plantarflexion (WB) | Pearson Correlation | 0.486 |
| | Sig. (2-tailed) | 0.092 |
| | N | 13 |
| Left Ankle Plantarflexion (WB) | Pearson Correlation | 0.508 |
| | Sig. (2-tailed) | 0.076 |
| | N | 13 |

| | | |
|---|---|---|
| Right Ankle Plantarflexion (NWB) | Pearson Correlation | 0.333 |
| | Sig. (2-tailed) | 0.265 |
| | N | 13 |
| Left Ankle Plantarflexion (NWB) | Pearson Correlation | 0.269 |
| | Sig. (2-tailed) | 0.374 |
| | N | 13 |
| Right Ankle Dorsiflexion (WB) | Pearson Correlation | -0.444 |
| | Sig. (2-tailed) | 0.128 |
| | N | 13 |
| Left Ankle Dorsiflexion (WB) | Pearson Correlation | -0.404 |
| | Sig. (2-tailed) | 0.171 |
| | N | 13 |
| Right Ankle Dorsiflexion (NWB) | Pearson Correlation | -0.296 |
| | Sig. (2-tailed) | 0.326 |
| | N | 13 |
| Left Ankle Dorsiflexion (NWB) | Pearson Correlation | -0.485 |
| | Sig. (2-tailed) | 0.093 |
| | N | 13 |
| Functional Turnout | Pearson Correlation | 0.233 |
| | Sig. (2-tailed) | 0.444 |
| | N | 13 |
| Compensated Turnout | Pearson Correlation | 0.350 |
| | Sig. (2-tailed) | 0.240 |
| | N | 13 |

There were no correlations between the biomechanical measurements and severity of the worst previous injuries. This is similar to the findings of Negus *et al*. (2005), who found no significant association between injury severity and 'turnout' measurements.

### 4.6.4.2 Biomechanical Measurements and Severity of Worst Current Injury

**Table 4.15 Biomechanical Measurements and Severity of Worst Present Injury**

| | | Injury 1 |
|---|---|---|
| Right Hip External Rotation (Active) | Pearson Correlation | -0.031 |
| | Sig. (2-tailed) | 0.941 |
| | N | 8 |
| Left Hip External Rotation (Active) | Pearson Correlation | 0.263 |
| | Sig. (2-tailed) | 0.529 |

| | | |
|---|---|---|
| | N | 8 |
| Right Hip External Rotation (Passive) | Pearson Correlation | 0.120 |
| | Sig. (2-tailed) | 0.776 |
| | N | 8 |
| Left Hip External Rotation (Passive) | Pearson Correlation | 0.317 |
| | Sig. (2-tailed) | 0.445 |
| | N | 8 |
| Right Q-Angle | Pearson Correlation | -0.455 |
| | Sig. (2-tailed) | 0.258 |
| | N | 8 |
| Left Q-Angle | Pearson Correlation | 0.395 |
| | Sig. (2-tailed) | 0.332 |
| | N | 8 |
| Right Femoral Torsion Angle | Pearson Correlation | 0.427 |
| | Sig. (2-tailed) | 0.292 |
| | N | 8 |
| Left Femoral Torsion Angle | Pearson Correlation | 0.434 |
| | Sig. (2-tailed) | 0.282 |
| | N | 8 |
| Right Ankle Plantarflexion (WB) | Pearson Correlation | 0.646 |
| | Sig. (2-tailed) | 0.083 |
| | N | 8 |
| Left Ankle Plantarflexion (WB) | Pearson Correlation | -0.043 |
| | Sig. (2-tailed) | 0.920 |
| | N | 8 |
| Right Ankle Plantarflexion (NWB) | Pearson Correlation | 0.521 |
| | Sig. (2-tailed) | 0.185 |
| | N | 8 |
| Left Ankle Plantarflexion (NWB) | Pearson Correlation | -0.068 |
| | Sig. (2-tailed) | 0.872 |
| | N | 8 |
| Right Ankle Dorsiflexion (WB) | Pearson Correlation | -0.458 |
| | Sig. (2-tailed) | 0.254 |
| | N | 8 |
| Left Ankle Dorsiflexion (WB) | Pearson Correlation | -0.138 |
| | Sig. (2-tailed) | 0.745 |
| | N | 8 |
| Right Ankle Dorsiflexion (NWB) | Pearson Correlation | -0.078 |
| | Sig. (2-tailed) | 0.855 |
| | N | 8 |
| Left Ankle Dorsiflexion (NWB) | Pearson Correlation | -0.026 |
| | Sig. (2-tailed) | 0.951 |

| | | |
|---|---|---|
| | N | 8 |
| Functional Turnout | Pearson Correlation | 0.331 |
| | Sig. (2-tailed) | 0.424 |
| | N | 8 |
| Compensated Turnout | Pearson Correlation | 0.391 |
| | Sig. (2-tailed) | 0.338 |
| | N | 8 |

No correlations were found between the biomechanical measurements and severity of the worst current injury. This is similar to the findings of Negus *et al*. (2005), who found no significant association between injury severity and 'turnout' measurements.

## 4.6.5 Biomechanical Measurements and Duration

### 4.6.5.1 Biomechanical Measurements and Duration of Worst Previous Injury

**Table 4.16 Biomechanical Measurements and Duration of Worst Previous Injury**

| Biomechanical Measurement | For how long did you suffer from injury 1? | | | | | | |
|---|---|---|---|---|---|---|---|
| | one month | 6 months | 10 months | 1 year | 1.5 years | 2 years | 7 years |
| | Mean | Mean | Mean | Mean | Mean | Mean | Mean |
| Right Hip External Rotation (Active) | 59.0 | 38.0 | 49.0 | 50.0 | 35.0 | 49.0 | 43.5 |
| Left Hip External Rotation (Active) | 51.0 | 32.0 | 46.0 | 46.5 | 27.0 | 39.8 | 42.5 |
| Right Hip External Rotation (Passive) | 59.0 | 50.0 | 51.0 | 52.0 | 45.0 | 50.2 | 49.5 |
| Left Hip External Rotation (Passive) | 52.0 | 34.0 | 54.0 | 52.0 | 33.0 | 43.2 | 42.5 |
| Right Q-Angle | 15.0 | 11.0 | 11.0 | 11.5 | 9.0 | 15.2 | 12.0 |
| Left Q-Angle | 11.0 | 11.0 | 13.0 | 10.5 | 13.0 | 10.6 | 12.0 |
| Right Femoral Torsion Angle | 13.0 | 6.0 | 9.0 | 11.0 | 9.0 | 13.2 | 8.0 |
| Left Femoral Torsion Angle | 14.0 | 6.0 | 11.0 | 11.0 | 8.0 | 11.4 | 8.0 |
| Right Ankle Plantarflexion (WB) | 63.0 | 69.0 | 60.0 | 68.0 | 61.0 | 65.8 | 70.0 |
| Left Ankle Plantarflexion (WB) | 66.0 | 72.0 | 69.0 | 70.0 | 68.0 | 75.2 | 72.0 |
| Right Ankle Plantarflexion (NWB) | 72.0 | 73.0 | 74.0 | 82.0 | 77.0 | 74.6 | 82.5 |
| Left Ankle Plantarflexion (NWB) | 67.0 | 69.0 | 85.0 | 80.0 | 81.0 | 73.6 | 79.0 |
| Right Ankle Dorsiflexion (WB) | 31.0 | 27.0 | 36.0 | 22.5 | 23.0 | 24.2 | 33.0 |
| Left Ankle Dorsiflexion (WB) | 29.0 | 28.0 | 37.0 | 24.0 | 25.0 | 25.0 | 34.0 |
| Right Ankle Dorsiflexion (NWB) | 7.0 | 9.0 | 7.0 | 5.0 | 3.0 | 6.4 | 15.0 |
| Left Ankle Dorsiflexion (NWB) | 5.0 | 7.0 | 5.0 | 4.5 | 9.0 | 6.0 | 13.5 |
| Functional Turnout | 159.0 | 142.0 | 155.0 | 150.0 | 116.0 | 131.2 | 126.0 |
| Compensated Turnout | 49.0 | 72.0 | 60.0 | 54.0 | 54.0 | 42.4 | 40.0 |

No statistical comparisons were done due to most categories only having one case of injury.

4.6.5.2 Biomechanical Measurements and Duration of Worst Current Injury

**Table 4.17 Biomechanical Measurements and Duration of Worst Current Injury**

| Biomechanical Measurement | For how long did you suffer from injury 1 | | | | | |
|---|---|---|---|---|---|---|
| | 4 months | 1 year | 1.5 years | 2 years | 2.5 years | 5 years |
| | Mean | Mean | Mean | Mean | Mean | Mean |
| Right Hip External Rotation (Active) | 55.0 | 54.0 | 35.0 | 40.7 | 49.0 | 47.0 |
| Left Hip External Rotation (Active) | 41.0 | 55.0 | 27.0 | 35.3 | 46.0 | 45.0 |
| Right Hip External Rotation (Passive) | 52.0 | 55.0 | 45.0 | 43.0 | 51.0 | 48.0 |
| Left Hip External Rotation (Passive) | 42.0 | 58.0 | 33.0 | 38.0 | 54.0 | 41.0 |
| Right Q-Angle | 16.0 | 11.0 | 9.0 | 14.0 | 11.0 | 11.0 |
| Left Q-Angle | 10.0 | 9.0 | 13.0 | 10.7 | 13.0 | 9.0 |
| Right Femoral Torsion Angle | 11.0 | 10.0 | 9.0 | 11.0 | 9.0 | 8.0 |
| Left Femoral Torsion Angle | 12.0 | 10.0 | 8.0 | 10.0 | 11.0 | 8.0 |
| Right Ankle Plantarflexion (WB) | 53.0 | 65.0 | 61.0 | 68.3 | 60.0 | 74.0 |
| Left Ankle Plantarflexion (WB) | 72.0 | 65.0 | 68.0 | 74.0 | 69.0 | 79.0 |
| Right Ankle Plantarflexion (NWB) | 60.0 | 74.0 | 77.0 | 78.7 | 74.0 | 78.0 |
| Left Ankle Plantarflexion (NWB) | 66.0 | 73.0 | 81.0 | 75.7 | 85.0 | 76.0 |
| Right Ankle Dorsiflexion (WB) | 28.0 | 26.0 | 23.0 | 21.0 | 36.0 | 24.0 |
| Left Ankle Dorsiflexion (WB) | 28.0 | 29.0 | 25.0 | 21.3 | 37.0 | 27.0 |
| Right Ankle Dorsiflexion (NWB) | 9.0 | 8.0 | 3.0 | 5.7 | 7.0 | 13.0 |
| Left Ankle Dorsiflexion (NWB) | 9.0 | 7.0 | 9.0 | 5.3 | 5.0 | 10.0 |
| Functional Turnout | 142.0 | 154.0 | 116.0 | 127.3 | 155.0 | 126.0 |
| Compensated Turnout | 46.0 | 46.0 | 54.0 | 51.3 | 60.0 | 34.0 |

Statistical comparisons were not done due to only one case in most of the categories.

## 4.6.6 Biomechanical Measurements and the Effect of Injuries on Dancing

### 4.6.6.1 Biomechanical Measurements and the Effect of Worst Previous Injuries on Dancing

**Table 4.18 Effect of Worst Previous Ballet-Related Injuries on Dancing according to Whether the Injuries Were Stopping the Participant From Dancing**

| Biomechanical Measurement | Did Injury 1 stop you from dancing? | | | *P* value |
|---|---|---|---|---|
| | Yes, totally | Yes, had to modify classes | No | |
| | Mean | Mean | Mean | |
| Right Hip External Rotation (Active) | 47.8 | 45.0 | 53.0 | 0.575 |
| Left Hip External Rotation (Active) | 41.4 | 40.5 | 45.7 | 0.724 |
| Right Hip External Rotation (Passive) | 50.2 | 49.3 | 55.3 | 0.608 |
| Left Hip External Rotation (Passive) | 44.8 | 42.5 | 50.3 | 0.611 |
| Right Q-Angle | 13.8 | 11.5 | 15.0 | 0.288 |
| Left Q-Angle | 13.2 | 9.3 | 10.0 | 0.050* |
| Right Femoral Torsion Angle | 11.0 | 8.8 | 14.0 | 0.297 |
| Left Femoral Torsion Angle | 11.2 | 9.3 | 11.0 | 0.685 |
| Right Ankle Plantarflexion (WB) | 67.6 | 65.5 | 65.7 | 0.910 |
| Left Ankle Plantarflexion (WB) | 75.2 | 66.5 | 75.0 | 0.121 |
| Right Ankle Plantarflexion (NWB) | 78.2 | 75.5 | 76.0 | 0.902 |
| Left Ankle Plantarflexion (NWB) | 80.8 | 67.3 | 78.0 | 0.079 |
| Right Ankle Dorsiflexion (WB) | 25.2 | 30.0 | 26.7 | 0.593 |
| Left Ankle Dorsiflexion (WB) | 25.6 | 31.5 | 27.0 | 0.496 |
| Right Ankle Dorsiflexion (NWB) | 8.2 | 9.0 | 6.0 | 0.663 |
| Left Ankle Dorsiflexion (NWB) | 6.4 | 9.0 | 5.0 | 0.450 |
| Functional Turnout | 144.0 | 136.3 | 133.0 | 0.585 |
| Compensated Turnout | 54.8 | 50.8 | 34.7 | 0.199 |

There was a borderline significant difference between the three categories for left Q-angle, where the left Q-angle was highest in those dancers whose injuries totally prevented them from dancing and lowest in those dancers whose injuries caused them to modify their classes. However, the left and right Q-angle measurement means were lower than the normal range.

4.6.6.2 Biomechanical Measurements and the Effect of Worst Current Injuries on Dancing

**Table 4.19 Effect of Worst Current Ballet-Related Injuries on Dancing according to Whether the Injuries Were Stopping the Participant From Dancing**

| Biomechanical Measurement | Did injury 1 stop you from dancing? | |
|---|---|---|
| | Yes, had to modify classes | No |
| | Mean | Mean |
| Right Hip External Rotation (Active) | 47.0 | 45.0 |
| Left Hip External Rotation (Active) | 45.0 | 39.3 |
| Right Hip External Rotation (Passive) | 48.0 | 47.4 |
| Left Hip External Rotation (Passive) | 41.0 | 43.0 |
| Right Q-Angle | 11.0 | 12.7 |
| Left Q-Angle | 9.0 | 11.0 |
| Right Femoral Torsion Angle | 8.0 | 10.3 |
| Left Femoral Torsion Angle | 8.0 | 10.1 |
| Right Ankle Plantarflexion (WB) | 74.0 | 63.4 |
| Left Ankle Plantarflexion (WB) | 79.0 | 70.9 |
| Right Ankle Plantarflexion (NWB) | 78.0 | 74.4 |
| Left Ankle Plantarflexion (NWB) | 76.0 | 76.0 |
| Right Ankle Dorsiflexion (WB) | 24.0 | 25.1 |
| Left Ankle Dorsiflexion (WB) | 27.0 | 26.1 |
| Right Ankle Dorsiflexion (NWB) | 13.0 | 6.3 |
| Left Ankle Dorsiflexion (NWB) | 10.0 | 6.6 |
| Functional Turnout | 126.0 | 135.6 |
| Compensated Turnout | 34.0 | 51.4 |

Statistical comparisons were not done due to only one case in one of the categories.

## 4.7 CONCLUSION

Statistical comparisons were not able to be carried out in many instances during the statistical analysis of the data due to there being inadequate numbers of cases. However, several significant comparisons and associations have been made that may contribute significantly to the outcome of the study.

# CHAPTER FIVE

# CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

## 5.1 CONCLUSIONS

This study showed comparable results to similar studies in terms of period prevalence of injury, frequency of injury, location of injury and onset of injury. It showed a 62% period prevalence of injury, with dancers sustaining a median of two injuries. The most common locations for injury were the low back and hamstring; and the majority of injuries occurred over time.

Biomechanical measurement values for bilateral ankle plantarflexion (weight-bearing and non weight-bearing), bilateral ankle dorsiflexion (weight-bearing) and 'functional turnout' were found to be higher than those of similar studies. Most biomechanical measurement values were lower than normal in injured dancers, which agreed with other similar studies.

The results of this study suggest that there is a considerable association between certain lower limb biomechanical measurements and ballet-related injury. This is apparent in that the results showed a significant association between musculoskeletal ballet-related injury and reduced weight-bearing ankle dorsiflexion; between injuries that occurred over time (overuse injuries) and decreased 'functional turnout'; as well as between overuse injuries and decreased non weight-bearing ankle dorsiflexion.

In conclusion, the findings of this study may help provide empirical information to support anecdotal suggestions of associations between biomechanical measurements and ballet-related injury. The results of this study suggest ankle plantarflexion and 'functional turnout' as risk factors for musculoskeletal ballet-related injury. These findings may assist in identifying these risk factors in ballet dancers.

## 5.2 LIMITATIONS

The study was limited in that findings only suggested associations between biomechanical measurements and injury; and not causality. The study was also limited to white, female dancers and only those who were willing to participate. A limited number of dancers were

available to participate in the study due to the age criteria of between 18 and 25 years. Also, the tool used to quantify the severity of injuries was subjective, which may have caused an inaccuracy in the measurement of injury severities.

## 5.3 RECOMMENDATIONS

### 5.3.1 Methodological Recommendations

- Future studies should make use of measurement tools that are more reliable than the universal goniometer to ensure more accurate measurements.

- It is recommended that dancers from the ages of 16 years to 25 years should be included in a future study, as this would include many more intermediate and advanced dancers in the study, as most amateur ballet dancers are advanced by the age of 18.

- Future studies should include male amateur ballet dancers, as this group is rarely studied and injury risk factors may vary due to the different roles of the male dancer compared to that of the female dancer.

- It is recommended that dancers of all races be included in a future study so as to compare results between the different race groups, which differ in skeletal development.

### 5.3.2 Recommendations for Future Studies

- The findings of this study should be investigated further to contribute toward the prevention of ballet-related injury.

### 5.3.3 Recommendations for Ballet Teachers

- It is recommended that ballet teachers are aware of variations in the body structures of ballet dancers, and that injury may be prevented through the identification of biomechanical risk factors such as ankle dorsiflexion and ‘functional turnout’ ranges and through not pushing dancers beyond their natural capabilities.

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**APPENDIX A1**
**LETTER OF INFORMATION & CONSENT – EXPERT GROUP**

Dear participant,
Welcome to the expert group of my study. Thank you for your interest.

## Title of the Research Study:

An investigation into associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.

**Principal Investigator/ Researcher:** Kate Allison (B. Tech: Chiropractic)

**Co-Investigator/ Supervisor:** Dr Anthony van der Meulen (M. Tech: Chiropractic)

**Brief Introduction and Purpose of the Study:**
Musculoskeletal injury is common in ballet dancers. Injury can cause debilitation in the daily life of a dancer and prevent her from training and performing to her best potential or at all. It has been said that certain variations in body structure may contribute towards causing ballet injury. Therefore this study aims to investigate associations between musculoskeletal injury and selected biomechanical measurements in ballet dancers.

The objectives of the study are:

1. To determine the prevalence and characteristics (location, onset, frequency and severity) of injury in the population
2. To determine selected lower limb biomechanical measurements in the population
3. To determine any associations between selected lower limb biomechanical measurements and the characteristics of injury in the population

The purpose of this expert group is to provide face validity for the questionnaire that will be used in my study to gather information from ballet dancers regarding their past and previous ballet-related injuries.

**Outline of the Procedures:**
After reading and completing this Letter of Information and Consent (Appendix G) and the Confidentiality Statement and Code of Conduct (Appendix H), the expert group will commence. Each question will be read out one after the other and discussed. Every member will be allowed to have his or her say and each comment will be taken into consideration. The meeting will last approximately 1 and a half hours to 2 hours.

**Risks or Discomforts to the Participant:**
There will be no risks to the reputations of the expert group members, as all that is said within the meeting will stay confidential.

**Benefits:**
Those expert group members who are either ballet dancers or involved in the musculoskeletal health of ballet dancers or the teaching of ballet dancers will benefit from the contribution that the study might have towards the prevention and treatment of ballet-related injury in the future.

**Reason/s why the Participant May Be Withdrawn from the Study:**
Expert group members are free to withdraw from the study at any time.

**Remuneration**:
Expert group members will not receive remuneration for participating in this expert group.

**Costs of the Study:**
There will be no costs to the expert group members.

**Confidentiality:**
Confidentiality will be maintained by the expert group members signing a confidentiality statement.

**Research-related Injury:**
There will be no research-related injury, as only the verbal opinions of the expert group members are required.

**Person to Contact in the Event of Any Problems or Queries:**
Please contact the researcher (084 961 0076), my supervisor (031 2620958) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

**Consent**

**Statement of Agreement to Participate in the Research Expert Group:**

I hereby confirm that I have been informed by the researcher, _____ (name of researcher), about the nature, conduct, benefits and risks of this expert group - Research Ethics Clearance Number: _____,

I have also received, read and understood the above written information (Letter of Information) regarding the expert group.

In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.

I may, at any stage, without prejudice, withdraw my consent and participation in the expert group.

I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the expert group.

I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

| _____ | _____ | _____ | _____ |
|---|---|---|---|
| **Full Name of Participant** | **Date** | **Time** | **Signature / Right Thumbprint** |

I, _____ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above expert group.

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Researcher** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Witness (If applicable)** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Legal Guardian (If applicable)** | **Date** | **Signature** |

**APPENDIX A2**

**IMPORTANT NOTICE: This form is to be read and filled in by every member participating in the expert group, before the expert group meeting convenes.**

**CONFIDENTIALITY STATEMENT AND CODE OF CONDUCT: EXPERT GROUP**

1. All information contained in the research documents and any information discussed during the expert group meeting must be kept private and confidential. This is especially binding to any information that may identify any of the participants in the expert group.

2. None of the information shall be communicated to any other individual or organisation outside of this specific expert group as to the decisions of this expert group.

3. The information from this expert group will be made public in terms of a dissertation/thesis and/or journal publication, which will in no way identify any of the participants involved in this expert group.
4. The returned questionnaires will be coded and kept anonymous in the research process.

5. The expert group may be either voice or video recorded, as a transcript of the proceedings will need to be made. The data will be stored securely under password protection.

6. All data generated from this expert group (including the recording) will be kept for 15 years in a secure location at Durban University of Technology and thereafter will be destroyed.

Once this form has been read and agreed to, please fill in the appropriate information below and sign to acknowledge agreement.

**Please print in block letters:**

Expert Group Member: _____Signature:_____

Witness Name: _____Signature:_____

Researcher's Name: _____Signature:_____

Supervisor's /

Co-supervisor's Name: _____Signature:_____

## APPENDIX A3 - Pre Expert Group Questionnaire

**Interview** **Questionnaire Number: _____**

**An investigation into association between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.**

**Section 1: Personal Information**

1. What is your age (in years)? _____ years

2. Which ethnic group do you belong to?

| Black | White | Coloured | Asian |
|---|---|---|---|
| 01 | 02 | 03 | 04 |

3. What is your height (in centimetres)? _____ cm

4. What is your weight (in kilograms)? _____ kg

**Section 2: Ballet History**

5. What level of ballet are you at?

| Intermediate | Advanced |
|---|---|
| 01 | 02 |

6. At what age did you start ballet? _____ years

7. How many years experience do you have in ballet? _____ years

8. Since you started ballet, how consistently have you danced?

| Very consistently | Consistently | Irregularly | Very Irregularly |
|---|---|---|---|
| 01 | 02 | 03 | 04 |

9. At present, how many ballet classes do you dance per week?

| 7 or more | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| 01 | 02 | 03 | 04 | 05 | 06 | 07 |

10. At present, how many hours do you dance per week?

| More than 10 hrs | 8 - 10 hrs | 5 - 7 hrs | 2 - 4 hrs |
|---|---|---|---|
| 01 | 02 | 03 | 04 |

**Section 3: Past Ballet-Related Injuries**

11. Have you sustained an injury from ballet dancing in the last 2 years?

| Yes | No |
|---|---|
| 01 | 02 |

12. How often have you sustained injuries from ballet in the last 2 years?

| 1 injury per month | 1 injury per 3 months | 1 injury per 6 months | 1 injury per 12 months | No injuries |
|---|---|---|---|---|
| 01 | 02 | 03 | 04 | 05 |

13 - 23. How many times have you sustained a ballet-related injury in the following areas in the last 2 years?

| | 01 | 02 | 03 | 04 | 05 |
|---|---|---|---|---|---|
| 13. Toe/Foot | 4 times or more | 3 times | Twice | Once | Never |
| 14. Ankle | 4 times or more | 3 times | Twice | Once | Never |
| 15. Achilles tendon | 4 times or more | 3 times | Twice | Once | Never |
| 16. Shin | 4 times or more | 3 times | Twice | Once | Never |
| 17. Calf | 4 times or more | 3 times | Twice | Once | Never |
| 18. Knee | 4 times or more | 3 times | Twice | Once | Never |
| 19. Quadriceps (front of thigh) | 4 times or more | 3 times | Twice | Once | Never |
| 20. Hamstring (back of thigh) | 4 times or more | 3 times | Twice | Once | Never |
| 21. Groin | 4 times or more | 3 times | Twice | Once | Never |
| 22. Hip | 4 times or more | 3 times | Twice | Once | Never |
| 23. Low back | 4 times or more | 3 times | Twice | Once | Never |

24. In which areas from Questions 13 - 23 did you sustain your four worst ballet-related injuries?

| | 24.1. One | 24.2. Two | 24.3. Three | 24.4. Four |
|---|---|---|---|---|
| Toe/Foot | 01 | 01 | 01 | 01 |
| Ankle | 02 | 02 | 02 | 02 |
| Achilles tendon | 03 | 03 | 03 | 03 |
| Shin | 04 | 04 | 04 | 04 |
| Calf | 05 | 05 | 05 | 05 |
| Knee | 06 | 06 | 06 | 06 |
| Quadriceps (front of thigh) | 07 | 07 | 07 | 07 |
| Hamstring (back of thigh) | 08 | 08 | 08 | 08 |
| Groin | 09 | 09 | 09 | 09 |
| Hip | 10 | 10 | 10 | 10 |
| Low back | 11 | 11 | 11 | 11 |
| N/A | 12 | 12 | 12 | 12 |

25. How would you describe the onset of your worst injuries mentioned in Question 24?

| | Injury occurred over time | Injury occurred due to a single traumatic | N/A |
|---|---|---|---|

| | | event | |
|---|---|---|---|
| | 01 | 02 | 03 |
| 25.1. Injury One | | | |
| 25.2. Injury Two | | | |
| 25.3. Injury Three | | | |
| 25.4. Injury Four | | | |

26. What was the severity of your worst injuries mentioned in Question 24?

| | | Severe | Moderate | Mild | N/A |
|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 |
| 26.1. Injury One | | | | | |
| 26.2. Injury Two | | | | | |
| 26.3. Injury Three | | | | | |
| 26.4. Injury Four | | | | | |

27. For how long did you suffer from your worst injuries mentioned in Question 24?

| | | > 6 months | 3 - 6 months | 1 - 2 months | Less than 1 month | N/A |
|---|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 | 05 |
| 27.1. Injury One | | | | | | |
| 27.2. Injury Two | | | | | | |
| 27.3. Injury Three | | | | | | |
| 27.4. Injury Four | | | | | | |

28. Did your worst injuries mentioned in Question 24 stop you from dancing?

| | | Yes, totally | Yes, I had to modify my classes | No | N/A |
|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 |
| 28.1. Injury One | | | | | |
| 28.2. Injury Two | | | | | |
| 28.3. Injury Three | | | | | |
| 28.4. Injury Four | | | | | |

**Section 4: Present Ballet-Related Inuries**

29. Are you presently suffering from any injuries due to ballet?

| Yes | No |
|---|---|
| 01 | 02 |

30. Which parts of your body are most injured at the moment?

| | 30.1. One | 31.2. Two | 32.3. Three | 33.4. Four |
|---|---|---|---|---|
| Toe/Foot | 01 | 01 | 01 | 01 |
| Ankle | 02 | 02 | 02 | 02 |
| Achilles tendon | 03 | 03 | 03 | 03 |
| Shin | 04 | 04 | 04 | 04 |
| Calf | 05 | 05 | 05 | 05 |
| Knee | 06 | 06 | 06 | 06 |
| Quadriceps (front of thigh) | 07 | 07 | 07 | 07 |
| Hamstring (back of thigh) | 08 | 08 | 08 | 08 |
| Groin | 09 | 09 | 09 | 09 |
| Hip | 10 | 10 | 10 | 10 |
| Low back | 11 | 11 | 11 | 11 |
| N/A | 12 | 12 | 12 | 12 |

31. How would you describe the onset of the injuries mentioned in Question 30?

| | Injury occurred over time | Injury occurred due to a single traumatic event | N/A |
|---|---|---|---|
| | 01 | 02 | 03 |
| 31.1. Injury One | | | |
| 31.2. Injury Two | | | |
| 31.3. Injury Three | | | |
| 31.4. Injury Four | | | |

32. What is the severity of the injuries mentioned in Question 30?

| | | Severe | Moderate | Mild | N/A |
|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 |
| 32.1. Injury One | | | | | |
| 32.2. Injury Two | | | | | |
| 32.3. Injury Three | | | | | |
| 32.4. Injury Four | | | | | |

33. For how long have you suffered from the injuries mentioned in Question 30?

| | > 6 | 3 - 6 | 1 - 2 | Less | N/A |
|---|---|---|---|---|---|

| | | months | months | months | than 1 month | |
|---|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 | 05 |
| 33.1. Injury One | | | | | | |
| 33.2. Injury Two | | | | | | |
| 33.3. Injury Three | | | | | | |
| 33.4. Injury Four | | | | | | |

34. Are the injuries mentioned in Question 30 stopping you from dancing?

| | | Yes, totally | Yes, I had to modify my classes | No | N/A |
|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 |
| 34.1. Injury One | | | | | |
| 34.2. Injury Two | | | | | |
| 34.3. Injury Three | | | | | |
| 34.4. Injury Four | | | | | |

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I, _____, confirm that the answers to the above questions are correct and true. Signature: _____

**APPENDIX A4**
**Expert Group Transcript**

TRANSCRIPT OF THE VIDEO RECORDINGS
26 April 2012

So the first question is 'What is your age in years?' Quite simple.
Do you want it at the last birthday?
I want it how old they are on that day 'cos it's age in years, so…
So if they put 13.5, what does that mean to you?
Um, ya, well I'd want it at their last birthday.
Just makes life a little easier if they give the date of their birthday and you work it out backwards and then you can convert it to any unit or sub-unit that you want.
Okay. What-
Do you want the date of birth in years? 'Cos you've said, 'in years'. That should be a year.
Well that's fine if she's writing it down, but if they're writing down the initial little bit…
Ya, I'm writing everything down. The whole thing is an interview.
'Cos there will be some extraneous idiot who writes a funny answer.
Ok, so do we agree that that question is fine then?
Yes.

Okay, the next one. What ethnic group do you belong to? And then I say, 'Black, White, Coloured or Asian?'
You should have it in alphabetical order so that you don't show any preference.
Okay, cool. Ok. And what does everyone else think about that?
I don't know anything about ballet dancers, but if you have an Indian dancer would she like be under other?
Isn't that Asian?
Are you going to classify them all as Asian?
So you're putting Indian and Chinese and Japanese and all of those in one group?
Like, should you not have other with a line?
Do you have to have an option? Why don't you say, 'What ethnic group are you?' and they say, 'I'm black'. Do you write down black? Like, have the line rather than an option?
Or even an 'other' option?
I would prefer to go with the suggestion now 'cos you could code them into your stats later. So if there's 5 different options, you could code them later while you're entering info into your stats sheet.
Ok. So does everyone agree with that? The line?
A suggestion is check what stats SA has on their page-
Or check like SARS where they have an official list.
Okay, so…
Either or.
Okay, so we'll put a line for-
Ya, so must it be a line for other or for the whole thing?
*Agreement.*

Um, okay, next question. What is your height in centimetres?

What if they only know that they're 5 foot 2?
Can't I convert it and then put it in for them?
Okay, so instead writing 'in cm', just put your height and then write it down later if they don't know what it is.
So shall I take that sentence out?
Unless you have a calculator and you convert.
I have my calculator on my cellphone.
And people that don't know their height?
People that don't know their height.
What are you going to do?
Um, I can take a tape measure with me? And measure them against the wall?
Yeah, you'll have to pre-arrange that so that it's already on the wall before you measure.
Okay. So we all agree that I must just take the sentences-
I think it would be better to just measure everybody.
Oh, so I just measure everyone. Okay.
And please make sure you have a little stool to stand on if you're not tall enough.
*Laughter.*
Ok. 'What is your weight in kgs'.
You may want to take a scale.
I'll take a scale.
These are dancers! They'd know their weight!
Any other comments about that?

Okay, section 2. This is on their ballet history. First one. 'What level of ballet are you at?' I'm only recruiting intermediate and advanced dancers for this study, so those are the only two possible levels that they'll be at. Any questions about that?
Ok.
Do you make it clear in your letter of information that you're only looking for those levels?
In my letter of?
Information to the actual potential participant. You need to make sure that they know you're only looking for intermediate or advanced so that nobody else gets to the stage of completing this.
Ok, but when I phone them for the inclusion criteria, if they're not intermediate or advanced, they don't get…
Okay, so there is a set somewhere in the process.
Ya, in my telephone appendix, it asks.
Cool. So long as that's somewhere.
So is that a grade or for like, years of dancing?
Oh, no, so like, it will be Cecchetti and RAD intermediate and advanced, ya. It doesn't matter which level. Ya… Everyone fine with that?
*Agreement.*

Okay. Six. 'At what age did you start ballet?'
For normal ballet, what would your criteria be for starting? It's like starting a sport. Do you just do it informally or do you do it as a structured routine or at what point…
They would know 'cos you start lessons as such. So you would know, oh I started at 5.

Okay. So is everyone fine with that?
*Agreement.*

Question seven. 'How many years' experience do you have in ballet?'
Is it logical to assume that everybody who starts at age five will continue from that point forward or are there breaks in between that you would classify as not having experience?
Okay…
Otherwise, you could just work that out by taking their age minus when they started.
Ok. Well, it is experience in ballet, so if they didn't dance for five years, those five years aren't experience in ballet.
But the chances of an intermediate or advanced not having danced for a big chunk is unlikely.
Well that's another question that I'm asking.
Well, they probably would have danced continuously without no significant break.
Ya.
Maybe the question should be – since you started, have you danced continuously and then you use the age and the time they started as the number of years they've been doing it.
Okay. So…
Well, what about the next…
Oh, yes, 'cos that's actually question eight. So what do we do about that?
I don't know if it's actually necessary.
Not necessary. Shall we take it out?
Well, I'm also tryna make sure you don't spend two hours questioning your individuals.
Ya, I'm hoping to not spend longer than thirty minutes with them. Uh, so that's fine? Everyone fine with question seven being taken out?
*Agreement.*
Okay.

So question eight. Since you started ballet, how consistently have you danced? So I'll say – very consistently, consistently, irregularly or very irregularly.
What are your criteria for those terms?
Okay…
Here's a little suggestion. Perhaps ask them 'have you ever stopped for more than a month?' 'Cos if you ask experience, they won't remember. But if you ask 'have you ever stopped'… You know, they might stop in the holidays, but they might have been sick for six months.
So what do we think is a significant amount of time?
Could you not suggest that maybe you keep question seven and say for question eight – have you ever not danced for a significant amount of time, and if so how long? So, for how many years have you danced – perhaps you should keep that. If you asked me I'd say 'oh, from five 'til whenever, you know. Has there been a period of not dancing? If so, how long? 'Cos then you don't need the… 'Cos then eight you could say consistently. Alright though your consistently is different to my consistently. Okay, there will be another question of you know... How… What…
Ya.

So maybe you should say number seven – I would suggest ‘how many years have you been dancing for and then number eight – what did I say – has there been a period where you have not danced in a period of time. If so, how long?
Okay. What does everyone think about that?
Yes. ‘Cos she could say I’ve danced for twenty years and then oh yes, there was a six month period.
Like matric.
Yeah.
Another thing is there would be like two or three periods. There may not be only one.
Like leave three spaces or…
That’ll be very much the interviewer-guided.
Ya. So it’ll be like have you stopped for any…
Ya, you could use ‘have you stopped performances for three to six months.
Oh. Like number ten.
Like naught to three months, three to six…
Okay. So what scale do we agree on for that? What options should we give?
I would put like…
Because in ballet, if you stop for like one month to go on holiday, that’s not too bad. But if you stop for two years, that’s hectic.
But you must remember that most studios stop over Christmas.
Yes.
So that is about one month every year. So maybe two months.
So we’ll have for two months?
Or say naught to six months. You don’t want to- it’s not really significant to stop for three months on holiday.
Ya.
Naught to six months, six to..
Seven to one year.
Ya.
Seven to twelve months.
The only problem I have, and it’s with most of the ones we’ve given by category, is that if we’re looking to do a statistical regression analysis to determine trends of who is likely to have this injury… Uh, using groups may obscure that data. So if you actually have a number, the raw data, then you can spot those trends a lot better.
Ya.
So give more than one period?
So maybe three options.
Or a line and you write – ‘cos you are…
You can always categorize it later.
You can get the statistician to do that, but if you don’t have the data from the beginning, you don’t have the information.
Mixed discussion.
Okay. So that one we’ll have a line. Is everyone happy with that?
*Agreement.*
Ok.

And then question nine. At present, how many ballet classes do you dance per week.

Just give a raw score.
Hey?
A raw score. So just a number as opposed to a list of numbers.
If the majority said more than seven, you're not going to be able to draw any data from that question.
Ok.
It's not likely that they will, but…
Are we happy with that?
You don't have to have options.
It's not hard to thingy it later.
It actually makes it a lot easier later.

Number ten. At present, how many hours do you dance per week. So change that too..
Yes.
Everyone happy with that?
*Agreement.*

Okay. Section three. Have you sustained an injury from ballet dancing in the last two years. Yes or no.
Why two years?
Because it has been pointed out by the DRC that because they are between the age of eighteen and twenty-five, there body has been changing as they have been growing. So if we ask about their whole life, their body structure is obviously different at different stages of their life. So if they got an injury when they were younger, it could be due to their development.
I understand that. I'm just thinking that if somebody later on in ethics asks a question in corrections to say 'why have you chosen two years, you can't just say 'cos the DRC said so.
Okay, but I understand why. It's because of their development.
Okay. Make sure you note that in your methodology, 'cos you-
When I said my age group, I said why.
Okay, so everyone happy with question eleven?
Yes.

Number twelve. How often have you sustained injuries from ballet in the last two years. We've got one injury per three months, one injury per six months, per twelve months and then no injuries. No injuries could be not applicable.
What happens if I have two or three injuries in one month?
Then you should stop dancing. What's the matter with you! Haha.
Okay, any suggestions?
Well, if you're looking at two years and twenty four months, is it not better to ask them how many injuries they've had in two years, divided by twenty-four months?
With a ratio of time to injury.
Ok, so how does everyone feel about that? So I'm gonna ask them how many injuries they've sustained in the last two years.
'Cos then you also give the option for the in between ones so if they've had one injury in two months.
Ok. So that's just gonna have a line hey.

Ya. It'll be a line with like a blank, a hyphen and twenty-four months. So it's x injuries in twenty-four months.
Okay.
Everyone happy with that?
*Agreement.*
Ok.

Question thirteen to twenty-three. Um. How many times have you sustained a ballet-related injury in the following areas in the last two years. So I'll go through them, so I'll say question thirteen, how many times have you had an injury in your toe or foot. Then I'll go 'fourteen, how many times have you had an injury in your ankle' and then give each option.
I have no objection to that, but what about upper back or neck injuries?
So shall we include upper limb and extremity injuries? It's lower limb biomechanical measurements.
Not lower limb musculoskeletal injuries.
Ya. The thing is-
You can get those injuries…
Mybe an 'other' option.
You can. Ya, perhaps. She just said you can put 'other' and then I fill it in and they say how many times.
You might have to put a few 'other' lines.
Ya. Give a few lines. You can get thoracic…
'Cos the thing is, like, compression, um, stress fractures… Okay, so what do we think? Shall I put-
Perhaps just leave some blank spaces.
Okay, but, okay... So I'll change the numbers. So question 24.
Unless you put for 'other', twenty-four point one, twenty-four point two, twenty-four point three. Then you won't have to change every single number all the way then.
'Cos you can't change the question numbering otherwise your excel spreadsheet won't match.
Say that again?
Your spreadsheet has columns and each column will match with a question on your questionnaire. So you can't have different numbers of columns based on whether people respond otherwise your columns won't match and you'll be comparing apples to oranges.
'Cos I'll need to have not applicable, not applicable, not applicable. Okay.
Which mens for anything that relates to any of the subsequent questions, you're gonna have to have a space for other.
Okay. So everyone's happy with thirteen to twenty-three.

So, for question twenty-four. In which areas in question thirteen to twenty-three did you sustain your four worst ballet-related injuries? So why I put your four worst – I had your worst, but we don't only want to look at their worst injury. We want to look at a few or most of them.
Otherwise your profile will skew to only worst injuries, so it will automatically turn into a traumatic profile as opposed to a general profile, which you're not trying to get.

‘Cos some are mild, but they’re still there. So, if I add in the other at the bottom there… So what will happen is I’ll say your second one – so if they’ve only had one, the rest will be not applicable. Okay, so is everyone fine with that?
*Agreement.*
Okay.

Twenty-five. How would you describe the onset of your worst injuries mentioned in question twenty-four. So for injury one, I’ll ask them, ‘did it happen over time or did it occur due to a single traumatic event? Or if they didn’t have one…
Everyone fine with that?
*Agreement.*

Okay. Twenty-six. What was the severity of your injury mentioned in twenty-four. Same thing. I’ll ask them, ‘was it severe, moderate, mild…’
Will you explain to them the pain scale, ‘cos my mild could be your severe, so it depends on their pain threshold. So will you describe a generalized pain scale to them, or I dunno…
Uh, any suggestions?
So like between zero and ten, what is your pain?
Okay. So I’ll put in brackets below the severe, moderate, mild… I’ll put… What are the suggestions for the scale to be?
You can use the pain rating scale, so where ten is the most and you ask them to rate on that scale.
So like four to eight could be moderate etc…
Either that or you just generate a number on a template that you’ve laminated and they write four little lines and that’s ten centimetres long, so you just measure them out and say that one was so much and so much and you stick the values into the table instead of classifying them as mild, moderate, severe. And then you’ve got a grading scale that you can use to compare them, as opposed to a word.
Say that again?
So you say, on a scale of one to ten, one being the least mild, ten is whatever, rate yours, but show them one to four is mild, five to…
You don’t necessarily need that classification. It’s like you do in a clinical trial – you have a ten centimeter line on a page and you literally draw on a line. They mark a line for each and you mark it as one, two and three and then you keep that as a separate page for the patient and you translate that into the questionnaire.
Okay.
You take a ruler and a ten centimeter line and say that one was four centimetres, so it’s a four out of ten and that one was eight centimeters, so eight out of ten, etc…
Okay, so what goes on the sheet there under the question?
I would just take the mild, moderate, severe out and say ‘fill in the NRS score’…
Okay, so the wording on the question?
Ok, so I say to them, on a scale of naught to ten, naught is no pain-
If you have the picture in front of you then you say ok this is the 10cm line, naught is no pain, ten is the worst pain. For injury number one, please put a line where you think it was.
So that will be the question that I ask then.
Yes.
Ya, so you give it to them and say this is no pain, this is the worst pain…

Yes.
Ya.
And it'll be on here, hey?
You'd have to make it… you can make it  one line and make four different colour pens for the different injuries.
Oh yes. Ok. So everyone's happy with that?
*Agreement.*
Ok.

Twenty seven. For how long did you suffer from your worst injuries mentioned in twenty four? Then I've got 'more than six months, three to six months, one to two months, less than a month etc. Everyone fine with that?
You'll need to get the raw data again.
Is it? Ok. Can we move on?
*Agreement.*

Twenty eight. Did your worst injuries mentioned in twenty four stop you from dancing? And then I'll say 'for injury one, did it – you'll say yes, it totally stopped me from dancing or yes, I had to modify my classes or no, it didn't. Everyone fine with that?
*Agreement.*
Ok.

Section four. Almost the same questions, but it's just about their present injuries.
Well, I'd just make a mental note there at the end of the previous section – if there's no injury, thank you for your participation and get them to sign off at that point because the rest has become irrelevant.
Okay. I didn't even think of that! You gotta go through the whole thing going 'no' 'no' 'no'.
*Laughter.*

Ok. Twenty-nine. Are you presently suffering from any injuries due to ballet? Yes or no.
You wouldn't have to have the no. You actually wouldn't have to have the question, cos if they fill it in, the answer is yes.
Ok. So do I take that out completely or do we keep it in and have them sign after that question?
Entirely up to you.
So at least we're having an answer?
Ok, so keep it and move that to after.
Ok. Then do I keep this twenty-nine where it is, 'cos I can't really have it in past injuries – I'll still have a section called present ballet injuries.

Ok. Thirty. Which parts of your body are most injured at the moment? So this question is almost like the thirteen to twenty-three.
Would you not want to stick to – you've used 'areas' when you refer to different body parts.
Oh.
To try and keep it consistent.
Ok, so I'm gonna change 'parts' to 'areas'.

And add ‘other’
And to use the word ‘currently’ instead of at the moment.
Yes, I would agree with you there.
Well, if it’s presently an injury whether they have it at the moment or currently, they still have it so-
So I say which areas pf your body are most injured?
Ya. Because you’ve already asked them in the previous question ‘are you suffering with something’.
Oh.
If so, what are they?
Ok, so I take out at the moment.
Ok.
Right, everyone happy with that? And adding ‘other’ at the end.
You could actually delete the not applicable, ‘cos they wouldn’t be answering the section.
That’s true.
Ok.

Thirty-one. How would you describe the onset of the injuries mentioned in question thrity? So that’s the same as twenty-five.
Ya.
Okay, is everyone happy with that?
*Agreement.*

Ok. Thirty-two.
What is the severity of the injuries mentioned in question thirty? And we’ll do that scale.
Ya.

Ok. Thirty-three. For how long have you suffered from the injuries mentioned in question thirty? Um.
Same as twenty-seven.
Ok, so put a line there.

And the last question – are the injuries mentioned in question thirty stopping you from dancing? Same as twenty-eight. Everyone fine with that?
*Agreement.*
Okay. So that’s it. Are there any other comments?
Just in terms of the background, are you looking for specific causes for the injuries? Whether they’re nutritional or environmental or…
I don’t know how we’d be able to state the cause of it.
Well, you won’t be able to state the causality anyway, you can only generate the association between compression fractures in the thoracic spine and not so good nutrition, I dunno.
What is the main point? Because of ballet… What is the point of your research?
So it’s basically saying ‘you have less flexible knees and ankles and you have this injury, so it’s saying that association. You have less flexibility there and you have an injury.’
I’m just wondering in terms of… Your biomechanical measures kinda measure the relationship of different joints to one another or joint surfaces to one another kind

of… Um, whether or not any bony anomaly from a nutritional source or any other source may affect those biomechanical measures that we haven't actually accounted for in what we've asked here.
'Cos we can't necessarily say because you have those knees, you have this.'
Ya.
We only know that you have this problem.
Ya, that's what I'm asking – are there any factors that could influence the way…
Ya, like, if they didn't have enough – like if they're bow-legged and they had rickets because they didn't have… So if they didn't have a certain amount of vitamins when they were younger, which caused their bones not to develop properly, then they'd be bow-legged and that is a measurement that I'm taking. So shall we ask them, do they eat well –
Well, they're ballet dancers.
*Laughter.*
They eat so much!
Chocolate!
*Laughter.*
Do you perhaps need a history question to ask have they ever had a traumatic event like a car accident; have they had medically diagnosed-
They're excluded if they had any major accidents or surgery.
So that's been taken care of. What about diagnosed conditions that are nutritional?
Also congenital anomalies, they won't be included.
Alright. Nutritional?
I haven't said nutritional.
'Cos we might then want to ask a nutritional question historically – have they had a disorder diagnosed?
Ok. Do you think that should be there? Also in _____'s questionnaire, you did have a question on nutrition or diet.
Just so that if your statistician does run an analysis, they can control for that, so they can see if there's any possible confounding in your analysis with regards to that diagnosis they've given us.
Ok. So I'll add that.
Put it under personal history right up front or something.
Personal.
While we're talking about weight!
*Laughter.*
Okay, what about sports?
Ballet has to be eighty percent of their dancing.
That doesn't mean to say that tennis or squash or whatever doesn't form a part of their…
Ok. What do you think?
I'm just thinking if there are any other areas that you haven't covered.
Oh, the wording of the nutritional one – how should I word it?
Maybe just ask if they've had any medically diagnosed nutritional disorder or condition.
So I must leave a line and they'll write yes and what it is.
Well even if you write what it is, then the answer is yes.
Ok. Anything else?
What about non-nutritional medical conditions?

Like hypertension or…
Ok.
Any medically diagnosed conditions.

Can I just ask about the sports question? Because although they may not be sporty as in like gym, they may run, they may surf. I mean, look at you with your injury from running. So maybe other non-related injuries. Like _____ has shin splints, not from dancing but it affects her dancing.
Ok. So-
Maybe in your personal info, do you participate in any other activities or sports and then have you had any injuries specifically related to that.
What about injuries not related to dancing?
But is that relevant because you're only wanting to know about dancing?
Oh ya, 'cos if I'm asking them 'do you have ballet-related injuries, they're not gonna tell me about the non-ballet-related ones. 'Cos they don't need to.
But they might be dancing with their shin splints, but that could be because of running.
Yes, ok, so that is relevant, but only 'cos it's related to their ballet injury. So you might have a pre-existing injury that affects your dancing.
Like for me, I started running and I got shin splints. Now when I dance it hurts, but it's not from ballet, it's from running.
And it's only relevant to you because of your ballet. You don't need to know that somebody happened to be playing tennis and they broke their arm.
Oh yes…
It's just gonna give you information that you don't need.
Ya.
Then perhaps only the question about do they participate in any other sport.
And any of the injuries that occur that have an impact on their ballet.
Wait wait, say that again?
Okay, so what- any other injuries. What sports do they participate in and have they had injuries from those sports that have an impact on their ballet.
Okay.
Right. Anything else? Nothing else? Um, so we're done. Thank you so much everyone for doing this.

**APPENDIX B1**

**Principal's Letter of Information & Consent**

Dear Principal/ Owner,

Thank you for allowing me to use some of your time for my study,

**Title of the Research Study:**

Associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.

**Principal Investigator/ Researcher:** Kate Allison (B. Tech: Chiropractic)

**Co-Investigator/ Supervisor:** Dr Anthony van der Meulen (M. Tech: Chiropractic)

**Brief Introduction and Purpose of the Study:**
Musculoskeletal injury is common in ballet dancers. Injury can cause debilitation in the daily life of a dancer and prevent her from training and performing to her best potential or at all. It has been said that certain variations in body structure may contribute towards causing ballet injury. Therefore this study aims to investigate associations between musculoskeletal injury and selected biomechanical measurements in ballet dancers.

**Outline of the Procedures:**
On visiting your ballet studio, you will be required to sign this Principal's Letter of Information & Consent after receiving a full explanation of what the research involves. This letter serves to request your permission for the recruitment of research participants at your studio through the placing up of an advert in the form of a poster and through the researcher verbally informing your students of the study. It also serves to request your permission for the participation of your students in the study. After you have signed this form, you will be given an advertisement in the form of a poster to place up in your studio. The researcher will then verbally inform your senior students of the study. The names and contact details of any dancers who respond immediately will be collected. The

meeting at your studio will take no longer than 30 minutes, and it will be scheduled at a time so as not to interrupt your classes.
At a later stage, each participant will be required to answer a few questions, telephonically, in order to determine whether she is eligible to join the study. Once accepted, she will be required to attend one appointment at the DUT Chiropractic Clinic at a time that suits her. This appointment will be conducted in a private clinic room under the supervision of a qualified clinician. The participant will be required to sign an informed consent form after receiving a full explanation of what the research involves and she will have the opportunity to ask questions about the procedure. The researcher will then interview her and take certain physical measurements of her lower limbs, as well as her height and weight measurements. The participant will then be thanked for her time and will be free to leave. The interview and measurements will take approximately 30 minutes to complete, and your classes will not be interrupted, as the appointment will take place at the Chiropractic Day Clinic.

**Risks or Discomforts to the Participant:**
There will be no health risks. The biomechanical measurements may produce mild discomfort, but the participant may report discomfort to the researcher at any time.

**Benefits:**
This study will help health care practitioners to improve prevention and treatment protocols for ballet-related injury. It will also increase the knowledge base in the fields of dance medicine and musculoskeletal injury.

**Reason/s why the Participant May Be Withdrawn from the Study:**
Participants are free to withdraw from the study at any time.

**Remuneration**:
Participants will not receive remuneration for participating in this study.

**Costs of the Study:**
There will be no costs to the participants.

**Confidentiality:**
Confidentiality will be maintained, as the questionnaires & data collection will be anonymous.

**Research-related Injury:**
There will be no research-related injury, as participants will not be treated.

**Person to Contact in the Event of Any Problems or Queries:**
Please contact the researcher (084 961 0076), my supervisor (031 2620958) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

**Consent**

**Statement of Agreement for Studio to Participate in the Research Study:**

I hereby confirm that I have been informed by the researcher, Kate Allison, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,

I have also received, read and understood the above written information (Principal's Letter of Information) regarding the study.

I am aware that the results of the study, including personal details regarding my students' sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.

My students may, at any stage, without prejudice, withdraw consent and participation in the study.

I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to allow my students to participate in the study.

I understand that significant new findings developed during the course of this research which may relate to my students' participation will be made available to me.

| _____ | _____ | _____ | _____ |
|---|---|---|---|
| **Full Name of Principal** | **Date** | **Time** | **Signature / Right Thumbprint** |

I, _____ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Researcher** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Witness (If applicable)** | **Date** | **Signature** |

**APPENDIX B2**

Are you a

**Female Advanced or Intermediate ballet dancer**

between the ages of

**18 – 25?**

Research is currently being conducted at the Durban University of Technology

For more information, please contact

**Kate**

084 961 0076

## APPENDIX B3

## Telephonic Screening

| **Question:** | **Answer required for inclusion into pilot study:** |
|---|---|
| Are you willing to participate in a research study? | Yes |
| Are you willing to answer a few questions that would determine whether you are eligible for the study or not? | Yes |
| Are you female? | Yes |
| Are you over the age of 18? | Yes |
| Is ballet your main form of dance, making up at least 80% of your dance activity? | Yes |
| Are you either at the Intermediate or Advanced level in ballet? | Yes |
| Do you have a minimum of 2 years ballet experience? | Yes |
| Do you attend at least 2 hours of ballet per week? | Yes |
| Have you ever sustained any major non ballet-related injuries to any muscles or joints? | No |
| Have you ever had major non ballet-related surgery on any muscles or joints? | No |
| Are you an amateur, professional or paid ballet dancer? | Yes |

**APPENDIX B4**

**Participant Letter of Information**

Dear Participant,

Thank you for volunteering your time to take part in my study.

**Title of the Research Study:**

Associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.

**Principal Investigator/ Researcher:** Kate Allison (B. Tech: Chiropractic)

**Co-Investigator/ Supervisor:** Dr Anthony van der Meulen (M. Tech: Chiropractic)

**Brief Introduction and Purpose of the Study:**
Musculoskeletal injury is common in ballet dancers. Injury can cause debilitation in the daily life of a dancer and prevent her from training and performing to her best potential or at all. It has been said that certain variations in body structure may contribute towards causing ballet injury. Therefore, this study aims to investigate associations between musculoskeletal injury and selected biomechanical measurements in ballet dancers.

**Outline of the Procedures:**
You as the participant will be required to answer a few questions, telephonically, in order to determine whether you are eligible to join the study. Once accepted, you will then be required to attend one appointment at the DUT Chiropractic Day Clinic at a time that suits you. This appointment will be conducted in a private clinic room under the supervision of a qualified clinician. You will be required to sign an informed consent form after receiving a full explanation of what the research involves & you will have the opportunity to ask questions about the procedure. The researcher will then interview you & take certain physical measurements of your lower limbs. The interview & measurements will take approximately 30 minutes to complete. You will then be thanked for your time and will be free to leave.

**Risks or Discomforts to the Participant:**
There will be no health risks. The biomechanical measurements may produce mild discomfort, but you may report discomfort to the researcher at any time.

**Benefits:**
This study will help health care practitioners to improve prevention and treatment protocols for ballet-related injury. It will also increase the knowledge base in the fields of dance medicine and musculoskeletal injury.

**Reason/s why the Participant May Be Withdrawn from the Study:**
You are free to withdraw from the study at any time.

**Remuneration**:
You will not receive remuneration for participating in this study.

**Costs of the Study:**
You will incur travelling costs for the trip to the Chiropractic Clinic for your appointment.

**Confidentiality:**
Confidentiality will be maintained, as the questionnaires & data collection will be anonymous.

**Research-related Injury:**
There will be no research-related injury, as you as the participant will not be treated.

**Person to Contact in the Event of Any Problems or Queries:**
Please contact the researcher (084 961 0076), my supervisor (031 2620958) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

**Consent**

**Statement of Agreement to Participate in the Research Study:**
I hereby confirm that I have been informed by the researcher, _____ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,

I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.

I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.

I may, at any stage, without prejudice, withdraw my consent and participation in the study.

I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

| _____ | _____ | _____ | _____ |
|---|---|---|---|
| **Full Name of Participant** | **Date** | **Time** | **Signature / Right Thumbprint** |

I, _____ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Researcher** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Witness (If applicable)** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Legal Guardian (If applicable)** | **Date** | **Signature** |

## APPENDIX B5 - Post Expert Group Questionnaire

**Interview** **Questionnaire Number: _____**

**Association between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.**

**Section 1: Personal Information**

1. What is your age (in years)? _____ years

2. Which ethnic group do you belong to? _____

3. What is your height (in centimetres)? _____ cm

4. What is your weight (in kilograms)? _____ kg

5. Do you have any medically diagnosed health conditions?
   If so, please state the condition/s:
   _____

6. Do you have any medically diagnosed nutritional disorders?
   If so, please state the disorder/s:
   _____

7. Do you participate in any sports?
   If so, please state the sport/s: _____

8.1. Do you have any sport-related injuries that have an impact on your ballet?

| Yes | No |
|---|---|
| 01 | 02 |

8.2. If you answered yes to question 8.1., please state the location/s of the injury/ injuries:

_____

_____

**Section 2: Ballet History**

9. What level of ballet are you at?

| Intermediate | Advanced |
|---|---|
| 01 | 02 |

10. At what age did you start ballet? _____ years

11. How many years experience do you have in ballet? _____ years

12. Since you started ballet, have you ever stopped dancing for a length of time? Please state each length of time:

_____

13. At present, how many ballet classes do you attend per week? _____

14. At present, how many hours do you dance per week? _____

**Section 3: Past Ballet-Related Injuries**

15. Have you sustained an injury from ballet dancing in the last 2 years?

| Yes | No |
|---|---|
| 01 | 02 |

16. How many injuries have you sustained from ballet in the last 2 years?

_____ / 24 months

17 - 30. How many times have you sustained a ballet-related injury in the following areas in the last 2 years?

| | 01 | 02 | 03 | 04 | 05 |
|---|---|---|---|---|---|
| 17.1. Right Toe/ Foot | 4 times or more | 3 times | Twice | Once | Never |
| 17.2. Left Toe/Foot | 4 times or more | 3 times | Twice | Once | Never |
| 18.1. Right Ankle | 4 times or more | 3 times | Twice | Once | Never |
| 18.2. Left Ankle | 4 times or more | 3 times | Twice | Once | Never |
| 19.1. Right Achilles tendon | 4 times or more | 3 times | Twice | Once | Never |
| 19.2. Left Achilles tendon | 4 times or more | 3 times | Twice | Once | Never |
| 20.1. Right Shin | 4 times or more | 3 times | Twice | Once | Never |
| 20.2. Left Shin | 4 times or more | 3 times | Twice | Once | Never |
| 21.1. Right Calf | 4 times or more | 3 times | Twice | Once | Never |
| 21.2. Left Calf | 4 times or more | 3 times | Twice | Once | Never |
| 22.1. Right Knee | 4 times or more | 3 times | Twice | Once | Never |
| 22.2. Left Knee | 4 times or more | 3 times | Twice | Once | Never |
| 23.1. Right Quadriceps | 4 times or more | 3 times | Twice | Once | Never |
| 23.2. Left Quadriceps | 4 times or more | 3 times | Twice | Once | Never |
| 24.1. Right Hamstring | 4 times or more | 3 times | Twice | Once | Never |

| | | | | | |
|---|---|---|---|---|---|
| 24.2. Left Hamstring | 4 times or more | 3 times | Twice | Once | Never |
| 25.1. Right Groin | 4 times or more | 3 times | Twice | Once | Never |
| 25.2. Left Groin | 4 times or more | 3 times | Twice | Once | Never |
| 26.1. Right Hip | 4 times or more | 3 times | Twice | Once | Never |
| 26.2. Left Hip | 4 times or more | 3 times | Twice | Once | Never |
| 27. Low Back | 4 times or more | 3 times | Twice | Once | Never |
| 28. Other: | 4 times or more | 3 times | Twice | Once | Never |
| 29. Other: | 4 times or more | 3 times | Twice | Once | Never |
| 30. Other: | 4 times or more | 3 times | Twice | Once | Never |

31. In which areas from Questions 17 - 30 did you sustain your four worst ballet-related injuries?

| | 31.1. One | 31.2. Two | 31.3. Three | 31.4. Four |
|---|---|---|---|---|
| Right Toe/Foot | 01 | 01 | 01 | 01 |
| Left Toe/ Foot | 02 | 02 | 02 | 02 |
| Right Ankle | 03 | 03 | 03 | 03 |
| Left Ankle | 04 | 04 | 04 | 04 |
| Right Achilles tendon | 05 | 05 | 05 | 05 |
| Left Achilles tendon | 06 | 06 | 06 | 06 |
| Right Shin | 07 | 07 | 07 | 07 |
| Left Shin | 08 | 08 | 08 | 08 |
| Right Calf | 09 | 09 | 09 | 09 |
| Left Calf | 10 | 10 | 10 | 10 |
| Right Knee | 11 | 11 | 11 | 11 |
| Left Knee | 12 | 12 | 12 | 12 |
| Right Quadriceps | 13 | 13 | 13 | 13 |
| Left Quadriceps | 14 | 14 | 14 | 14 |
| Right Hamstring | 15 | 15 | 15 | 15 |
| Left Hamstring | 16 | 16 | 16 | 16 |
| Right Groin | 17 | 17 | 17 | 17 |
| Left Groin | 18 | 18 | 18 | 18 |
| Right Hip | 19 | 19 | 19 | 19 |
| Left Hip | 20 | 20 | 20 | 20 |
| Low back | 21 | 21 | 21 | 21 |
| Other: | | | | |
| Other: | | | | |
| Other: | | | | |
| N/A | | | | |

32. How would you describe the onset of your worst injuries mentioned in Question 31?

| | Injury occurred over time | Injury occurred due to a single traumatic event | N/A |
|---|---|---|---|
| | 01 | 02 | 03 |
| 32.1. Injury One | | | |
| 32.2. Injury Two | | | |
| 32.3. Injury Three | | | |
| 32.4. Injury Four | | | |

33. On a scale of 0 to 10, where 0 is least severe & 10 is the most severe, how would you rate the severity of each injury mentioned in Question 31? Please plot a mark for each injury on the line below and mark it with 1, 2, 3 or 4:

0 10

34. For how long did you suffer from your worst injuries mentioned in Question 31?

Injury 1: Injury 2:

Injury 3: Injury 4:

35. Did your worst injuries mentioned in Question 24 stop you from dancing?

| | | Yes, totally | Yes, I had to modify my classes | No | N/A |
|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 |
| 35.1. Injury One | | | | | |
| 35.2. Injury Two | | | | | |
| 35.3. Injury Three | | | | | |
| 35.4. Injury Four | | | | | |

**Section 4: Present Ballet-Related Inuries**

36. Are you presently suffering from any injuries due to ballet?

| Yes | No |
|---|---|
| 01 | 02 |

If you answered no to the above question (Question 36), you are not required to complete the rest of the interview. Thank you for your time.

I, _____, confirm that the answers to the above
questions are correct and true. Signature: _____

37. Which areas of your body are currently most injured?

| | 37.1. One | 37.2. Two | 37.3. Three | 37.4. Four |
|---|---|---|---|---|
| Right Toe/Foot | 01 | 01 | 01 | 01 |
| Left Toe/ Foot | 02 | 02 | 02 | 02 |
| Right Ankle | 03 | 03 | 03 | 03 |
| Left Ankle | 04 | 04 | 04 | 04 |
| Right Achilles tendon | 05 | 05 | 05 | 05 |
| Left Achilles tendon | 06 | 06 | 06 | 06 |
| Right Shin | 07 | 07 | 07 | 07 |
| Left Shin | 08 | 08 | 08 | 08 |
| Right Calf | 09 | 09 | 09 | 09 |
| Left Calf | 10 | 10 | 10 | 10 |
| Right Knee | 11 | 11 | 11 | 11 |
| Left Knee | 12 | 12 | 12 | 12 |
| Right Quadriceps | 13 | 13 | 13 | 13 |
| Left Quadriceps | 14 | 14 | 14 | 14 |
| Right Hamstring | 15 | 15 | 15 | 15 |
| Left Hamstring | 16 | 16 | 16 | 16 |
| Right Groin | 17 | 17 | 17 | 17 |
| Left Groin | 18 | 18 | 18 | 18 |
| Right Hip | 19 | 19 | 19 | 19 |
| Left Hip | 20 | 20 | 20 | 20 |
| Low back | 21 | 21 | 21 | 21 |
| Other: | | | | |
| Other: | | | | |
| Other: | | | | |
| N/A | | | | |

38. How would you describe the onset of your current injuries mentioned in Question 37?

| | | Injury occurred over time | Injury occurred due to a single traumatic event |
|---|---|---|---|
| | | 01 | 02 |
| 38.1. Injury One | | | |
| 38.2. Injury Two | | | |
| 38.3. Injury Three | | | |
| 38.4. Injury Four | | | |

39. On a scale of 0 to 10, where 0 is least severe & 10 is the most severe, how would you rate the severity of each of your current injuries mentioned in Question 37? Please plot a mark for each injury on the line below and mark it with 1, 2, 3 or 4:

0 10

40. For how long have you suffered from your current injuries mentioned in Question 37?

Injury 1: Injury 2:

Injury 3: Injury 4:

41. Are your current injuries mentioned in Question 37 stopping you from dancing?

| | | Yes, totally | Yes, I modify my classes | No |
|---|---|---|---|---|
| | | 01 | 02 | 03 |
| 41.1. Injury One | | | | |
| 41.2. Injury Two | | | | |
| 41.3. Injury Three | | | | |
| 41.4. Injury Four | | | | |

I, _____, confirm that the answers to the above

questions are correct and true. Signature: _____

## APPENDIX B6

**Lower Limb Biomechanical Measurement Data Sheet** **Participant Number: _____**

| Biomechanical Measurement | Normal | Measurement 1 | Measurement 2 | Measurement 3 | Average | High | Low | Normal |
|---|---|---|---|---|---|---|---|---|
| 1. Right Hip External Rotation (Active) | 40 - 60° | | | | | 01 | 02 | 03 |
| 2. Left Hip External Rotation (Active) | 40 - 60° | | | | | 01 | 02 | 03 |
| 3. Right Hip External Rotation (Passive) | 40 - 60° | | | | | 01 | 02 | 03 |
| 4. Left Hip External Rotation (Passive) | 40 - 60° | | | | | 01 | 02 | 03 |
| 5. Right Q-Angle | 18 - 22° | | | | | 01 | 02 | 03 |
| 6. Left Q-Angle | 18 - 22° | | | | | 01 | 02 | 03 |
| 7. Right Femoral Torsion Angle | 8 - 15° | | | | | 01 | 02 | 03 |
| 8. Left Femoral Torsion Angle | 8 - 15° | | | | | 01 | 02 | 03 |
| 9. Right Ankle Plantarflexion (WB) | 50° | | | | | 01 | 02 | 03 |
| 10. Left Ankle Plantarflexion (WB) | 50° | | | | | 01 | 02 | 03 |
| 11. Right Ankle Plantarflexion (NWB) | 50° | | | | | 01 | 02 | 03 |
| 12. Left Ankle Plantarflexion (NWB) | 50° | | | | | 01 | 02 | 03 |
| 13. Right Ankle Dorsiflexion (WB) | 20° | | | | | 01 | 02 | 03 |
| 14. Left Ankle Dorsiflexion (WB) | 20° | | | | | 01 | 02 | 03 |
| 15. Right Ankle Dorsiflexion (NWB) | 20° | | | | | 01 | 02 | 03 |
| 16. Left Ankle Dorsiflexion (NWB) | 20° | | | | | 01 | 02 | 03 |
| 17. Functional Turnout | 100 - 131° | | | | | 01 | 02 | 03 |
| 18. Compensated Turnout | 5 - 69° | | | | | 01 | 02 | 03 |
| 19. Pronation of foot (right) | <10mm | | | | | 01 | 02 | 03 |
| 20. Pronation of foot (left) | <10mm | | | | | 01 | 02 | 03 |
| 21. Knee Alignment: Genu Varum | <4cm between | | | | | 01 | 02 | 03 |
| 22. Knee Alignment: Genu Valgum | <9cm between | | | | | 01 | 02 | 03 |

*WB – Weight-Bearing *NWB – Non-Weight-Bearing

**APPENDIX C1**

**Principal's Letter of Information & Consent**

Dear Principal/ Owner,

Thank you for allowing me to use some of your time for my study,

**Title of the Research Study:**

Associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.

**Principal Investigator/ Researcher:** Kate Allison (B. Tech: Chiropractic)

**Co-Investigator/ Supervisor:** Dr Anthony van der Meulen (M. Tech: Chiropractic)

**Brief Introduction and Purpose of the Study:**
Musculoskeletal injury is common in ballet dancers. Injury can cause debilitation in the daily life of a dancer and prevent her from training and performing to her best potential or at all. It has been said that certain variations in body structure may contribute towards causing ballet injury. Therefore this study aims to investigate associations between musculoskeletal injury and selected biomechanical measurements in ballet dancers.

**Outline of the Procedures:**
On visiting your ballet studio, you will be required to sign this Principal's Letter of Information & Consent after receiving a full explanation of what the research involves. This letter serves to request your permission for the recruitment of research participants at your studio through the placing up of an advert in the form of a poster and through the researcher verbally informing your students of the study. It also serves to request your permission for the participation of your students in the study. After you have signed this form, you will be given an advertisement in the form of a poster to place up in your studio. The researcher will then verbally inform your senior students of the study. The names and contact details of any dancers who respond immediately will be collected. The

meeting at your studio will take no longer than 30 minutes, and it will be scheduled at a time so as not to interrupt your classes.
At a later stage, each participant will be required to answer a few questions, telephonically, in order to determine whether she is eligible to join the study. Once accepted, she will be required to attend one appointment at the DUT Chiropractic Clinic at a time that suits her. This appointment will be conducted in a private clinic room under the supervision of a qualified clinician. The participant will be required to sign an informed consent form after receiving a full explanation of what the research involves and she will have the opportunity to ask questions about the procedure. The researcher will then interview her and take certain physical measurements of her lower limbs, as well as her height and weight measurements. The participant will then be thanked for her time and will be free to leave. The interview and measurements will take approximately 30 minutes to complete, and your classes will not be interrupted, as the appointment will take place at the Chiropractic Day Clinic.

**Risks or Discomforts to the Participant:**
There will be no health risks. The biomechanical measurements may produce mild discomfort, but the participant may report discomfort to the researcher at any time.

**Benefits:**
This study will help health care practitioners to improve prevention and treatment protocols for ballet-related injury. It will also increase the knowledge base in the fields of dance medicine and musculoskeletal injury.

**Reason/s why the Participant May Be Withdrawn from the Study:**
Participants are free to withdraw from the study at any time.

**Remuneration**:
Participants will not receive remuneration for participating in this study.

**Costs of the Study:**
There will be no costs to the participants.

**Confidentiality:**
Confidentiality will be maintained, as the questionnaires & data collection will be anonymous.

**Research-related Injury:**
There will be no research-related injury, as participants will not be treated.

**Person to Contact in the Event of Any Problems or Queries:**
Please contact the researcher (084 961 0076), my supervisor (031 2620958) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

**Consent**

**Statement of Agreement for Studio to Participate in the Research Study:**

I hereby confirm that I have been informed by the researcher, Kate Allison, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,

I have also received, read and understood the above written information (Principal's Letter of Information) regarding the study.

I am aware that the results of the study, including personal details regarding my students' sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.

My students may, at any stage, without prejudice, withdraw consent and participation in the study.

I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to allow my students to participate in the study.

I understand that significant new findings developed during the course of this research which may relate to my students' participation will be made available to me.

| _____ | _____ | _____ | _____ |
|---|---|---|---|
| **Full Name of Principal** | **Date** | **Time** | **Signature / Right Thumbprint** |

I, _____ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Researcher** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Witness (If applicable)** | **Date** | **Signature** |

**APPENDIX C2**

Are you a

**Female Advanced or Intermediate ballet dancer**

between the ages of

**18 – 25?**

Research is currently being conducted at the Durban University of Technology

For more information, please contact

**Kate**

084 961 0076

## APPENDIX C3

## Telephonic Screening

| **Question:** | **Answer required for inclusion into the study:** |
|---|---|
| Are you willing to participate in a research study? | Yes |
| Are you willing to answer a few questions that would determine whether you are eligible for the study or not? | Yes |
| Are you female? | Yes |
| Are you between the ages of 18 and 25? | Yes |
| Is ballet your main form of dance, making up at least 80% of your dance activity? | Yes |
| Are you either at the Intermediate or Advanced level in ballet? | Yes |
| Do you have a minimum of 2 years ballet experience? | Yes |
| Do you attend at least 2 hours of ballet per week? | Yes |
| Have you ever sustained any major non ballet-related injuries to any muscles or joints? | No |
| Have you ever had major non ballet-related surgery on any muscles or joints? | No |
| Are you a professional, paid or beginner ballet dancer? | No |

**APPENDIX C4**

**Participant Letter of Information**

Dear Participant,

Thank you for volunteering your time to take part in my study.

**Title of the Research Study:**

Associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.

**Principal Investigator/ Researcher:** Kate Allison (B. Tech: Chiropractic)

**Co-Investigator/ Supervisor:** Dr Anthony van der Meulen (M. Tech: Chiropractic)

**Brief Introduction and Purpose of the Study:**
Musculoskeletal injury is common in ballet dancers. Injury can cause debilitation in the daily life of a dancer and prevent her from training and performing to her best potential or at all. It has been said that certain variations in body structure may contribute towards causing ballet injury. Therefore, this study aims to investigate associations between musculoskeletal injury and selected biomechanical measurements in ballet dancers.

**Outline of the Procedures:**
You as the participant will be required to answer a few questions, telephonically, in order to determine whether you are eligible to join the study. Once accepted, you will then be required to attend one appointment at the DUT Chiropractic Day Clinic at a time that suits you. This appointment will be conducted in a private clinic room under the supervision of a qualified clinician. You will be required to sign an informed consent form after receiving a full explanation of what the research involves & you will have the opportunity to ask questions about the procedure. The researcher will then interview you & take certain physical measurements of your lower limbs. The interview & measurements will take approximately 30 minutes to complete. You will then be thanked for your time and will be free to leave.

**Risks or Discomforts to the Participant:**
There will be no health risks. The biomechanical measurements may produce mild discomfort, but you may report discomfort to the researcher at any time.

**Benefits:**
This study will help health care practitioners to improve prevention and treatment protocols for ballet-related injury. It will also increase the knowledge base in the fields of dance medicine and musculoskeletal injury.

**Reason/s why the Participant May Be Withdrawn from the Study:**
You are free to withdraw from the study at any time.

**Remuneration**:
You will not receive remuneration for participating in this study.

**Costs of the Study:**
You will incur travelling costs for the trip to the Chiropractic Clinic for your appointment.

**Confidentiality:**
Confidentiality will be maintained, as the questionnaires & data collection will be anonymous.

**Research-related Injury:**
There will be no research-related injury, as you as the participant will not be treated.

**Person to Contact in the Event of Any Problems or Queries:**
Please contact the researcher (084 961 0076), my supervisor (031 2620958) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

**Consent**

**Statement of Agreement to Participate in the Research Study:**
I hereby confirm that I have been informed by the researcher, _____ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,

I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.

I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.

I may, at any stage, without prejudice, withdraw my consent and participation in the study.

I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

| _____ | _____ | _____ | _____ |
|---|---|---|---|
| **Full Name of Participant** | **Date** | **Time** | **Signature / Right Thumbprint** |

I, _____ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Researcher** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Witness (If applicable)** | **Date** | **Signature** |

| _____ | _____ | _____ |
|---|---|---|
| **Full Name of Legal Guardian (If applicable)** | **Date** | **Signature** |

## APPENDIX C5 - Post Expert Group Questionnaire

**Interview** **Questionnaire Number: _____**

**Association between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers.**

**Section 1: Personal Information**

1. What is your age (in years)? _____ years

2. Which ethnic group do you belong to? _____

3. What is your height (in centimetres)? _____ cm

4. What is your weight (in kilograms)? _____ kg

5. Do you have any medically diagnosed health conditions?
   If so, please state the condition/s:

   _____

6. Do you have any medically diagnosed nutritional disorders?
   If so, please state the disorder/s:

   _____

7. Do you participate in any sports?
   If so, please state the sport/s: _____

8.1. Do you have any sport-related injuries that have an impact on your ballet?

| Yes | No |
|---|---|
| 01 | 02 |

8.2. If you answered yes to question 8.1., please state the location/s of the injury/ injuries:

_____

_____

**Section 2: Ballet History**

9. What level of ballet are you at?

| Intermediate | Advanced |
|---|---|
| 01 | 02 |

10. At what age did you start ballet? _____ years

11. How many years experience do you have in ballet? _____ years

12. Since you started ballet, have you ever stopped dancing for a length of time? Please state each length of time:

_____

13. At present, how many ballet classes do you attend per week? _____

14. At present, how many hours do you dance per week? _____

**Section 3: Past Ballet-Related Injuries**

15. Have you sustained an injury from ballet dancing in the last 2 years?

| Yes | No |
|---|---|
| 01 | 02 |

16. How many injuries have you sustained from ballet in the last 2 years?

_____ / 24 months

17 - 30. How many times have you sustained a ballet-related injury in the following areas in the last 2 years?

| | 01 | 02 | 03 | 04 | 05 |
|---|---|---|---|---|---|
| 17.1. Right Toe/ Foot | 4 times or more | 3 times | Twice | Once | Never |
| 17.2. Left Toe/Foot | 4 times or more | 3 times | Twice | Once | Never |
| 18.1. Right Ankle | 4 times or more | 3 times | Twice | Once | Never |
| 18.2. Left Ankle | 4 times or more | 3 times | Twice | Once | Never |
| 19.1. Right Achilles tendon | 4 times or more | 3 times | Twice | Once | Never |
| 19.2. Left Achilles tendon | 4 times or more | 3 times | Twice | Once | Never |
| 20.1. Right Shin | 4 times or more | 3 times | Twice | Once | Never |
| 20.2. Left Shin | 4 times or more | 3 times | Twice | Once | Never |
| 21.1. Right Calf | 4 times or more | 3 times | Twice | Once | Never |
| 21.2. Left Calf | 4 times or more | 3 times | Twice | Once | Never |
| 22.1. Right Knee | 4 times or more | 3 times | Twice | Once | Never |
| 22.2. Left Knee | 4 times or more | 3 times | Twice | Once | Never |
| 23.1. Right Quadriceps | 4 times or more | 3 times | Twice | Once | Never |
| 23.2. Left Quadriceps | 4 times or more | 3 times | Twice | Once | Never |
| 24.1. Right Hamstring | 4 times or more | 3 times | Twice | Once | Never |

| | | | | | |
|---|---|---|---|---|---|
| 24.2. Left Hamstring | 4 times or more | 3 times | Twice | Once | Never |
| 25.1. Right Groin | 4 times or more | 3 times | Twice | Once | Never |
| 25.2. Left Groin | 4 times or more | 3 times | Twice | Once | Never |
| 26.1. Right Hip | 4 times or more | 3 times | Twice | Once | Never |
| 26.2. Left Hip | 4 times or more | 3 times | Twice | Once | Never |
| 27. Low Back | 4 times or more | 3 times | Twice | Once | Never |
| 28. Other: | 4 times or more | 3 times | Twice | Once | Never |
| 29. Other: | 4 times or more | 3 times | Twice | Once | Never |
| 30. Other: | 4 times or more | 3 times | Twice | Once | Never |

31. In which areas from Questions 17 - 30 did you sustain your four worst ballet-related injuries?

| | 31.1. One | 31.2. Two | 31.3. Three | 31.4. Four |
|---|---|---|---|---|
| Right Toe/Foot | 01 | 01 | 01 | 01 |
| Left Toe/ Foot | 02 | 02 | 02 | 02 |
| Right Ankle | 03 | 03 | 03 | 03 |
| Left Ankle | 04 | 04 | 04 | 04 |
| Right Achilles tendon | 05 | 05 | 05 | 05 |
| Left Achilles tendon | 06 | 06 | 06 | 06 |
| Right Shin | 07 | 07 | 07 | 07 |
| Left Shin | 08 | 08 | 08 | 08 |
| Right Calf | 09 | 09 | 09 | 09 |
| Left Calf | 10 | 10 | 10 | 10 |
| Right Knee | 11 | 11 | 11 | 11 |
| Left Knee | 12 | 12 | 12 | 12 |
| Right Quadriceps | 13 | 13 | 13 | 13 |
| Left Quadriceps | 14 | 14 | 14 | 14 |
| Right Hamstring | 15 | 15 | 15 | 15 |
| Left Hamstring | 16 | 16 | 16 | 16 |
| Right Groin | 17 | 17 | 17 | 17 |
| Left Groin | 18 | 18 | 18 | 18 |
| Right Hip | 19 | 19 | 19 | 19 |
| Left Hip | 20 | 20 | 20 | 20 |
| Low back | 21 | 21 | 21 | 21 |
| Other: | | | | |
| Other: | | | | |
| Other: | | | | |
| N/A | | | | |

32. How would you describe the onset of your worst injuries mentioned in Question 31?

| | Injury occurred over time | Injury occurred due to a single traumatic event | N/A |
|---|---|---|---|
| | 01 | 02 | 03 |
| 32.1. Injury One | | | |
| 32.2. Injury Two | | | |
| 32.3. Injury Three | | | |
| 32.4. Injury Four | | | |

33. On a scale of 0 to 10, where 0 is least severe & 10 is the most severe, how would you rate the severity of each injury mentioned in Question 31? Please plot a mark for each injury on the line below and mark it with 1, 2, 3 or 4:

0 10

34. For how long did you suffer from your worst injuries mentioned in Question 31?

Injury 1: Injury 2:

Injury 3: Injury 4:

35. Did your worst injuries mentioned in Question 24 stop you from dancing?

| | | Yes, totally | Yes, I had to modify my classes | No | N/A |
|---|---|---|---|---|---|
| | | 01 | 02 | 03 | 04 |
| 35.1. Injury One | | | | | |
| 35.2. Injury Two | | | | | |
| 35.3. Injury Three | | | | | |
| 35.4. Injury Four | | | | | |

**Section 4: Present Ballet-Related Inuries**

36. Are you presently suffering from any injuries due to ballet?

| Yes | No |
|---|---|
| 01 | 02 |

If you answered no to the above question (Question 36), you are not required to complete the rest of the interview. Thank you for your time.

I, _____, confirm that the answers to the above
questions are correct and true. Signature: _____

37. Which areas of your body are currently most injured?

| | 37.1. One | 37.2. Two | 37.3. Three | 37.4. Four |
|---|---|---|---|---|
| Right Toe/Foot | 01 | 01 | 01 | 01 |
| Left Toe/ Foot | 02 | 02 | 02 | 02 |
| Right Ankle | 03 | 03 | 03 | 03 |
| Left Ankle | 04 | 04 | 04 | 04 |
| Right Achilles tendon | 05 | 05 | 05 | 05 |
| Left Achilles tendon | 06 | 06 | 06 | 06 |
| Right Shin | 07 | 07 | 07 | 07 |
| Left Shin | 08 | 08 | 08 | 08 |
| Right Calf | 09 | 09 | 09 | 09 |
| Left Calf | 10 | 10 | 10 | 10 |
| Right Knee | 11 | 11 | 11 | 11 |
| Left Knee | 12 | 12 | 12 | 12 |
| Right Quadriceps | 13 | 13 | 13 | 13 |
| Left Quadriceps | 14 | 14 | 14 | 14 |
| Right Hamstring | 15 | 15 | 15 | 15 |
| Left Hamstring | 16 | 16 | 16 | 16 |
| Right Groin | 17 | 17 | 17 | 17 |
| Left Groin | 18 | 18 | 18 | 18 |
| Right Hip | 19 | 19 | 19 | 19 |
| Left Hip | 20 | 20 | 20 | 20 |
| Low back | 21 | 21 | 21 | 21 |
| Other: | | | | |
| Other: | | | | |
| Other: | | | | |
| N/A | | | | |

38. How would you describe the onset of your current injuries mentioned in Question 37?

| | | Injury occurred over time | Injury occurred due to a single traumatic event |
|---|---|---|---|
| | | 01 | 02 |
| 38.1. Injury One | | | |
| 38.2. Injury Two | | | |
| 38.3. Injury Three | | | |
| 38.4. Injury Four | | | |

39. On a scale of 0 to 10, where 0 is least severe & 10 is the most severe, how would you rate the severity of each of your current injuries mentioned in Question 37? Please plot a mark for each injury on the line below and mark it with 1, 2, 3 or 4:

0 10

40. For how long have you suffered from your current injuries mentioned in Question 37?

Injury 1: Injury 2:

Injury 3: Injury 4:

41. Are your current injuries mentioned in Question 37 stopping you from dancing?

| | | Yes, totally | Yes, I modify my classes | No |
|---|---|---|---|---|
| | | 01 | 02 | 03 |
| 41.1. Injury One | | | | |
| 41.2. Injury Two | | | | |
| 41.3. Injury Three | | | | |
| 41.4. Injury Four | | | | |

I, _____, confirm that the answers to the above

questions are correct and true. Signature: _____

## APPENDIX C6

**Lower Limb Biomechanical Measurement Data Sheet** **Participant Number: _____**

| Biomechanical Measurement | Normal | Measurement 1 | Measurement 2 | Measurement 3 | Average | High | Low | Normal |
|---|---|---|---|---|---|---|---|---|
| 1. Right Hip External Rotation (Active) | 40 - 60° | | | | | 01 | 02 | 03 |
| 2. Left Hip External Rotation (Active) | 40 - 60° | | | | | 01 | 02 | 03 |
| 3. Right Hip External Rotation (Passive) | 40 - 60° | | | | | 01 | 02 | 03 |
| 4. Left Hip External Rotation (Passive) | 40 - 60° | | | | | 01 | 02 | 03 |
| 5. Right Q-Angle | 18 - 22° | | | | | 01 | 02 | 03 |
| 6. Left Q-Angle | 18 - 22° | | | | | 01 | 02 | 03 |
| 7. Right Femoral Torsion Angle | 8 - 15° | | | | | 01 | 02 | 03 |
| 8. Left Femoral Torsion Angle | 8 - 15° | | | | | 01 | 02 | 03 |
| 9. Right Ankle Plantarflexion (WB) | 50° | | | | | 01 | 02 | 03 |
| 10. Left Ankle Plantarflexion (WB) | 50° | | | | | 01 | 02 | 03 |
| 11. Right Ankle Plantarflexion (NWB) | 50° | | | | | 01 | 02 | 03 |
| 12. Left Ankle Plantarflexion (NWB) | 50° | | | | | 01 | 02 | 03 |
| 13. Right Ankle Dorsiflexion (WB) | 20° | | | | | 01 | 02 | 03 |
| 14. Left Ankle Dorsiflexion (WB) | 20° | | | | | 01 | 02 | 03 |
| 15. Right Ankle Dorsiflexion (NWB) | 20° | | | | | 01 | 02 | 03 |
| 16. Left Ankle Dorsiflexion (NWB) | 20° | | | | | 01 | 02 | 03 |
| 17. Functional Turnout | 100 - 131° | | | | | 01 | 02 | 03 |
| 18. Compensated Turnout | 5 - 69° | | | | | 01 | 02 | 03 |
| 19. Pronation of foot (right) | <10mm | | | | | 01 | 02 | 03 |
| 20. Pronation of foot (left) | <10mm | | | | | 01 | 02 | 03 |
| 21. Knee Alignment: Genu Varum | <4cm between | | | | | 01 | 02 | 03 |
| 22. Knee Alignment: Genu Valgum | <9cm between | | | | | 01 | 02 | 03 |

*WB – Weight-Bearing *NWB – Non-Weight-Bearing

# APPENDIX D

ATTENTION: Kate Allison
Department of Chiropractic
Durban University of Technology

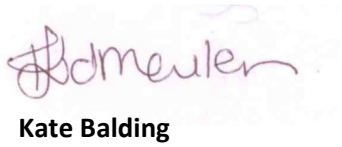
8 April 2013

Dear Kate

**Re: Permission to use questionnaire**

This letter serves to confirm that I give permission for you to use the questionnaire from my dissertation entitled: "An epidemiological investigation of dance injuries in ballet dancers in the Greater Durban Area" (2004); as needed in your 2013 research.

Yours sincerely,



**Kate Balding**
(031-2620776 / 072 1475335)

# APPENDIX E

**Institutional Research Ethics Committee**
Faculty of Health Sciences
Room MS 49, Mansfield School Site
Gate 8, Ritson Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2900
Fax: 031 373 2407
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

**www.dut.ac.za**

26 August 2013

IREC Reference Number: **REC 54/13**

Ms K B Allison
12 Esser Road
Marianhill Park
Pinetown
3610

Dear Ms Allison

**Associations between musculoskeletal injury and selected lower limb biomechanical measurements in female amateur ballet dancers**

I am pleased to inform you that Full Approval has been granted to your proposal REC 54/13.

The Proposal has been allocated the following Ethical Clearance number IREC 068/13. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.
Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

Prof J K Adam
Chairperson: IREC