

DIFFERENCES IN THE PREVALENCE OF LOWER LIMB INJURIES  
IN CLASSICAL BALLET DANCERS WITH AND WITHOUT  
LUMBAR-PELVIC STABILITY

A dissertation prepared by Michelle Swart (SWRMIC 003) in partial fulfillment of the requirements for the Master of Philosophy degree in Sports Physiotherapy (MPhil Sports Physiotherapy) from the University of Cape Town

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## DECLARATION

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

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Signed by candidate

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21 November 2005

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## LIST OF ABBREVIATIONS, TERMINOLOGY AND DEFINITIONS:

### Abbreviations:

<b>EMG</b>	electromyography
<b>EO</b>	external oblique
<b>IO</b>	internal oblique
<b>RA</b>	rectus abdominis

### Terminology:

**Segmental control:** refers to the maintenance of the neutral zone between a vertebra in relationship to the vertebrae above and below. This position is maintained by the local muscles: transversus abdominis, multifidus and to a lesser extent the internal oblique muscles. The neutral zone is a region in the spine where the load-deformation behavior of the spinal segment is non-linear and a region of laxity in the vicinity of the neutral position (Panjabi, 1992)

**Lumbar-pelvic stability:** refers to maintaining a position of the lumbar spine (midway between extension and flexion) in relation to the pelvis. This position is maintained by both local and global trunk muscles.

### Definition of ballet terms:

**Allegro, grand:** The combinations of expansive jumping movements that incorporate advanced-level leaps.

**Allegro, petit:** Small jumps performed at a quick tempo.

**Arabesque:** The body position when supported on one leg whilst the other leg is fully extended behind the dancer. This position necessitates hip extension in external rotation with lumbar spine extension and a lesser degree of rotation.

**Barre:** This refers to the set of warm-up exercises performed whilst holding onto the bar (a long pipe-shaped bar usually attached to the wall) at the beginning of class.

**Class:** The ballet class follows a set structure: barre, centre practice including adage (slow sustained movements) and pirouettes (turning movements on one leg) and allegro (jumps). The class is structured to progress from a warm-up through to explosive jumps. Class forms the basis of a ballet dancers' training and is attended every day.

**Corps de ballet:** Refers to the members of the ballet company that dance the non-lead roles.

***Demipointe:*** The position of the foot when the dancer is poised on the ball of the foot.

***En Pointe:*** The position of the foot in a pointe shoe, in which the heel is raised, the ankle and midfoot fully plantarflexed and the dancer stands balanced on top of the dancer's toes, principally the first and second digits.

***Jete`:*** A leap through the air with one leg extended forward and the other backwards.

***Pas de deux:*** Refers to two dancers dancing together and includes the male dancer lifting the female dancer, usually above shoulder height.

***Plie`:*** The movement whereby the dancer slowly bends the knees in line with the fully turned-out feet.

***Demi-plie`:*** The above movement without lifting heels off the ground.

***Rolling in:*** An incorrect position of the supporting foot in which the bodyweight is allowed to fall through the longitudinal arch causing excessive pronation.

***Turnout:*** External rotation of the hips in an attempt to place the feet at an angle of 180°. This angle is measured at the intersection of the longitudinal axis of the feet.

**CHAPTER 1: INTRODUCTION AND SCOPE OF  
THE THESIS**

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The grace and ease with which a dancer entertains an audience is deceptive with respect to the sweat and tears shed to achieve such elegance of movement.

Ballet demands great flexibility and strength. This is showcased as a story told through movement, full of emotion and expressed to music. As a physiotherapist one watches a ballet in absolute awe of the stresses the human body has to endure. What adaptations are necessary within the musculoskeletal system to allow such movement? Do these adaptations lead to injury?

Yes, ballet dancers do get injured. The literature shows that these injuries are mostly confined to the lower back and lower limb (Garrick and Requa, 1993; Rovere et al, 1983; Nilsson et al, 2001). Muscle injuries appear to be the most common (Byhring and Bø, 2002) with female dancers being more prone to overuse injuries and male dancers to acute injuries (Hamilton et al, 1989).

The mechanism of injury is either extrinsic factors i.e. training technique, training (Krivickas, 1997), dance shoes (Macintyre and Joy, 2000) or dance surfaces (Seals, 1987) or intrinsic factors such as ballet technique (Howse and Hancock, 1992), flexibility (Knapik et al, 1991), hypermobility (Klemp and Learmonth, 1984), strength (Mostardi et al, 1983) and muscle imbalances (Hamilton et al, 1992).

The ballet technique of turnout may lead to a whole chain of compensatory movements, starting at the foot and ending in the spine. Dancers strive to achieve

180° turnout (sum of external rotation) at the hip (Khan et al, 1995; Reid, 1988; Howse and Hancock 1992). However, most dancers do not have 90° external rotation at the hip (Reid, 1988; Quirk, 1994) and therefore use various compensatory movements to achieve 180°. These compensatory movements including “rolling in”, “screwing the knees” and anterior pelvic tilt, may lead to injury.

Anterior pelvic tilt may result in the development of a number of muscle imbalances. Weak lumbar-pelvic stabilising muscles and tight hip flexors may result from repetitive anterior pelvic tilt positioning (Kendall et al, 1993). This position is often assumed by dancers during common ballet positions i.e. “arabesque” and “jete” (see pg. 9). Does the position of anterior pelvic tilt effect the lumbar-pelvic stability of dancers? Or do ballet dancers have adequate abdominal muscle strength to maintain lumbar-pelvic stability in a position of anterior pelvic tilt without incurring injuries.

Increasing evidence suggests that transversus abdominis is important in the stabilising of the lumbar spine (lumbar-pelvic region) (Cresswell et al, 1992; Hodges and Richardson, 1997 a, b). It is hypothesised that the contraction of transversus abdominis and to a lesser extent internal oblique, increases the abdominal pressure and in doing so may contribute to increased segmental spinal stability, which may be instrumental in preventing injury of the lumbar spine.

In particular questions that arise are; do ballet dancers have adequate segmental spinal stability and are they able to stabilise the lumbar-pelvic region? Does the lack of lumbar-pelvic stability result in lumbar spine and/or lower limb injuries?

Chapter 2 is the review of literature in regards to (i) the epidemiology and aetiology of injuries in the ballet dancer and (ii) the involvement of abdominal muscles' activity in lumbar-pelvic stability. Chapter 3 determines the body composition, morphology and injury history: type, site and time and management of the injuries, sustained in a group of ballet dancers. Chapter 4 assesses the ballet dancer's ability to perform the "draw in" manoeuvre at which time the EMG activity of internal oblique, external oblique and rectus abdominis was recorded. Lumbar-pelvic stability was evaluated during the task of lowering a leg, while maintaining a neutral spine. This was monitored by placing a pressure biofeedback unit under the lumbar spine. The results were then used to create a lumbar-pelvic stability index. A relationship between the prevalence of injury and lumbar-pelvic stability index was thereafter evaluated.

## **CHAPTER 2: REVIEW OF THE LITERATURE**

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### Introduction:

Is ballet a performing art or a sport? Ballet dancers see themselves as artists performing in front of an audience, moving to the rhythm of the music expressing emotions. However, as in most sports, ballet demands flexibility, strength and endurance.

Female dancers are expected to have a sylph-like appearance, yet they are required to execute explosive jumps, turns and often balance on one leg whilst bending forward lifting the other leg into extension. This necessitates muscle strength and flexibility, but unlike gymnasts, who have well defined muscles, female ballet dancers are reprimanded for such muscle development. Male dancers are able to appear more muscular within reason. The aesthetic lean look may prevent ballet dancers from developing adequate muscle strength to execute the ballet technique. This may be compounded by the ballet technique that requires great flexibility resulting in dancers concentrating more on flexibility to the detriment of strength. As in many other sports, footwear, training surfaces and training programmes may also contribute to injuries.

Very little research had been done up until the mid-1970's to establish the injury profile of ballet dancers and the possible causes of the injuries. Since then several studies have examined epidemiology and aetiology of injury in various forms of dance.

The aim of this review is to: (i) establish an injury profile for ballet dancers and to determine which injuries are the most common, (ii) establish the extrinsic and intrinsic factors that may lead to injury, (iii) define lumbar-pelvic stability and determine which local and global trunk muscles maintain lumbar-pelvic stability and (iv) determine whether the lack of lumbar-pelvic stability lead to injury in ballet dancers?

### Epidemiology:

Washington (1978) did an extensive dance injury survey and reported on 1662 dance related injuries. Two questionnaires were designed; one questionnaire was sent to physicians, dance teachers and administrators to record the area of injuries sustained by dancers that they were managing (General Information Group forms). The second questionnaire obtained specific information from the injured dancer or the physician treating the injury (Individual Information forms). Table 2.1 shows the incidence of injuries at lumbar and lower limb sites sustained by dancers. The data was obtained from the Individual Information forms and General Information Group forms.

**Table 2.1:** Results to questionnaires (Individual Information forms and General Information Group forms) of lumbar spine and lower limb injuries (%) by dancers (Washington, 1978).

Information forms	Lumbar spine	Hip	Knee	Shin	Ankle	Foot
Individual Injuries (n=414)	12%	7%	14%	14%	13%	10%
General injuries (n=1248)	6%	7%	34%	0%	21% (ankle and foot)	

The remainder of the reported injuries involved the upper extremities, thoracic and cervical spine. In this study no differentiation was made between classical ballet, modern or contemporary dance forms. Consequently, a relationship between specific dance forms and injury profile could not be established.

A subsequent survey monitored 185 theatrical dance students at the North Carolina School of Arts 115 ballet students and 70 modern dance students (Rovere et al, 1983). Table 2.2 indicates the distribution of the recorded injuries in both the ballet and modern dance students.

**Table 2.2:** Distribution of injuries of spine and lower limb (n = 352) (Rovere et al, 1983).

	Spinal	Knee	Ankle	Foot	Other
Injuries (n=352)	17%	15%	22%	15%	31 %
	(69% lumbar)	(57% chondromalacia patella)	(44% ligament, 42% Achilles tendon)	(mostly big toe injuries)	(upper limb)

Cervical and upper back strains occurred twice as often in modern dancers as in ballet dancers whereas lower back strain, hamstring strains and shin splints occurred twice as often in ballet dancers. This was attributed to the different dance forms placing greater strain on different parts of the body.

Hamilton et al, (1989) questioned 29 (14 male and 15 female) soloists and principal dancers from the New York City Ballet and American Ballet theatre in their study. Table 2.3 shows the classification of injuries (n = 69 injuries female, n = 43 injuries male) sustained by the dancers.

*Table 2.3: Injury classification (%) of female and male dancers (Hamilton et al, 1989).*

	Female (n=69 injuries)	Male (n=43 injuries)
Minor injuries	54%	43%
Major injuries	46%	57%

Seventy seven percent of the injuries sustained by the female dancers were chronic overuse injuries, whereas only 50% of injuries sustained by the male dancers were chronic overuse injuries. Unfortunately the locations of the injuries were not specified, and only the soloist and principal dancers were questioned. The injuries sustained by the rest of the company were not taken into consideration, so the injury profile of all the dancers in both companies remains unclear.

A further study assessed the workers compensation insurance records of a major professional ballet company spanning three years (Garrick and Requa, 1993). One hundred and four dancers were injured during the period investigated, sustaining 309 injuries. Table 2.4 shows the distribution of lumbar spine and lower limb injuries of the dancers.

**Table 2.4:** *Distribution of injuries (n=309) of lumbar spine and lower limb sustained by dancers (n=104) (Garrick and Requa, 1993).*

	Lumbar spine	Pelvis, hip, thigh	Knee	Leg	Ankle	Foot, toe
Injuries (n=309)	23%	7%	7%	6%	13%	24%

Fifty seven percent of the injuries were located in the lower limb. Twenty-four dancers sustained 5 or more injuries each and accounted for 52 % of all injuries. Self treated injuries and injuries that had not incurred any treatment costs, were excluded from this study. The exclusion of the less serious injuries gives an incomplete picture of the injuries incurred by the company as a whole.

Milan (1994) reviewed the literature regarding the prevalence of injury in ballet dancers. Lower limb injuries accounted for 65 - 80% of all injuries in ballet dancers. Musculoskeletal injuries of the spine comprised 10 - 17%, of which 69% were lumbo-sacral, 21% thoracic spine and 10% cervical spine injuries. The majority of the remaining 5 - 15% was attributed to upper limb injuries. Traumatic injuries occur less often in dance, accounting for only 35%, whilst overuse injuries account for 65% of all injuries.

A combined retrospective (2 years) and prospective (3 years) study, recording injuries sustained by dancers in a Swedish classical ballet company, was conducted (Nilsson et al, 2001). Ninety-eight dancers (mean age 27 years) incurred 390 injuries. A resident orthopaedic consultant diagnosed the injuries. Only five percent of the dancers did not suffer an injury during this period. In 75% of cases the injury was located in the lower limb. Table 2.5 lists the lumbar spine and lower limb injuries.

*Table 2.5: Distribution of injuries (n=390) of lumbar spine and lower limb sustained by dancers (n=98) (Nilsson et al, 2001)*

	Lumbar, gluteal areas	Thigh, groin	Knee	Lower leg	Ankle, foot	Upper limb	Miscellaneous
Injuries (n=390)	18%	4%	11%	2.8%	54%	7%	3.2%

In general, 40% of the injuries affecting the male dancers were traumatic injuries such as contusions and sprains, while 65% of the injuries sustained by the female dancers were overuse injuries especially around the foot and ankle region (Nilsson et al, 2001). Although the orthopaedic consultant was only present once a week, the authors felt that the study surveyed most of the injuries, as the company's resident osteopath, worked closely with the consultant and referred the injuries directly to him (Nilsson et al, 2001). The injury profile in this study is perhaps more accurate than the questionnaire studies as the injuries were diagnosed by an orthopaedic consultant rather than self-reported as occurs in the questionnaire studies.

In a recent study members of the Norwegian National Ballet (n = 41) were clinically assessed and their injuries registered in a prospective cohort study spanning 19 weeks (Byhring and Bø, 2002). Forty-one of the dancers (27 female and 14 men) experienced one or more injuries during the time that the study was conducted. Twenty two percent of the injuries were classified as acute and 78% as chronic. Table 2.6 shows the classification of soft tissue injuries in this study.

*Table 2.6: Distribution of soft tissue injuries (n=64) sustained by dancers (n=41) (Byhring and Bø, 2002).*

	Muscle	Ligament	Tendon	Other
Injuries (n=64)	37%	3%	11%	13%

The majority of the injuries (acute and chronic) were localised to the ankle and foot, and resulted in the greatest amount of absence from work. The dancers believed that the factors associated with a risk of injury were related to training, organisation and environment. Seventy eight percent of the dancers experienced "negative" stress at work. This study however, showed no significant association between these psychological factors and musculoskeletal injuries (Byhring and Bø, 2002).

None of the above studies described the injuries in depth (Byhring and Bø, 2002; Nilsson et al, 2001; Garrick and Requa, 1993; Hamilton et al, 1989; Rovere et al, 1983; Washington, 1978). The injuries were either classified according to (i) anatomical location, and in some studies no differentiation was made between

foot, ankle and toe, or (ii) type of injury: acute or overuse, or (iii) the soft tissue involved. It is therefore difficult to establish a clear picture of any one group's injury profile in terms of mechanism, area, type and severity of injury. The above studies do however show that most dancers sustain at least one injury during their careers. However the impact of this injury on their dance careers is not known. Table 2.7 demonstrates a wide range of injury rate (injuries per dancer) that can be attributed to the wide variation in the mode of data collection, from self-reporting questionnaires to injuries diagnosed by an orthopaedic consultant. However despite these limitations in study design there is a high risk of injury in dancers.

*Table 2.7: Injury rate (injuries per dancer) of the groups of dancers studied.*

Article	Washing- ton (1978)	Rovere et al, (1983)	Hamilton et al, (1989)	Garrick and Requa (1993)	Nilsson et al, (2001)	Byhring and Bø (2002)
Dancers	—	185	29	270	98	41
Injuries	1662	352	112	309	390	64
Injury rate	—	1.9	3.9	1.1	4.0	1.6

Injuries to the lumbar spine, knee, ankle and foot appear to occur at similar rates. Chronic overuse injuries are more common than traumatic acute injuries (Byhring and Bø, 2002; Nilsson et al, 2001; Milan, 1994). Ballet technique requires the dancer to work at the limit of the range of movement of the lumbar spine, knee, ankle and foot. These techniques are often held for a period of time, repeated or

executed very quickly. If these techniques are not executed correctly stress may be placed on the musculoskeletal structures leading to injury (Howse and Hancock, 1992). The sustained and repeated techniques used in ballet may predispose the dancer to chronic overuse injuries whilst the jumps and turns may predispose the dancer to traumatic acute injuries (Macintyre and Joy, 2000).

### Injury Aetiology:

Injuries are classified as either traumatic acute injuries or overuse chronic injuries (Brukner and Khan, 1993). Traumatic acute injuries occur as the result of one incident leading to tissue damage whereas overuse chronic injuries are defined as musculoskeletal damage as a consequence of repetitive and cumulative micro-trauma imposed on the tissue (Brukner and Khan, 1993; Nabeshinna et al, 2001).

### Mechanism of injuries:

A combination of extrinsic and intrinsic factors may predispose ballet dancers to injuries. Extrinsic factors include training errors, inadequate footwear and training surfaces (Krivickas, 1997) and equipment and environmental conditions (Brukner and Khan, 1993). Intrinsic factors include bony alignment of the extremities, flexibility deficits, ligamentous laxity (Krivickas, 1997), leg length discrepancy, muscle imbalances, muscle weakness, lack of flexibility and body composition (Brukner and Khan, 1993). The bony alignment relates to the geometrical configuration components of the skeletal system that will determine the alignment

of the extremities. The soft tissue flexibility affects joint range of motion. The structures involved include muscles, tendon and ligaments (Krivickas, 1997; Brukner and Khan, 1993).

Extrinsic factors:

Medical practitioners and orthopaedic surgeons have been managing and treating ballet dancers for a number of years and have written many articles based on their personal experience in managing these athletes. Although this evidence is anecdotal, it is of interest and may lead to subsequent research.

Training and technique:

Inappropriate training methods and incorrect technique due to poor teaching have been cited as extrinsic factors resulting in overuse injuries in ballet dancers (Macintyre and Joy, 2000; Ende and Wickstron, 1982; Howse and Hancock, 1988). Further reasons for incorrect technique may include anatomical limitations preventing the development of the correct technique (limited external rotation of the hip) and a dancer's limited technical knowledge of specific ballet positions and movements (Stone, 2001; Ende and Wickstron, 1982). Inadequate warm-up, lack of training specificity, poor pre-season conditions, rehearsal and performance schedules, improper teaching of technique, starting ballet training too late and development of muscle imbalances were listed as possible factors related to the cause of injury in a group of student and professional dancers attending a summer school programme (Stephens, 1987). However, no studies

have established a cause-effect relationship between any of these factors. The anecdotal evidence provides a weak association between these variables.

A further study regarding risk factors that may lead to injury showed that 61% of dancers believed that factors relating to their training programme increased the risk of injuries (Byhring and Bø, 2002). Poor warm-up, inadequate stretching, insufficient preparation prior to rehearsals and performances as well as insufficient pre-season training were reported as risk factors. The dancers also reported that environmental factors such as lack of space in class and on stage, low temperatures and poor ventilation as well as hard and slippery dance floors contributed to injury. These causes however, were not linked to specific injuries but based on the dancer's subjective opinion on possible risk factors. These subjective findings provide researchers with areas for further investigations.

#### *Dance shoes and floors:*

Dance shoes can be a source of injuries due to the lack of shock absorption and support of the foot, as ballet shoes are primarily designed to maintain the foot "en pointe" (Macintyre and Joy, 2000). Therefore, the lower extremity is required to absorb the impact forces and may be a contributing factor in the development of shin splints in dancers (Milan, 1994; Wajswelner, 1995). However, more research is needed to investigate the relationship between dance shoes and injury.

Resiliency and shock-absorption are important characteristics of dance floors (Seals, 1987). A comparison of gross injury rates, time loss due to injury, and specific injury rates associated with the type of flooring failed to reveal any significant findings (Garrick et al, 1986). The authors were of the opinion that the weight-bearing surface during activities such as aerobic dance should be an important consideration in determining the risk of injury. The fact that such an influence could not be shown in this study does not mean that it might not exist in conjunction with other variables such as ballet shoes. However evaluation of such variables was beyond the scope of this investigation. Further research is required in this area.

#### Intrinsic factors:

Intrinsic factors can be described in terms of biomechanical imbalances, previous injuries, physical fitness, demography and morphology, disability and psychological/psychosocial factors (Vicenzino and Vincenzino, 1995). A biomechanical imbalance is defined as an alteration of structure and function, which is reflected in a variety of combinations of ligament laxity (articular mobility), muscle inflexibility, muscle weakness and/or poor alignment of body segments. Studies have examined the relationship between intrinsic factors and injury in athletes and ballet dancers however; the results of such studies have been conflicting (Lysens et al, 1989; Knapik et al, 1991; Ekstrand and Gillquist, 1982; Orchard et al, 1997; Klemp and Learmonth, 1984; Hamilton et al, 1992 and Mostardi et al, 1983, Klemp et al, 1984)

Articular mobility:

Are ballet dancers genetically hypermobile (articular flexibility due to ligament laxity) or is their increased mobility acquired? A study of 28 principal and soloist dancers showed that none of the dancers were hypermobile (Hamilton et al, 1992). However, it did show that dancers have an increased range of movement of the lower limb joints. Ankle plantar flexion and hip external rotation, abduction and flexion were increased compared to the normal population. However, this was associated with a decrease in ankle dorsiflexion and hip internal rotation and adduction. Another study showed that only 2 of 47 professional ballet dancers and 34 of the 330 student dancers were found to be hypermobile (Klemp et al, 1984). The authors concluded that hypermobility was largely acquired through training.

A follow up study compared the injury history of professional dancers with and without hypermobility (Klemp and Learmonth, 1984). There was no difference in the number or nature of the injuries sustained by the two hypermobile dancers in this study compared with ten dancers of similar age and dancing experience. The number of hypermobile dancers in this study was too small for statistical evaluation. As in some previous studies (Garrick and Requa, 1993), only the Workman's Compensation records were used for assessing the injury history of the dancers. This research design may not provide a true reflection of the total number of injuries sustained by the dancers, as minor injuries may not have been included in the Workman's Compensation records. The Hamilton et al, (1992)

study compared mobility and injury. Male dancers with an increased total turnout had more overuse injuries in comparison to the female dancers. Female dancers, however with less total turnout and with less bilateral "plie" (dorsiflexion) incurred more overuse injuries. This would suggest that both increased or decreased total turnout range may be a risk for injury. Whether this range of movement is due to articular mobility or muscle flexibility is difficult to assess as both factors affect the ultimate range of movement at any given joint.

#### Muscle flexibility:

Several studies (Ekstrand and Gillquist, 1982, Orchard et al, 1997, Jones and Knapik, 1999, Reid et al, 1987, Winslow and Yoder, 1995) have attempted to find an association between flexibility of muscles and injuries sustained by athletes and ballet dancers. Unfortunately the relationship between flexibility and injury in most of the studies is tentative as no clear cause and affect relationship was established.

In a retrospective study seventy-eight percent of a group of soccer players (n = 180) with one or more inflexible muscles in the lower limb sustained lower limb injuries (n = 465), most of which were muscle strains (Ekstrand and Gillquist, 1982). However all players had increased hamstring flexibility as measured by an increased hip flexion, in comparison to a group of non-soccer players (n = 86). No direct correlation was drawn between those subjects with muscle inflexibility and injury to the inflexible muscle. The authors found that a major limitation of a

retrospective study was whether or not the muscle inflexibility was the result or cause of injury.

Orchard et al, (1997) did not find a relationship between hamstring flexibility and hamstring injury when testing 37 professional footballers. They found a poor relationship between the sit-and-reach test values and injury. A criticism of this study was the lack of the effectiveness of the flexibility test as it is a non-specific test. The lack of hamstring flexibility can be compensated for in lower back flexibility and vice versa. A prospective study measured the toe touching ability of US Army trainees and indicated that both the high and low extremes of back and hamstring flexibility resulted in injury (Jones and Knapik, 1999). These data suggests that there is a need to re-examine the belief primarily based on clinical suspicion that greater flexibility protects against injury.

Flexibility patterns, suggestive of muscle tightness, were shown in ballet dancers during a study investigating the relationship of lower extremity flexibility patterns to both lateral hip and knee pain syndromes (Reid et al, 1987). On measuring the range of movement of the hip, it was found that the dancers had significantly greater passive hip external rotation, flexion, abduction and extension than the non-dancer controls. This may be due to the fact that ballet movements emphasised hip flexion, external rotation and abduction while hip adduction and internal rotation are rarely adopted. It could be proposed that adaptive shortening of the lateral hip joint capsule and external rotators occur, thus limiting internal

rotation. In addition, adaptive shortening of the gluteus medius and iliotibial band leads to limited hip adduction. A relationship between the presence of hip and knee symptoms and tightness in the abductor muscles and iliotibial band was found (Reid et al, 1987). This finding was supported by another study which found a correlation between iliotibial band tightness and tibial external rotation, which was seen as a contributing factor in patellofemoral pain in a group of dancers (Winslow and Yoder, 1995).

It would appear from the above research that muscle length changes occur in athletes and dancers. These changes may develop in an individual as a result of adaptation to the specific requirements needed to participate in sport and ballet. These adaptations may increase the risk of injury. However, further research needs to be done to demonstrate a cause-effect relationship.

#### Muscle strength:

In a group of 28 principal classical ballet dancers, various muscle groups demonstrated imbalances in muscle strength (Hamilton et al, 1992). A significant reversal of the abduction/adduction ratio was found in male (n = 14) and female (n = 14) dancers when compared to the recognised norm. The knee flexor/extensor ratios were normal in both male and female dancers, although male dancers showed weakness of both the knee extensors and flexors. The strength of the plantar flexors and dorsiflexors were significantly greater than normative values in both male and female dancers but the plantar

flexion/dorsiflexion ratios were normal. The muscles of the right hip and knee were significantly stronger than the muscles on the left, in the female dancers. These muscle imbalances may be due to ballet techniques requiring the achievement of certain positions that strengthens one muscle more than the opposing muscle. Ballet dancers may also favour the dominant leg and in so doing strengthen that leg more than the other.

There are factors to be considered when analysing these results. The isokinetic dynamometer can only measure muscle strength in standard positions and at a relatively slow speed of contraction. This does not allow for testing hip, knee and ankle strength in the functional position of turnout in ballet. Only the principal and soloist dancers were tested in this study excluding the corps de ballet, and therefore the results may create an altered picture of strength and flexibility in ballet dancers. Principle and soloists dancers perform more strenuous ballet techniques, which would require greater strength.

Mostardi et al, (1983) demonstrated that female professional dancers were able to develop similar levels of torque per body mass in both the left and right legs, whereas the male dancers had stronger right legs. This may be explained by the fact that male dancers performed more jumps than female dancers and that the right leg was used in most of the jumps to take off and land.

### Muscle imbalances:

Muscle imbalances may be seen in terms of an asymmetry in strength, power and endurance of muscles when comparing muscles of two extremities within an individual or comparing opposing muscle groups within the same extremity (Grace, 1985). Muscle imbalances can also be seen in terms of muscle length differences where a mobiliser may be shortened and associated with a stabiliser that is lengthened with poor inner range endurance, causing changes in segment alignment (Norris, 2001). A question arising from these studies is whether these asymmetries predispose athletes to injury.

A study on collegiate athletes (female n = 67, male n=118) showed that ligament laxity with muscle inflexibility predisposed athletes to overuse injuries whilst muscle flexibility predisposed athletes to acute injuries (Lysens et al, 1989). Hamstring-to-quadriceps ratios were demonstrated as an important indicator of injury risk to the hamstring muscle (Orchard et al, 1997). The subjects, 37 professional footballers, were tested for hamstring and quadriceps muscle concentric peak torque at 60, 180 and 300 degrees/second. The best predictors for hamstring injury were the ratios of hamstring-to-quadriceps muscle strength and hamstring-to-opposite hamstring muscle strength at 60 degrees/second. Although the sample size was relatively small the authors thought a good functional model was established to predict injury on the basis of these peak torque ratios.

On comparing a group of athletes (17 gymnasts, 14 figure skaters, 18 ballet dancers) to a group of non-athletes, it was found that the athletes had a greater cross-sectional area of psoas, multifidus and erector spinae and a greater strength of trunk flexion and extension forces when expressed relative to body mass (Peltonen et al, 1998). The results suggest that the intense physical training adopted by these athletes promotes hypertrophy of trunk musculature. These sports require appropriate spinal stability that may have increased the activity of these muscles. This study cannot be seen in isolation as other variables may play a role in both torque generation and muscle hypertrophy.

A group of both college and professional dancers (n=800) demonstrated muscle imbalance in terms of a relative imbalance in flexibility and deficit in strength (Liederbach, 2000). Seventy-six percent of the dancers tested positive for calf tightness and 63 % tested positive on the Thomas Test for hip flexor tightness. In the same population 38 % failed the supine double leg-lowering test for abdominal strength and trunk stability. The tightness of hip flexors and weakness of abdominal muscles could be indicative of poor control of the lumbar-pelvic complex.

It would appear from the above articles that there is conflicting evidence as to the cause of injuries. This could be explained by the fact that injuries result from a combination of, or the interaction between, both extrinsic and intrinsic factors, rather than from a single factor (Jones and Knapik, 1999). However, there is

limited evidence linking specific injuries to intrinsic and extrinsic factors in ballet dancers.

### **Ballet technique:**

#### **Turnout:**

The most important technical requirement for a ballet dancer is turnout (Khan et al, 1995; Reid, 1988; Howse and Hancock, 1992). Turnout is achieved by externally rotating the leg and is important for two reasons: to create a visual effect on a line running from hip to a pointed foot. The second is that turnout has a sound anatomical basis to allow greater hip abduction without impingement of the greater trochanter (Reid, 1988; Quirk, 1994). Dancers strive to achieve a flat turnout of 180° (McCormack, 2001). This is measured as the angle made by the medial borders of the feet with the heels together and legs externally rotated.

Turnout is however restricted at the hip by several anatomical factors including femoral ante-version, capsular flexibility, orientation of the acetabulum and muscle tendon unit flexibility (Stone, 2001). Kendall et al, (1993) suggest that the hip joint allows for 45° of external rotation. However, Khan et al (2000) tested 48 elite ballet dancers (16-18 years old) and found a mean external rotation of the left hip of 41° ( $\pm 10^\circ$ ) and external rotation of the right hip of 43° ( $\pm 9$ ), whilst Micheli et al, (1984) demonstrated an external rotation of 48° ( $\pm 7$ ).

Functional turnout:

A study compared the sum of passive external rotation of both hips to the angle achieved with functional turnout (the angle between the turned out feet) in the 5 different ballet positions (Gilbert et al, 1998). Twenty female classical ballet dancers (11 to 14 years old) with at least 3 years training were measured. The results showed that the sum of passive hip external rotation ( $79 \pm 12^\circ$ ) was significantly less than functional turnout angles for all of the ballet positions (average  $95^\circ$ ). If turnout primarily results from external rotation of the hip joints, the result should have shown no differences among the sum of passive hip external rotation and the five ballet positions. These measurements indicate that functional turnout is not limited to external rotation of the hip. This implies that additional degrees of turnout of the legs may be achieved by movements at anatomical sites other than the hip joints, such as the lower back, knee, ankle and foot. The knee would have to compensate by allowing increased range of tibial rotation. The ankle and foot joints do not allow for external rotation and compensate by pronating. It is logical to assume that these compensatory movements may lead to injury.

Compensatory turnout and injury occurrence was demonstrated in a study where non-injured dancers ( $n=16$ ) had an average functional turnout of  $100 \pm 16^\circ$  with a  $5 \pm 16^\circ$  compensatory turnout and injured dancers ( $n=14$ ) that had an average functional turnout of  $119 \pm 18^\circ$  with  $25 \pm 21^\circ$  compensatory turnout (Coplan, 2002). The injuries were located at the knee ( $n=8$ ), shin ( $n=5$ ), lower back ( $n=3$ )

and the ankle (n=3). It is likely that the amount of functional turnout is not related to injuries as much as compensated turnout is related to injury. The primary limitations of the study were the lack of formal diagnosis of injury and the limited number of subjects.

It would appear from the above evidence that 90° external rotation at the hip is not possible and therefore dancers are forced to achieve functional turnout of 90° of the leg by adjusting the position of the lumbar spine to the pelvis and increasing the range of movement of joints distally to the hip.

#### **Compensatory Movements:**

Few dancers are able to achieve ideal turnout without compensation at the pelvis/lumbar spine, knee, ankle and foot joints (Gilbert et al, 1998). These compensations may be allowed and even encouraged by dance instructors who stress the importance of ideal turnout. Unfortunately, it is believed that forceful compensation for reduced hip external rotation can, and may lead to many of the musculoskeletal injuries seen in dancers (Stephens, 1987; Coplan, 2002).

Depending on the individual's anatomical restrictions and soft tissue compliance dancers may use one, or all, of the three recognised compensatory movements to achieve 90 ° turnouts. These include "rolling in of the feet" (Khan et al, 1995; Macintyre and Joy, 2000; Stephens, 1987); "screwing the knee" (Reid, 1988) and

anterior pelvic tilt resulting in an increased lumbar lordosis (Solomon, et al 2000; Howse and Hancock, 1992).

"Rolling In":

"Rolling in" during turnout is prevented by three qualitative criteria: keeping the center of the knee over the midline of the foot; keeping equal weight over both feet and keeping weight evenly distributed between the calcaneus, the first metatarsal head and the fifth metatarsal (Gilbert et al, 1998).

When a dancer uses "rolling in" as a compensatory movement to achieve turnout the metatarsal joints abduct with excessive subtalar pronation. This leads to flattening of the longitudinal arch (Marshall, 1988). The ligamentous laxity characteristic of the pronated foot may place excessive demands on the extrinsic muscles of the foot in an effort to stabilise the longitudinal arch. This may predispose the tendons and the associated synovial sheaths and attachments to injuries such as posteromedial shin splints, flexor hallucis longus tenosynovitis or plantar fasciitis (Khan et al, 1995; Macintyre and Joy, 2000; Stephens, 1987).

The excessive pronation may also place a strain on the medial structures of the foot and knee. This may cause laxity of the medial collateral ligament, pain of the posterior tibialis muscle or tendon, and tenderness in the subtalar and midtarsal joints (Khan et al, 1995; Macintyre and Joy, 2000; Stephens, 1987). The increased weight bearing through the first metatarsal head may predispose the dancer to sesamoid problems (Khan et al, 1995).

"Screwing the knee":

Another compensation, to increase turnout, commonly seen in dancers is called "screwing the knee". Miller et al (1975) describe "screwing of the knee" as forcing the turnout from the floor up rather than from the hips down. The dancer achieves this by assuming a "demiplié" position (half-squat in the first position) and places the feet in 180° of turnout then forcefully straightens the knees without moving the feet. "Screwing the knee" places a sheer force on the knee because of the femur's need to internally rotate with full extension while the tibia and foot are passively held in external rotation due to the 180° of turnout (Miller et al, 1975). This shear force may place stress on the knee and strain or damage the medial collateral ligament, medial capsular structures and the medial meniscus (Ende and Wickstrom, 1982; Reid et al, 1987).

Anterior pelvic tilt:

A third compensatory movement that the dancer uses to increase turnout is the anterior pelvic tilt. Stephens (1987) suggests that by tilting the pelvis anteriorly, secondary hip flexion occurs. This decreases the tension on the ilio-femoral ligament and allows the further external rotation of the hip. This anterior tilting of the pelvis results in extension of the lumbar spine and forces the dancer to adjust her/his weight placement, which affects all the musculature around the lumbar-pelvic-hip region (Howse and Hancock, 1992). Teitz (2000) suggests that the iliopsoas muscle may be one of the muscles affected by this posture. The iliopsoas muscle, because of its anatomical position, is used by the dancer to

centre their body weight through the pelvis, without allowing excessive increase or decrease of lumbar lordosis. However, Grossman and Wilmerding (2000) suggest that a deficit in control of the lower abdominal muscle may interfere with the maintenance of a level pelvis (lumbar-pelvic stability) during the execution of a variety of dance skills. The extension of the lumbar spine may be increased further by faulty technique. One example of faulty technique is seen when doing an "arabesque" (Gelabert, 1986). During "arabesque" the dancer extends the leg backwards using hip extension. If a dancer's hip extension and external rotation of the hip is limited by a tight ilio-femoral ligament the dancer will try and achieve this by hyper-extending the lumbar spine and/or lifting the hip to the side by rotating the pelvis on the spine (Gelabert, 1986).

Based on the above evidence, it would be prudent to conclude that the technical demand of achieving turnout may lead to the development of certain biomechanical adaptations. The most prevalent adaptations are anterior pelvic tilt at the top, "screwing of the knees" in the middle and pronation of the foot at the bottom of the kinetic chain (Potts and Irrgang, 2001; Khan et al, 1995; Reid, 1987). The anterior pelvic tilt with lumbar extension posture may lead to the development of weakness in the abdominal stabilisers with tightness and shortening of erector spinae and the hip flexors especially iliopsoas (Kendall et al, 1993; Janda and Jull, 1994).

### **What is lumbar-pelvic stability?**

Bergmark (1989) designed a model to explain how the mechanical stability of the human lumbar spine is maintained. The model was based on the hypothesised effect of loading of the spine through the shoulders to determine the forces placed on the spinal structures. In this model Bergmark (1989) distinguishes between two types of components of the musculoskeletal system: a passive component and an active component. The passive component consists of the bony and cartilagenous elements, ligaments, tendons and fascia of the lumbar spine. Forces are transferred from the upper body through the thoracic cage via the lumbar spine to the pelvis. These passive components deform depending on the forces applied to them. The active component consists of the muscles that result in the development of intra-abdominal pressure. Bergmark (1989) differentiated between global and local muscles. The main role of the global system appears to be to balance the outer load so that the resulting forces transferred to the lumbar spine can be handled by the local system (Bergmark, 1989). The local system is used to control the curvature of the spine and to provide sagittal and lateral stiffness to maintain mechanical stability of the lumbar spine (Bergmark, 1989). The global system can also change the position of the thoracic cage in relation to the pelvis. Table 2.8 presents the global and local muscle system of the trunk.

Table 2.8: Global and local muscle system of the trunk (Bergmark, 1989).

Classification	Muscles
Global muscles	Thoracic part of lumbar iliocostalis, rectus abdominis, external oblique, lateral part of quadratus lumborum
Local muscles	Lumbar multifidus, interspinals and spinalis, quadratus lumborum, lumbar part of the lumbar iliocostalis, transverses abdominis and some fibres of internal oblique

However, a limitation of the model was that the lumbar stability was based on a neutral spine with symmetrical loading (Bergmark, 1989).

Panjabi (1992) conceptualised a spinal stabilising system consisting of three subsystems (passive, active and neural control). According to this model the passive musculoskeletal subsystem included the vertebrae, facet articulations, intervertebral discs, spinal ligaments and joint capsules. The active musculoskeletal subsystem consists of muscles and tendons surrounding and acting on the spinal segment. The third subsystem was defined as the neural control subsystem constituting the neural control centres that receive information from various transducers in the ligaments and tendons and causes the active system to react to achieve stability. This was expanded on in terms of spinal instability. A region of laxity or high flexibility around the neutral position of a spinal segment, called the "neutral zone", was conceptualised (Panjabi, 1992). The deformation of the ligaments under load within the neutral zone provides a feedback signal to the neural control centre. This allows the neural control centre to determine the requirements needed to stabilise the spine. In response to the neural control centre the active subsystem provides stability by selecting

appropriate muscles and adjusting individual muscle tensions to accommodate change in physiological postures, spinal movements and spinal loads. Panjabi (1992) also believed that spinal stability was controlled by the deep intersegmental muscles as these muscles are placed closer to the centre of rotation of the spine and connect adjacent vertebrae at appropriate angles. The superficial back muscles, because of their large size, are better adapted to counter balancing the external loads and to achieving the overall spinal posture and movement. These models are supported by emerging evidence from research presented by Cresswell et al (1992) and Hodges and Richardson (1996 b; 1997a,b) to verify the trunk muscles involvement in lumbar-pelvic stability.

#### The role of transversus abdominis in lumbar-pelvic stability

Changes in intra-abdominal pressure and abdominal muscle activity during isometric trunk loading, trunk movements and graded pulsed Valsalva manoeuvres were measured by Cresswell et al (1992). The results showed that the transversus abdominis and to a lesser extent internal oblique muscles, had direct links with the development of intra-abdominal pressure. Furthermore, the transversus abdominis contracted with all trunk movements and was recruited prior to all other abdominal muscles with any perturbation of trunk movements. The authors suggest that the fibre orientation of transversus abdominis prevents it from generating either a flexion or extension torque of the trunk, but rather that it is activated during the movements of flexion and extension at a sustained level. It is possible that the transversus abdominis provides trunk stability and

compensates for unequal levels of activation between the right and left sides of rectus abdominis, internal and external oblique during trunk movements.

Transversus abdominis activity in subjects with low back pain:

Hodges and Richardson (1996 b; 1997 a, b) designed a series of experiments to establish the activity of transversus abdominis during stabilisation of the trunk. The relationship between a laboratory test (using fine-wire EMG) and a clinical test (using a pressure biofeedback unit) of transversus abdominis function, as a measure of trunk stability, was explored (Hodges et al, 1996 a). The laboratory test demonstrated that all the subjects without low back pain activated transversus abdominis before anterior deltoid, whereas all the subjects with low back pain showed delayed onset of transversus abdominis after anterior deltoid activity. Although the correlation between the absolute magnitude of pressure change and the magnitude of the transversus abdominis-anterior deltoid (TrA-AD) activation did not reach a level of significance, 93% (14/15) of the subjects could be correctly categorised into those with low back pain and those without low back pain by use of the TrA-AD latency data and 80% (13/15) on the basis of the pressure change data (Hodges et al, 1996 a).

The authors concluded that the two tests were capable of detecting a change in the function of transversus abdominis and could accurately identify subjects with or without low back pain. The pressure biofeedback unit is a useful indicator of

trunk stability in the non-athletic population but does not provide information as to neural control or level of transversus abdominis activity.

Transversus abdominis activity challenged by arm and leg movement:

The function of transversus abdominis was investigated further. When the stability of the lumbar spine is challenged by rapid arm and leg movements, transversus abdominis is the first trunk muscle activated ahead of deltoid and the hip flexors, abductors and extensors and the onset of its activity is not significantly affected by the direction of the reactive force (Hodges and Richardson, 1997 a, b). The transversus abdominis may contribute to the control of spinal stiffness through its role in the production of intra-abdominal pressure or via the tensioning of thoracolumbar fascia. The reaction time of the transversus abdominis and obliquus internus abdominis did not change with change of direction of arm and leg movements except for shoulder flexion. This indicates that the contraction of these muscles is not influenced by the direction of the reactive forces. One could thus conclude that contraction of these muscles is linked to the control of the stability of the spine against the perturbation produced by any movement of the limbs (Hodges and Richardson, 1997 a, b).

Trunk muscle activity during arm movement was also monitored in subjects with low back pain (Hodges and Richardson, 1996 b). The subjects with low back pain contracted transversus abdominis after the deltoid during all shoulder movements. The authors concluded that the delayed onset of contraction of

transversus abdominis indicates a deficit of motor control and results in inefficient muscular stabilisation of the spine.

A further study examined the co-activation of trunk flexor and extensor muscles in ten healthy individuals during the execution of slow trunk flexion-extension tasks (Cholewicki et al, 1997). The results showed low levels of antagonistic muscle co-activation, exhibited by normal healthy individuals during the execution of slow trunk flexion and extension tasks around the neutral trunk posture. In addition, the antagonistic muscle co-activation increased in response to increased axial loads on the spine. It would appear that flexor-extensor muscle co-activation observed in the healthy individuals played a role in providing mechanical stability to the lumbar spine around the neutral posture. When the six monitored muscles were examined individually a variety of muscle co-activation strategies existed (Cholewicki et al, 1997). Most of the individuals maintained a constant level of internal oblique muscle activity regardless of the trunk angle. Some individuals activated the multifidus in a similar way. Other subjects exhibited an overlap of activity between all of the trunk flexors and extensors. This implies that different individuals used different muscle recruitment strategies to stabilise the lumbar spine. The authors were of the opinion that such individual differences were due to the vast redundancy present in the human neuromuscular system.

The literature suggests that transversus abdominis and to a lesser degree internal oblique, is important for the maintenance of lumbar-pelvic stability (Hodges and Richardson, 1996 b; Cresswell et al, 1992 and Cholewicki et al, 1997). The contraction of the transversus abdominis and internal oblique muscles is not only observed during isometric trunk loading but also during arm and leg movements. The efficiency of these muscles may be inhibited by various factors such as low back pain (Hodges and Richardson 1997 a,b).

### Summary

Ballet dancers incur lumbar spine and lower limb injuries more frequently than upper limb injuries (Rovere et al, 1983; Hamilton et al, 1989; Garrick and Requa, 1993 and Nilsson et al, 2001). Lumbar spine injuries (23 %) were the most common in one group of dancers (Garrick and Requa, 1993) with ankle and foot injuries (54%) more dominant in a second group of dancers (Nilsson et al, 2001). Muscle injuries were the most common soft tissue injury (37%) in a dance company where 78% of the injuries were classified as chronic overuse injuries (Byhring and Bø, 2002).

The mechanism of injury varies in the ballet dancer but it is probably the combination of extrinsic and intrinsic causes. Incorrect ballet technique (Howse and Hancock, 1992) appears to be the most common extrinsic cause affecting the ballet dancer, while anatomical restrictions appear to be the most likely intrinsic cause. These anatomical restrictions such as decreased external

rotation of the hip (Stone, 2001) often force the dancer to use compensatory movements. The most recognised compensatory movements: anterior pelvic tilt, "screwing the knees" and "rolling in" may lead to injury of the lumbar spine and lower limb (Khan et al, 1995; Reid, 1987). More research is required to confirm this hypothesis.

Anterior pelvic tilt may predispose the dancer to developing muscle imbalances (Kendall et al, 1993). Muscle imbalances have been observed in the dancer that may be related to anterior pelvic tilt; increased strength of the psoas muscle (Peltonen et al, 1998) and weakness of abdominal muscles (Liederbach, 2000). The research demonstrates that the transversus abdominis and internal oblique muscles are activated in an attempt to stabilise the lumbar-pelvic region (Hodges and Richardson, 1996 b; 1997 a,b; Cresswell et al, 1992 and Cholewicki et al, 1997). The inability to recruit abdominal muscles may play a role in lumbar-pelvic stability in the ballet dancer. This has however not been investigated.

The literature suggests that ballet dancers have a high incidence of lumbar spine and lower limb injuries and are predisposed to the development of muscle imbalances around the lumbar-pelvic region. Although there is limited evidence on the aetiology of injury in the ballet dancer it is logical to conclude that lumbar-pelvic stability may be associated with lumbar spine and lower limb injuries.

The next phase of this study will determine the prevalence of injury in a group of ballet dancers. This will be followed by the experimental section where the

relationship between lumbar-pelvic stability and lumbar spine and lower limb injuries will be addressed.

University of Cape Town

**CHAPTER 3: THE BODY COMPOSITION,  
MORPHOLOGY AND INJURY HISTORY OF A  
GROUP OF PROFESSIONAL AND STUDENT  
CLASSICAL BALLET DANCERS IN CAPE TOWN.**

### Abstract

**Background:** The ballet dancer's career can be effected by injury. This may lead not only to the loss of possible roles but also to a loss of income. It is therefore important to be aware of the injury occurrence and possible factors that may predispose the ballet dancers to injury. Hence, the body composition, morphology and injury history of professional and student classical ballet dancers in Cape Town were measured and documented.

**Objectives:** The purpose of this study was twofold: (i) to determine the body composition, morphology of classical ballet dancers, and (ii) to determine the ballet career and training programme, and history of present and past injuries.

**Method:** An anthropometric assessment was done to measure height, body mass and percentage body fat. The subjects then completed a questionnaire designed to obtain information on their general ballet careers and training programmes, health and injury history.

**Results:** Thirty-eight ballet dancers (professional and students) ( $23.8 \pm 5.3$  years), with an average height of  $167.6 \pm 8.8$  cm, mass of  $57.2 \pm 10.1$  kg and average sum of skinfolds of  $70.3 \pm 24.7$  mm participated in this study. The first questionnaire showed that this group of dancers sustained 139 injuries, and an injury rate of 3.7 injuries per dancer. Back injuries were the most common followed by knee, shin and ankle. The second questionnaire showed that of the injuries ( $n=126$ ) sustained by the dancers 61 were acute, 55 chronic and 10 injuries acute-on-chronic.

**Conclusion:** Ballet dancers are relatively thin and are of short stature. Ballet dancers run the risk of injury, predominantly involving the lumbar spine and lower limb.

**Keywords:** Ballet dancer, injuries, epidemiology, anthropometric profile.

University of Cape Town

## Introduction

Classical ballet originated in the Italian courts during the 15<sup>th</sup> century but was developed by the French in the 16<sup>th</sup> and 17<sup>th</sup> centuries (Terry, 1976). Initially performed by the nobility as a form of entertainment, the "ballet dancer" was born when the movements started to become more complex. In the early 1830's dancing "en pointe" or on the tips of the toes was popularised. This was seen as a step forward as it gave the female dancer an ethereal sylph-like appearance. However, from an injury risk prospective it was most likely a step backwards (Quirk, 1994).

Ballet differs from other sports in that it is not just an athletic activity but also a performing art (Hamilton et al, 1992). The dancer is expected to express a variety of emotions whilst executing difficult movements to the time of the music. It is therefore not surprising that the ballet dancer spend hours perfecting their movements in the pursuit of excellence and aesthetics.

\* The technique of ballet is very demanding (Klemp and Learmonth, 1984). A ballet dancer requires flexibility whilst having to maintain strength and control, especially at the outer limits of range. A ballet dancer lacking the necessary range of movement develops compensatory movements to create the illusion of flexibility (Klemp and Learmonth, 1984). An individual dancer's limitations should be identified and considered from the beginning of their careers so that cautious and meticulous training with the proper understanding can take place (Gelabert,

1986). Khan et al, (1995) postulated that incorrect ballet technique is the cause of a large number of clinical presentations amongst ballet dancers. If these compensatory movements or incorrect techniques are repeated during class, rehearsals and performances, excessive strain may be placed on the musculoskeletal structures resulting in injury.

In ballet dancers the injury rate of the lumbar spine (12-23%) (Washington, 1978; Rovere et al, 1983; Garrick and Requa, 1993; Nilsson et al, 2001) is similar to the injury rate of the ankle (13-22%) (Washington, 1978; Rovere et al, 1983; Garrick and Requa, 1993) and the foot and toe (10-23%) (Washington, 1978; Rovere et al, 1983; Garrick and Requa, 1993). Knee injuries (11-15%) were the least common lower limb injury (Washington, 1978; Rovere et al, 1983; Nilsson et al, 2001). Sixty five percent of the injuries were chronic overuse injuries (Milan, 1994). There was a difference between genders with male dancers incurring 50% acute injuries and female dancers incurring only 23% acute injuries (Hamilton, 1989). The most frequently injured soft tissue was muscle at 58% followed by 17% tendon injuries and 5% ligament injuries (Byhring and Bø, 2002).

Dancers will often try to work through pain and injury and will only seek treatment when they are no longer able to dance (Macintyre and Joy, 2000). This may be done for a number of reasons. For example, dancers may conceal their medical problems for fear of retribution by artistic directors (Garrick and Requa, 1993). They may not want to miss an audition and consequently miss out on securing a

solo role. Minor injuries that may impair their ability to perform or a major injury that may jeopardise a career remain a constant concern in the back of a dancer's mind. It is therefore important to continually assess the injury history in a ballet company, in order to manage ballet dancers' injuries effectively. This information can be helpful in identifying the causes of injuries and in doing so prevent further injuries.

Therefore the aim of this study was to collect data pertaining to the ballet careers and training programmes, health and injury histories, of dancers of the Cape Town City Ballet and UCT Ballet School.

## Method

### **Subjects:**

Classical ballet dancers were recruited for this study and divided into two groups: professionals and students. All the professional dancers (n = 9 males; 11 females) from the Cape Town City Ballet Company and all the students majoring in classical ballet (n = 1 male; 17 females) at the University of Cape Town Ballet School participated in this study. All the available dancers were used. One female and two male professional dancers were unable to be tested due to rehearsal commitments and transport problems. All the student dancers attending the ballet school, at the time of testing, were tested. Ballet dancers with lower back pain were excluded from participating in the study, however none had back pain at the time of testing. The Ethics Committee of the Faculty of

Health Sciences at the University of Cape Town granted approval for this study (Appendix A). The dancers signed informed consent forms, after the study design had been explained to them (Appendix B).

### **General Procedure:**

An anthropometric assessment was done to measure height, mass and body fat. One tester took these measurements. Body fat was represented by the sum of seven skinfolds (triceps, biceps, subscapular, suprailiac, calf, thigh, abdomen) (Appendix C). These skinfolds were measured according to the method described by Ross and Marfell-Jones (1991). The subjects then completed a questionnaire designed to obtain general ballet career and training programme, health information and injury history (Appendix D). The injury questionnaire was two fold: the first recorded all of the injuries sustained by the dancer whilst the second recorded more detailed information regarding the last 5 injuries sustained. The questionnaires sought information related to (i) region and type of injury; (ii) tissue injured; (iii) divided into three time frames and (iv) activity during which injury was sustained. The management of the injury was also described.

### **Statistical Analysis:**

All values were expressed as mean  $\pm$  standard deviation and minimum and maximum (min – max) where appropriate. An independent t test was used to determine differences between professional and student, and male and female dancers respectively for the continuous variables. A Chi squared test was used to determine differences in the occurrences of injuries between professional and

student dancers. Statistica Software package (Version 6, Statsoft, Tulsa, OK, USA) was used to analyse the data. Statistical significance was accepted when  $P < 0.05$ .

## Results

### Demographic information:

Thirty-eight classical ballet dancers, 20 professional and 18 students participated in this study. The average age of the participants was  $23.8 \pm 5.3$  years (17 – 41 years; min-max), average height  $167.6 \pm 8.8$  cm (147.0 – 186.0 cm), average weight  $57.2 \pm 10.1$  kg (40.8 – 81.5 kg) and sum of skinfolds  $70.4 \pm 24.7$ mm (29.0 – 155.0 mm). The breakdown of these data for professionals and students and males and females are shown in table 3.1.

**Table 3.1: General characteristics of professional and student, male and female dancers. Values are expressed as mean  $\pm$  SD and minimum and maximum in brackets.**

	<b>Professional</b> (n = 20)	<b>Student</b> (n = 18)	<b>Male</b> (n = 10)	<b>Female</b> (n = 28)
Age (years)	27.7 $\pm$ 4.5 * (23.0 – 41.0)	19.4 $\pm$ 1.1 (17.0 – 22.0)	28.7 $\pm$ 6.3 # (19.0 – 41.0)	22.0 $\pm$ 3.6 (17.0 – 31.0)
Height (cm)	170.0 $\pm$ 9.5 (147.0 – 186.0)	165.0 $\pm$ 7.4 (153.0 - 184.0)	178.0 $\pm$ 6.1 # (168.0 – 186.0)	163.9 $\pm$ 6.3 (147.0 – 178.0)
Mass (kg)	59.2 $\pm$ 11.7 (41.0 – 82.0)	54.9 $\pm$ 7.7 (44.0 – 75.0)	70.5 $\pm$ 8.0 # (52.0 – 82.0)	52.4 $\pm$ 6.4 (41.0 – 65.0)
Sum of skinfolds (mm)	53.7 $\pm$ 11.3* (29.0 – 75.0)	88.8 $\pm$ 22.4 (51.0 – 155.0)	51.8 $\pm$ 12.3 # (29.0 – 64.0)	77.0 $\pm$ 24.8 (39.0 – 155.0)
BMI (kg/m <sup>2</sup> )	20.1 $\pm$ 1.7 (17.8 – 23.2)	21.3 $\pm$ 2.3 (17.0 – 24.3)	22.2 $\pm$ 1.7 # (18.6 – 24.3)	19.4 $\pm$ 1.6 (17.0 – 23.3)

\*  $P < 0.0000001$  Professional vs Student

#  $P < 0.005$  Male vs Female

The professional dancers consisted of 7 principal, 4 soloists and 8 "corpse de ballet" (lesser role dancers), with 8 students also participating in productions as "corpse de ballet". The average age at which the male and female dancers started dancing was  $10 \pm 5$  years (3 -17 years) and  $5 \pm 2$  (3 – 13 years) respectively.

Thirty dancers were Royal Academy of Ballet trained, seven dancers were trained in accordance with Cecchetti and one dancer was trained in both disciplines. The average cumulative years of dancing amongst the professionals was  $19 \pm 6$  years (9 – 29 years), with the students averaging  $14 \pm 1$  years (11 – 18 years).

### Dancing programme:

The hours of dancing per week have been divided into two categories: (i) for a non-performing week, and (ii) for a week during which performances occur. This is relevant as the hours spent rehearsing decreases during a performing week. These data are shown in Table 3.2. The 10 students that did not perform would have similar hours of class per non-performing week as the 8 students that did perform. The students (n = 8) that performed in the "corpse de ballet" often had longer rehearsal hours to compensate for their lack of experience. The longer class hours, as noted by the students, was due to some of the students taking extra classes in the evening.

**Table 3.2:** Time (minutes / week) spent during (i) non-performing week in class and rehearsal and (ii) performing week in class, rehearsal and performing.

	Professionals (n = 20)	Students (n = 8)
<b>CLASS (min/week)</b>		
Non-performing	443 ± 47 **	590 ± 152
Performing	445 ± 37	454 ± 80
<b>REHEARSAL (min/week)</b>		
Non-performing	1809 ± 908 *	893 ± 408
Performing	794 ± 221	820 ± 175
<b>PERFORMANCE (min/week)</b>		
	1029 ± 250 *	833 ± 93

\*  $P < 0.05$  Professionals vs Students

\*\*  $P < 0.001$  Professionals vs Students

The professional dancers danced for 7.5 hours / day during non-performing weeks (5 day) and 6.3 hours / day during a performing week (6 day). The 8

students danced for 4.9 hours / day in a non-performing week (5 day) and 5.9 hours / day in a performing week (6 day).

### **General health:**

Fourteen dancers complained of headaches, of which 8 had experienced headaches in the last month. Six dancers reported having had a cold in the last month and six more a cold within the last year. Seven dancers were asthmatic. A history of weight loss or gain of 3 kg or more was reported by 15 dancers, five suffered with heartburn regularly and 5 had experienced fainting spells.

### **Injury profile:**

The first questionnaire showed that the dancers had sustained a total of 139 injuries with the second questionnaire reporting on the last 5 injuries totaling to 126 injuries. The first injury questionnaire showed that the dancers had sustained one hundred and thirty nine injuries, throughout their entire ballet careers (n = 99 for professional; n = 40 for student dancers). Back injuries were the most common injury (n = 22), followed by knee injuries (n = 17), shin injuries (n = 16) and ankle injuries (n = 14). The remaining injuries were sustained in the following areas: neck (n=6), shoulder and arm (n=16), rib (n=1), hip joint and muscle (n=11), groin and thigh (n=10), foot (n=16) and toe (n=10). Of these injuries, 25 were current (less than a month old), 40 injuries had been sustained less than a year ago and 74 were sustained more than one year ago. A more detailed breakdown of these injuries is shown in Table 3.3.

**Table 3.3:** *Injury history: comparison of the location of injury between professional (n = 20) and student (n = 18) and whether the injury is current, less than 1 year or greater than 1 year old (n = 139 injuries).*

Location of injury	Professional			Student		
	current	< 1 year	>1 year	current	< 1 year	> 1 year
Neck, shoulder, arm, rib	2	4	14	2	1	1
Back, hip, groin, thigh	3	7	23	2	7	0
Shins, knee, ankle, foot	8	11	27	8	10	9
<b>Total</b>	<b>13</b>	<b>22</b>	<b>64</b>	<b>12</b>	<b>18</b>	<b>10</b>

A Chi squared test showed there was a significant association ( $X^2 = 18.1$ ;  $P < 0.0001$ ) in the occurrence of total injuries greater than 1 year between professional (n=64 injuries) vs student (n=10 injuries).

The second questionnaire with information regarding the injuries (n = 126 injuries) sustained in the last 5 years by each dancer, was obtained detailing the type of injury, mechanism of injury and preferred treatment. Not all the students had incurred five injuries whereas some of the professionals had incurred more than 5 injuries. Of these injuries 61 were acute, 55 chronic and 10 were acute-on-chronic. The type of tissue injured was recorded with muscle injuries being the most prevalent.

A more detailed breakdown of the injuries is shown in Table 3.4.

Table 3.4: *Different categories of soft tissue injury (5 most recent injuries for each dancer).*

	LOCATION							
	Joint	Ligament	Cartilage	Tendon	Muscle	Disc	Bone	Total
Number of injuries	28	24	3	15	35	3	18	126

Table 3.5 shows at what stage during the class the injury was sustained. The class is divided into "barre", "allegro", "pas de deux" and "en pointe" (see page 8 for definitions).

Table 3.5: *Activity during class at which time injury was sustained..*

Class	"barre"	"allegro"	"pas de deux"	"en pointe"
Number of injuries	17	40	12	1

Table 3.6 shows at what stage (start, middle and end) during rehearsal and performance the injury was sustained. Although some of the dancers were aware of symptoms of their chronic injuries at the beginning and at the end of the rehearsal or performance, there appears to be more injuries sustained in the middle of rehearsals however, this was not significant ( $X^2 = 2.7$ ;  $P = 0.26$ ).

**Table 3.6:** Activity (rehearsal and performance) during which injury was sustained.

	Start	Middle	End
Rehearsal	11	36	12
Performance	6	10	8

The dancers were asked to describe the management of the injuries and the time period, if any, that they were unable to dance. The total time off for the 126 injuries was 2352 days, of which nine injured dancers were absent for 1524 days. Of these 9 injuries, the maximum time spent recuperating from injury was 240 days by two dancers after knee surgery for torn menisci. A bone and tendon injury kept two dancers away from work for 180 days with recovery from knee meniscus, ligament and spinal disc injuries taking 153, 126 and 91 days respectively. Of the remaining 117 injuries, 64 injured dancers took no time off work and the remaining 53 injuries accounted for 828 absent days averaging out at 16 days of absenteeism per injury. Some of the dancers felt that they had not totally recovered from injury and nine of the injuries still lead to stiffness, pain ( $n = 37$ ) and weakness ( $n = 2$ ). The management of injuries is shown in Table 3.7. Many of the dancers managed their injuries with more than one modality.

**Table 3.7: Management of injuries**

Type of Treatment	Number of modalities used to manage injuries
Medication	32
Physiotherapy	84
Strapping	32
Rehabilitation	27
Surgery	6
Electrotherapy	56
Manual Therapy	79
<b>Total</b>	<b>316</b>

**Discussion:**

The anthropometric profile of male dancers (mass of  $70.5 \pm 8.0$  kg and height  $178 \pm 6.1$  cm) and the female dancers (mass of  $52.4 \pm 6.4$  kg and height  $163.9 \pm 6.3$  cm) in this study was similar to those found in a group of professional dancers (Mostardi et al, 1983). For example, this study showed that the average mass of male dancers was  $64 \pm 6$  kg and their height was  $175 \pm 5$  cm with the female dancers weighing an average of  $50 \pm 4$  kg and with an average height of  $165 \pm 6$  cm. Another study of female dancers reported a weight of  $53.1 \pm 6.6$  kg and an average height of  $166.6 \pm 6.7$  cm (Calabrese et al, 1983).

The first injury questionnaire showed that of the 139 injuries sustained by the dancers 18.5% were foot and toe, 16% back, 15 % hip, groin and thigh, 12% knee, 12% shin and 10% were ankle injuries. Neck, shoulder, arm and rib injuries made up the remaining 16.5%. These findings compare well to the ballet injuries described in the literature where the prevalence of foot and toe were 15-24% (Rovere et al, 1983; Garrick and Requa, 1993), lumbar spine injuries were between 12-23% (Washington, 1978; Rovere et al, 1983; Garrick and Requa, 1993; Nilsson et al, 2001), knee injuries 11-15% (Washington, 1978; Rovere et al, 1983; Nilsson et al, 2001), shin injuries 3-14% (Washington, 1978; Nilsson et al, 2001) and the ankle injuries 13-22% (Washington, 1978; Rovere et al, 1983; Garrick and Requa, 1993).

Back injuries are common. This has been documented in other studies (Bachrach, 1987; Washington, 1978; Rovere et al, 1983; Garrick and Requa, 1993; Nilsson et al, 2001). This may be largely due to dance technique that requires repetitive movement in the combined position of lumbar and hip extension. These positions are held either for a period of time i.e. "arabesque" or during an explosive leap i.e. "jete". Acute knee and ankle injuries are possibly sustained after landing incorrectly after a jump, "falling off pointe" in the female dancers or mishaps i.e. tripping over props on stage or dancers colliding with one another (Macintyre and Joy, 2000). Jumps are high risk as the jumps often include turning mid air or landing on one leg.

The shin injuries were highest amongst the students and may be due to bad or poor technique (Howse and Hancock, 1992). The students are still learning the correct techniques i.e. "plie". "Rolling in" (pronating) during "plie" is a common compensatory position in an attempt to maintain turnout (Marshall, 1988).

Repeated "rolling in" (pronating) may place strain on the musculature of the lower leg which may lead to anterior shin pain (Viitasalo and Kvist, 1983). The students also had to attend classes of other dance forms that necessitated foot stamping such as Spanish dancing, which may exacerbate the pain experienced in the lower leg.

The second injury questionnaire recorded the tissue injured (n=126) showing muscles to be injured the most at 28%, followed by joint injuries at 22%, ligament 19%, bone 14% and tendon 12%. The remaining 5% were menisci and lumbar disc injuries. This differs slightly from the literature with the most frequently injured soft tissue being muscle at 58% followed by 17% tendon injuries and 5% ligament injuries (Byhring and Bø, 2002). The reasons for muscles being the most injured soft tissue may be explained by inappropriate warm-up, muscle weakness or inflexibility, especially at the end of range of movement or cooling down in between rehearsals or whilst waiting to go on stage. These factors are perceived as contributing factors for injury by ballet dancers (Byhring and Bø, 2002). Tendon injuries often occur around the ankle and foot because of absorbing excessive strain in "turn out" and "en pointe" (Khan et al, 1995). Bone injuries may occur due to bad landing technique or decreased muscle strength,

~~X~~ reducing shock absorption by soft tissue and this may lead to stress fractures (Wajswelner, 1995). However, most of these mechanisms are postulated and no cause-effect relationships have been established in studies.

48%  
~~X~~ Forty eight percent of the injuries (n=126) sustained were acute, 44% chronic overuse and 8% acute-on-chronic injuries. On reviewing the literature Milan (1994) found that 65% of ballet injuries were chronic overuse injuries with 35% being acute injuries. Hamilton (1989) found that 77% of injuries in female dancers were chronic overuse injuries and 50% injuries observed among male dancers were chronic.

The professionals and students had a similar number of injuries currently and within the last year however, there was a difference between injuries sustained more than one year ago by professionals (46%) and students (7%). This difference in injury prevalence in the "over one year ago" category between professionals and students would be expected as the professionals have been dancing for a greater number of years.

One hundred and twenty six injuries were reported by the dancers in response to the second injury questionnaire pertaining to the last 5 injuries sustained by each dancer. The most injuries (n = 40) were sustained during the "Allegro" part of class with the middle of rehearsal being the period during which 36 injuries were sustained. The period of "Allegro", during which most injuries were sustained is

expected, as this is when leaps and jumps are practiced and the dancers are at more risk of sustaining injuries on landing such jumps (Macintyre and Joy, 2000). The fact that injuries were sustained midway through rehearsal may also be explained by dancers cooling down whilst waiting to rehearse their specific role.

The data should be interpreted in the context that the injury history questionnaire was completed by the dancers and therefore the responses were dependant on their ability to recall the mechanism, diagnosis and management of their injuries. Although this may weaken the interpretability of the data it was observed that most of the dancers were able to associate the injury with a specific season and were very aware of the circumstances surrounding the injury.

### Conclusion:

The results of this study are comparable to other studies with respect to anthropometric measurements, site of injury, type of tissue injured but differ in respect to nature of injury. These injuries seem to be confined to the lumbar spine and lower limb. The first injury questionnaire showed that of the 139 injuries sustained by the dancers 18.5% were foot and toe, 16% back, 15 % hip, groin and thigh, 12% knee, 12% shin and 10% were ankle injuries. Neck, shoulder, arm and rib injuries made up the remaining 16.5%. The second injury questionnaire recorded the tissue injured (n=126) showing muscles to be injured the most at 28%, followed by joint injuries at 22%, ligament 19%, bone 14% and

tendon 12%. The remaining 5% were menisci and lumbar disc injuries. Forty eight percent of the injuries (n=126) sustained were acute, 44% chronic overuse and 8% acute-on-chronic injuries. It would appear that the dancer runs a risk of injury with an injury rate of 3.7 which may affect the dancer's career.

**CHAPTER 4: RELATIONSHIP BETWEEN LUMBAR-  
PELVIC STABILITY AND THE PREVALENCE OF  
LOWER BACK AND LOWER LIMB INJURIES IN  
CLASSICAL BALLET DANCERS.**

## Abstract

**Background:** Ballet dancers used a few compensatory movements to achieve 180° turnout. One of these compensatory movements is anterior pelvic tilt. This position may lead to the development of muscle imbalances around the lumbar-pelvic area. This may effect lumbar-pelvic stability. The lack of lumbar-pelvic stability may predispose the ballet dancer to injury. However, the relationship between lumbar-pelvic stability and the injury prevalence in ballet dancers has not been investigated.

**Objectives:** The purpose of this study was: (i) to measure electromyographic (EMG) activity of three groups of abdominal muscles (rectus abdominis, external oblique and internal oblique) during two tests to establish a lumbar-pelvic stability index and (ii) to compare the lumbar-pelvic stability index results to prevalence of injury.

**Method:** All the available ballet dancers participated in this study, excluding dancers with lower back pain. The first test measured EMG activity of the rectus abdominis, external oblique and internal oblique muscles during the "draw in" manoeuvre. Simultaneously the activation and isolation of the transversus abdominis muscle was monitored using the pressure biofeedback unit placed under the abdomen. The "draw in" manoeuvre was executed in prone. The second test challenged lumbar-pelvic movement in supine whilst executing a single leg lowering movement. Lumbar-pelvic stability was monitored by the placing of pressure biofeedback unit under the lumbar spine. A lumbar-pelvic stability index was established (grade 1, 2 and 3, with grade 3 being the

strongest lumbar-pelvic stability index) and using these scores the relationship with the prevalence of injury was assessed.

**Results:** A significant difference in EMG activity was observed between internal oblique (46.0 % MVC) versus rectus abdominis (2.8 % MVC) ( $p < 0.001$ ) and between internal oblique (46.0 % MVC) and external oblique (10.6 % MVC) ( $< 0.001$ ) ( $F = 47.7$  and  $p = 0.000001$ ) during transversus abdominis activation and isolation testing of “draw in” in prone. A similar pattern of muscle activity was seen with “draw in” in supine between internal oblique versus rectus abdominis ( $p < 0.001$ ) and between the internal oblique and external oblique ( $p < 0.001$ ) ( $F = 32.6$  and  $p = 0.000001$ ). During the single leg lowering movement ten subjects were graded with a grade 1 lumbar-pelvic stability index (poor), 13 were graded 2 (average) and 15 were graded 3 (good). There was no relationship between the lumbar-pelvic stability index and prevalence of injury.

**Conclusion:** The lumbar-pelvic stability index was not associated with an increased prevalence of injury in ballet dancers. These data suggest that ballet dancers may have developed advanced or different strategies to stabilise the lumbar spine, however the test to determine the lumbar-pelvic stability may not be sensitive enough to identify differences in stabilisation strategies of dancers.

**Keywords:** ballet dancer, injury prevalence, lumbar-pelvic stability index.

### Introduction:

Spinal instability was described by Panjabi (1992) in terms of a region of laxity or high flexibility around the neutral position of a spinal segment, called the "neutral zone". Panjabi (1992) also believed that spinal stability was controlled by the deep intersegmental muscles as these muscles are placed closer to the centre of rotation of the spine and connect adjacent vertebrae at appropriate angles.

Anatomical, biomechanical and physiological features of muscles determine their function and are accordingly categorised into two groups: mobilisers and stabilisers (Richardson et al, 1992). Mobilising muscles are able to generate rapid, ballistic movements whilst stabilisers are slow, endurance and posture maintaining muscles. The mobilising muscles of the lumbar-pelvic region include rectus abdominis, lateral fibres of the internal oblique, external oblique, quadratus lumborum, iliopsoas and erector spinae. The stabilising muscles of the lumbar-pelvic region can be categorised into primary and secondary stabilisers (Norris, 2001). Primary stabilisers are those muscles which cannot create significant joint movement, such as the multifidus and transversus abdominis whilst secondary stabilisers have stabilising qualities but are able to cause joint movement, such as internal oblique (Norris, 2001).

Structural changes in muscles may lead to altered function (Sahrmann, 2002). Length changes occur in both mobilisers and stabilisers. Mobilisers tend to 'shorten' (tighten) and stabilisers tend to 'weaken' (lengthen) (Norris, 2001). The

'weakness' refers to the inability of the lengthened muscle to maintain a full contraction within the inner range of the muscle. This combination of tightness and weakness seen in muscle imbalances may affect a specific joint or adjacent body segments. When an imbalance occurs between the agonist and antagonist the alignment of the joint is altered changing the weight bearing stresses of that joint (Norris, 2001). Muscle imbalances between adjacent body segments where one segment is stiff (tighten) and the other lax (lengthen), may lead to the lack of accurate segmental control (White and Sahrmann, 1994).

In ballet, compensatory movements develop in an attempt by the dancer to achieve 180° turnout (Khan, 1995; Reid, 1987). These compensatory movements may result in muscle imbalances and injuries (Stephens, 1987; Coplan, 2002). There are three recognised compensatory movements: "rolling in" (Khan et al, 1995; Macintyre and Joy, 2000; Stephens, 1987), "screwing of the knee" (Reid, 1988) and anterior pelvic tilt (Solomon et al, 2000; Howse and Hancock, 1992). A theoretical model suggests that anterior pelvic tilt with lumbar extension may lead to the development of tightness and shortening of the hip flexors, especially iliopsoas and erector spinae and weakness in the abdominal stabilisers (Kendall et al, 1993; Janda and Jull, 1994). This is a posture that ballet dancers often assume (Bachrach, 1987). Grossman and Wilmerding (2000) suggest that poor lower abdominal control may interfere with a dancer's ability to stabilise in a turnout position. A deficit in control of the lower abdominal muscles may interfere

with the maintenance of a level pelvis during the execution of a variety of dance skills.

Transversus abdominis and to a lesser extent internal oblique, have direct links with the development of intra-abdominal pressure (Cresswell et al, 1992).

Furthermore, transversus abdominis contracts prior to all other abdominal muscles during perturbations of the trunk movements (Cresswell et al, 1992).

Transversus abdominis has been found to begin firing prior to the prime limb mover during both arm and leg movements (Hodges and Richardson, 1997 a, b).

The authors suggest that transversus abdominis may contribute to the control of spinal stiffness through its role in the production of intra-abdominal pressure or via the tensioning of thoracolumbar fascia (Hodges and Richardson, 1997 a).

To assess whether this pattern of muscle contraction is repeated with increased loading of the spine, the abdominal and multifidus muscles were monitored during leg movement (Hodges and Richardson, 1997 b). The transversus abdominis was invariably the first muscle to be activated during movement of the lower limb following contralateral weight shifting. This may suggest that transversus abdominis is involved in the preparation of the body for the disturbance produced by the movement. During various leg movements, failure of the reaction time of the transversus abdominis and obliquus internus abdominis to change indicates that the contraction of these muscles is not influenced by the direction of the reactive forces. One could thus conclude that contraction of these muscles is linked to the control of stability of the spine

against the perturbation produced by the movement of the lower limb itself. This contraction of the transversus abdominis and multifidus muscles in anticipation of reaction forces produced by limb movements may be evidence of central nervous system involvement.

Previous studies have used fine-wire EMG to measure transversus abdominis activity during various activities (Cresswell et al, 1992; Hodges et al, 1996 a). A clinical test was designed to quantify the ability of subjects to specifically displace the anterior abdominal wall in a way consistent with the function of the transversus abdominis muscle (Hodges et al, 1996 a). This was evaluated through the use of an air-filled pressure bag connected to a sphygmomanometer gauge (Stabiliser, Chattanooga, Australia). A linear relationship between the pressure change and loading, recorded with this apparatus, has been established previously (Jull et al, 1993). The magnitude of the performance of this manoeuvre was assessed as a change in pressure in the air-filled cells (Stabiliser) as the abdomen was lifted off the device. This was done in prone with the Stabiliser placed under the abdomen and the subjects were instructed to draw the abdomen off the Stabiliser. A further test demonstrated that during the clinical testing of transversus abdominis, the subjects with low back pain were less able to "draw in" the abdominal wall as a voluntary function, compared to subjects without pain (Hodges et al, 1996 a).

This evidence suggests that transversus abdominis and to a lesser degree internal oblique, is vital in the maintaining of intersegmental stability. The activation of transversus abdominis during drawing in of the abdominal wall and limb movement in subjects with low back pain is delayed (Hodges et al, 1996 a; Hodges and Richardson 1997 a, b). This would suggest that the efficiency of these muscles might be inhibited by various factors such as low back pain. The aim of this study was to (i) measure internal oblique, external oblique and rectus abdominis activity (using EMG) and transversus abdominis activity (indirectly using the pressure biofeedback unit), (ii) establish lumbar-pelvic stability index and to (iii) establish a relationship between this index and prevalence of injury in a group of ballet dancers.

## Methods

### Subjects:

Classical ballet dancers were recruited for this study and divided into two groups: professionals and amateurs. The professional dancers (n = 9 males; 11 females) were all members of the Cape Town City Ballet and the amateurs (n = 1 male; 17 females) were all students of the University of Cape Town Ballet School who were majoring in classical ballet. The subjects were tested randomly this depended on their availability due to having to attend classes and rehearsals. All the available dancers were used. One female and two male professional dancers were unable to be tested due to rehearsal commitments and transport problems. All the student dancers attending the ballet school, at the time of testing, were

tested. Ballet dancers with lower back pain were excluded from participating in the study, although some of the dancers ( $n = 22$ ) have had a previous episode of lower back pain, none had back pain at the time of testing.

Ballet dancers with lower back pain were excluded from participating in the study, however none had back pain at the time of testing. This study proposal was approved by the Ethics Committee of the Faculty of Health Sciences of the University of Cape Town (Appendix A). The dancers signed informed consent forms, after the study had been explained to them (Appendix B).

#### **General Procedure:**

A telemetric EMG (Noraxon USA Inc. Scottsdale, Arizona, USA) with seven channels was used to measure the EMG activity. Two surface electrodes (Blue Sensor, Medicotest A/S, Ølstykke, Denmark) were attached at each measuring point. The electromyographic (EMG) activity of three groups of abdominal muscles: rectus abdominis, external oblique and internal oblique muscles were measured during two tests. The first test measured EMG activity of the rectus abdominis, external oblique and internal oblique muscles during isolation and activation of the transversus abdominis muscle in a prone position.

Simultaneously a pressure biofeedback unit (Stabilizer, Chattanooga, Australia Pty. Ltd.) was placed under the abdomen to monitor change in pressure (mmHg). The pressure biofeedback unit comprised an inflatable rectangular cushion (23 cm x 14 cm) connected to a pressure gauge and inflation device.

The second test was designed to challenge trunk stability (by monitoring lumbar-pelvic movement). The subjects were tested in a supine position with their hips flexed at 70° and knees flexed (90°) with feet supported on the plinth. Each subject lifted one foot up and lowered the leg until it was parallel to the underlying surface. EMG activity of the abdominal muscles was measured during this activity and lumbar-pelvic movement monitored by means of the pressure biofeedback unit (Stabiliser, Chattanooga, Australia Pty. Ltd.) which was placed under the lumbar spine.

#### **Electromyographic (EMG) testing:**

Electromyographic activity was recorded in the rectus abdominis, external oblique and internal oblique muscles. The left and the right rectus abdominis, external oblique and internal oblique muscles EMG activity was measured. The positioning of the electrodes has been previously described by Ng et al (2002). The electrodes for the rectus abdominis was placed 1 cm above the umbilicus along the midline and then 2 cm lateral from this point. The electrodes over the external oblique muscle were placed just below the ribcage, along the line connecting the most inferior point of the ribcage margin and the contralateral pubic tubercle. This was done by placing a measuring tape starting at the most inferior point of the 12 th rib and ending on the pubic tubercle. The subject placed this end of the tape on the pubic tubercle. The electrodes over the internal oblique muscles were placed 1 cm medially to the anterior superior iliac spine and 1 cm beneath the line joining the left and right anterior superior iliac spine.

The measuring tape was placed running between the left and right anterior superior iliac spine. The electrodes were then placed 1cm medially and then 1cm distally from this spot. The ground electrode was placed over the right anterior superior iliac spine. The electrodes were placed 25 mm apart (centre to centre) and aligned parallel to the underlying muscle fibres. In preparation for electrode attachment the skin was shaved to remove dead skin cells and cleansed with alcohol swabs. This facilitated electrode adherence and conduction of the EMG signal. The electrodes were connected to an amplifier box from which the signal was transferred telemetrically to a computer with MyoResearch Software (Noraxon USA Inc. Scottsdale, Arizona, U.S.A.). All EMG data were sampled at 2000 Hz and the raw data were band pass filtered between 10 and 200 Hz to remove interference from electrical sources. The filtering procedure was performed using MyoResearch Software (Noraxon USA Inc. Scottsdale, Arizona, U.S.A.).

**Experimental procedure:**

The EMG activity of the rectus abdominis, external oblique and internal oblique was measured during an attempted sit-up against resistance and provided a baseline by which EMG data could be normalised. A maximum voluntary isometric contraction was used to normalise the amplitude of the EMG as this was shown to be the most reliable method of normalising EMG data (Burden and Bartlett, 1999; Burden et al, 2003). None of the subjects had lower back pain during testing. The subjects lay supine with a chest restraint, arms at their sides

and legs straight. A sit-up was attempted against the resistance of the chest restraint and manual resistance against the shoulders. Verbal encouragement was given to ensure that a maximal effort was produced. Each subject was tested three times with a 30 second rest period between contractions. The average of these three tests was used for normalisation.

The subjects were briefed on the anatomy of the abdominal muscles to enable them to visualise which muscle they needed to activate during the testing. The subjects were then positioned on their hands and knees in a four point kneeling position and given instructions to "draw in" the lower abdominal wall. Richardson and Jull (1995) described this technique of pulling the navel up and towards the spine to facilitate the contraction of the transversus abdominis. This movement was referred to as "drawing in" of the lower abdominal wall. The ribcage and pelvis had to remain still and the subject had to continue breathing normally throughout the contraction. The subjects were instructed to contract the transversus abdominis at only 30-40% of maximum. Richardson et al (1999) suggested that this was the optimal contraction of the transversus abdominis muscle during stabilisation of the trunk. All the subjects received the same instructions and three practice attempts were allowed. Faulty technique was not corrected as the dancer's to ability to isolate and activate transverses abdominis was being tested.

(i) Testing the isolation and activation of the transversus abdominis muscle in prone:

The subjects lay prone with the pressure biofeedback unit (Stabilizer, Chattanooga, Australia Pty. Ltd.) positioned under the abdomen. The distal end of the unit was placed along a line running between the right and left anterior superior spine (Hodges et al, 1996 a). The pressure biofeedback unit was pumped up to 60 mmHg and the valve closed. The resting pressure was recorded before activation of the transversus abdominis muscle to facilitate the calculation of the change in pressure. Jull and Richardson (1994) and suggested that the pressure should decrease by  $\geq 4$  mmHg if the transversus abdominis was recruited successfully. Two practice attempts were allowed before recording EMG activity. The instructions for activation of the transversus abdominis were recorded on a tape to insure that all the subjects received the same instructions at the same time interval. The EMG activity was measured coinciding with the command to the subjects to "draw in" their abdominal wall in (pulling the navel in and towards the spine). The change in pressure was noted. This process was repeated three times with a minimum rest period of 30 seconds between contractions.

(ii) Testing of abdominal muscle activity during movement of the lower limb:

The subjects positioned themselves in a supine position on a firm surface with their hips flexed at 70° and knees flexed (90°) with the feet supported on the plinth. The pressure biofeedback unit (Stabilizer, Chattanooga, Australia Pty.

Ltd.) was positioned under the lumbar spine between L2-S2. The unit was pumped up to 60 mmHg and the valve closed. Any decrease in pressure, due to extension of the lumbar spine, indicated a loss in lumbar-pelvic stability (Jull et al 1993). The subjects were instructed to “draw in” the abdominal wall to activate the transversus abdominis muscle to prevent lumbar extension and in doing so preventing lumbar-pelvic movement. First, the right foot was lifted up and the leg was straightened until it was parallel to the surface. The lowering of the leg was designed to challenge lumbar-pelvic stability. The subjects had five counts to lower the leg. The instructions for this test were also recorded and played to the subjects. Each subject had two practice runs after which the right leg was tested three times. The test was repeated with the left leg. The subjects had one minute to rest between each test. EMG activity of the abdominal muscles (rectus abdominis, internal oblique and external oblique) was recorded for the “draw in” manoeuvre only. Pressure changes were noted of the biofeedback unit corresponding with the instructions to “draw in”, “lift leg” and “lower leg”. These instructions were recorded to ensure consistency.

#### Data analysis:

The EMG amplitude was calculated using the root mean square equation to quantify the amplitude of the EMG signals (MyoResearch Software, Noraxon USA Inc Scottsdale, Arizona, U.S.A.). EMG data of the individual muscles was normalised relative to the maximal EMG values of the corresponding muscles this was measured during the maximal voluntary isometric contraction. The normalised muscle activity data were expressed as a percentage of the

maximum contraction. The EMG data was sampled for the “draw in” manoeuvre only as the subjects prepared to lower the leg. The change in pressure of the pressure biofeedback unit was noted and measured in mmHg. The EMG data for the second test in the supine position was sampled on the instruction to “draw-in”. The change in pressure of the pressure biofeedback unit was recorded during “draw-in” maneuver, the start and end of leg lowering movement. These data were normalised and the averages calculated for statistical analysis.

### Statistics:

All values are expressed as mean  $\pm$  standard deviation. A two-way analysis of variance with repeated measures was used to determine differences between EMG activity of rectus abdominis, internal oblique and external oblique muscles during the draw-in maneuver. A Tukey's post hoc test was used to identify specific differences when the F value was significant. A Spearman rank order correlation was used to determine differences between the lumbar-pelvic stability index and prevalence of injury. A Chi test was used to determine whether there were different incidences of injury in subjects with different lumbar-pelvic stability indices. Statistica Software package (Version 6, Statsoft, Tulsa, OK, USA) was used to analyse the data. Statistical significance was accepted as  $P < 0.05$ .

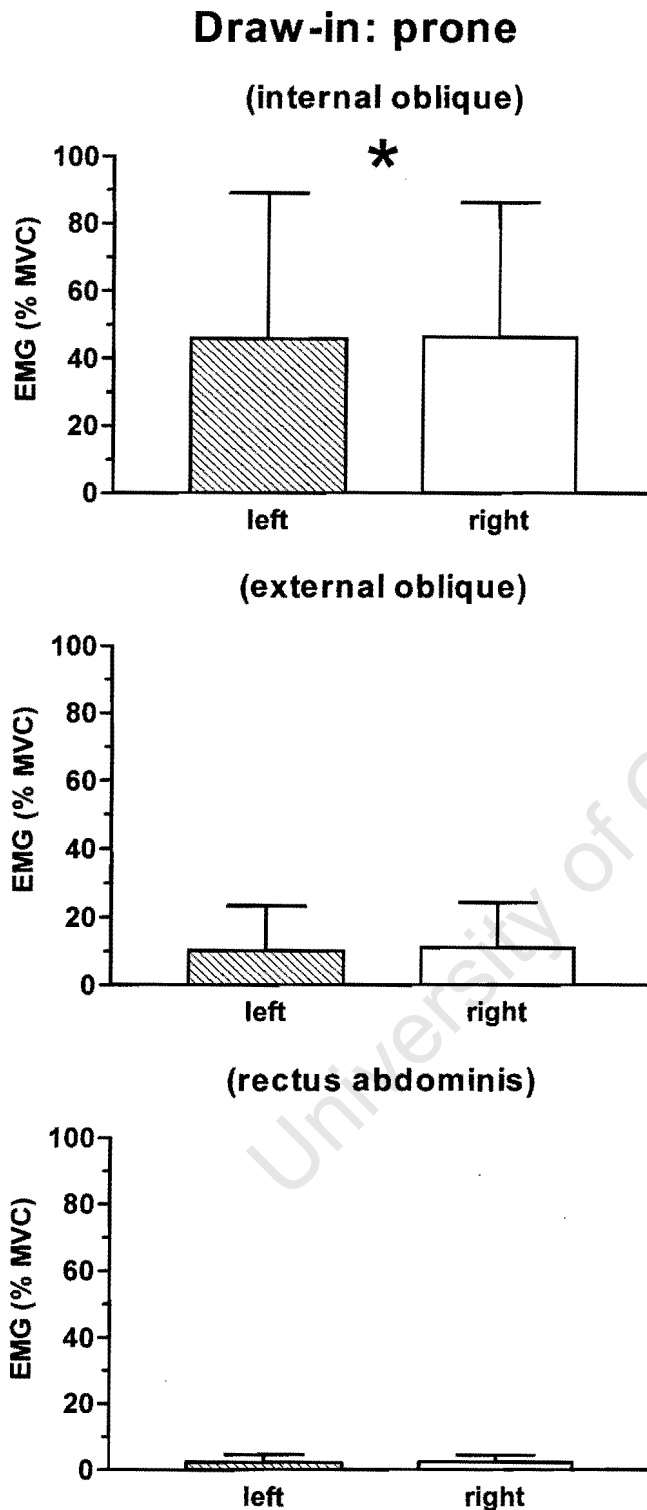
### Results:

The injury profile of the professional and student ballet dancers have been described in Chapter 3. Thirty-eight classical ballet dancers, 20 professional and 18 students participated in this study. The average age of the participants was

24 years (17 – 41 years; min-max), average height  $167.6 \pm 8.8$  cm (147.0 – 186.0 cm), average weight  $57.2 \pm 10.1$  kg (40.8 – 81.5 kg) and sum of skinfolds  $70.4 \pm 24.7$ mm (29.0 – 155.0 mm). The following results are used to investigate the relationship between the lumbar-pelvic stability index and injury prevalence.

**Prone test:**

The mean pressure change recorded by the pressure biofeedback cuff during “draw in” was  $4.1 \pm 2.5$  mmHg (–2.0 - 9.0 mmHg; min-max). The mean normalised EMG activity of the left and right abdominal muscles (IO  $45.8 \pm 43.2$  vs  $46.3 \pm 39.9$  % MVC; EO  $10.2 \pm 13.0$  vs  $10.9 \pm 13.3$  % MVC; RA  $2.3 \pm 2.3$  vs  $2.3 \pm 2.2$  % MVC; left vs right) were compared during the “draw in” manoeuvre and no significant difference was found. However there was a significant difference between the internal oblique (46.0 % MVC) versus the rectus abdominis (2.8 % MVC) ( $p < 0.001$ ) and the internal oblique (46.0 % MVC) versus the external oblique (10.6 % MVC) ( $p < 0.001$ ) ( $F = 47.7$  and  $p = 0.000001$ ). Figure 4.1 demonstrates that of the three muscles (internal oblique, external oblique and rectus abdominis) tested, internal oblique appears to contribute the most to the “draw in” manoeuvre.



*Figure 4.1: EMG activity of internal oblique, external oblique and rectus abdominis during "draw in" test in prone.*

\* internal oblique vs rectus abdominis  $p < 0.01$

\* internal oblique vs external oblique  $p < 0.01$

**Supine test:**

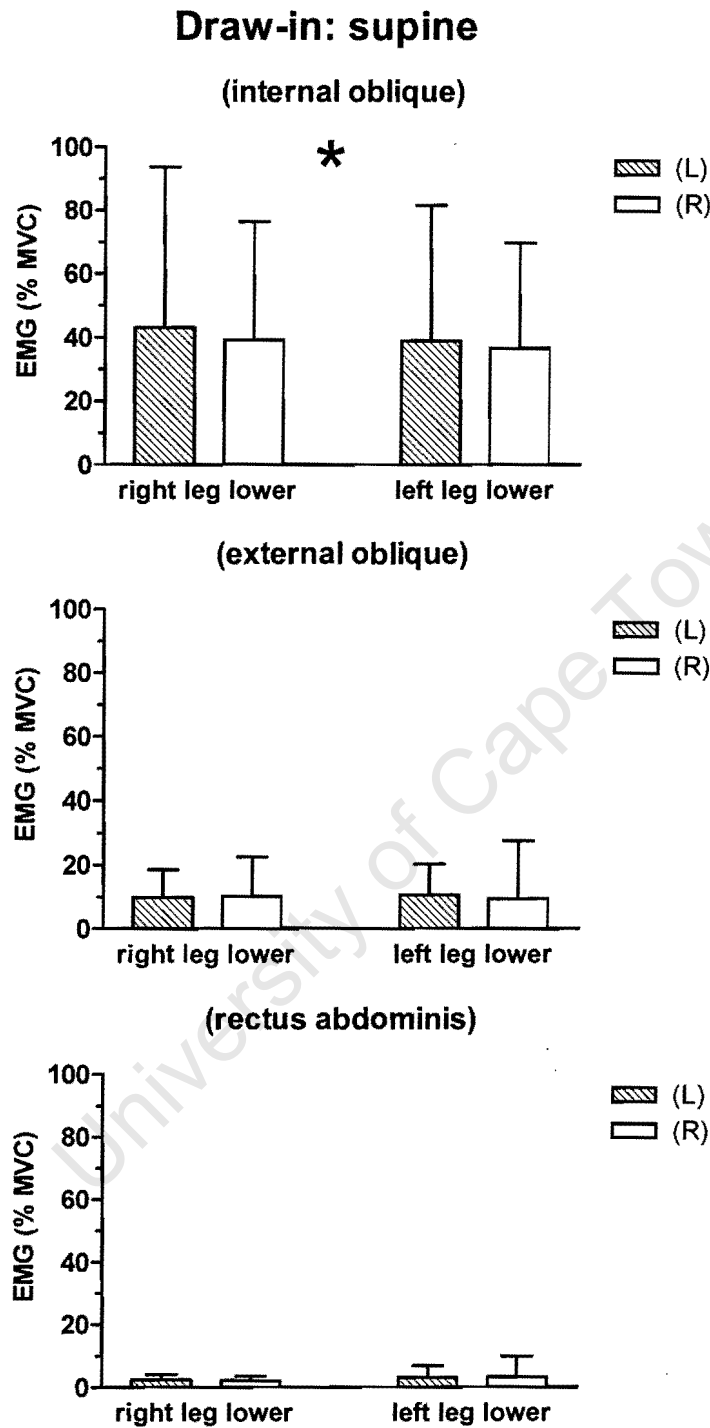
The mean pressure change recorded by the pressure biofeedback cuff during “draw in” manoeuvre in preparation for lowering the right leg was  $2.7 \pm 3.2$  mmHg ( $-2.0 - 14.0$  mmHg; min-max) and in preparation for lowering the left leg was  $3.1 \pm 4.4$  mmHg ( $-0.1 - 26.0$  mmHg; min-max). The mean normalised EMG activity of the left and right abdominal muscles were compared during the “draw in” manoeuvre in preparation for lowering the left and the right leg. No significant differences were found. However there was a significant difference between internal oblique versus the rectus abdominis ( $p < 0.001$ ) for lowering the left and the right leg. There was also a significant difference between internal oblique versus the external oblique ( $p < 0.001$ ) for lowering the left and the right leg ( $F = 32.6$  and  $p = 0.000001$ ). As with the “draw in” manoeuvre in prone, the “draw in” manoeuvre in supine would also activate the internal oblique muscle and increased activity of this muscle in comparison to external oblique and rectus abdominis is expected (Richardson and Jull, 1995).

Table 4.1 demonstrates the EMG activity of internal oblique, external oblique and rectus abdominis during the “draw in” manoeuvre in supine.

**Table 4.1:** Normalised EMG activity of muscles during “draw in” manoeuvre in supine. (RA – rectus abdominis, EO – external oblique, IO – internal oblique)

	EMG (% MVC)					
	Left RA	Right RA	Left EO	Right EO	Left IO	Right IO
In preparation to lower right leg	3 ± 3	2 ± 1	10 ± 9	10 ± 13	43 ± 51	39 ± 37
In preparation to lower left leg	3 ± 4	3 ± 7	11 ± 10	9 ± 18	39 ± 43	37 ± 33

Figure 4.2 shows the EMG activity of internal oblique, external oblique and rectus abdominis during “draw in” in supine.



**Figure 4.2:** Shows EMG activity of internal oblique, external oblique and rectus abdominis during “draw in” in supine.

- \* internal oblique vs rectus abdominis  $p < 0.01$
- \* internal oblique vs external oblique  $p < 0.01$

**Lumbar-pelvic stability index:**

The ability to stabilise the lumbar-pelvic region (maintain a neutral spine) was graded according to the loss of pressure on the pressure biofeedback cuff below the pressure achieved during the “draw in” phase of the supine leg-lowering test. The subject had to lower the leg within 5 counts. The count on which the pressure was lost, was noted. Loss of ability to stabilise on counts 1.0 - 2.5 was graded as a 1 (poor), loss of ability to stabilise on counts 3.0 - 3.5 was graded as a 2 (average) and, loss of ability to stabilise on counts 4.0 – 5.0 was graded as a 3 (good). Ten subjects were graded as 1’s, thirteen were graded as 2’s and fifteen were graded as 3’s. Table 4.2 indicates the grading of the dancers into the lumbar-pelvic stability index.

**Table 4.2:** *The grading of the dancers into the lumbar-pelvic stability index.*

Lumbar-pelvic stability index			
Grade	1	2	3
Number of dancers	10	13	15

To assist in an injury pattern recognition and to compensate for the small sample group, the injuries were grouped into three regions: group 1: neck, shoulder and arm; group 2: rib, back, hip, groin and thigh; and group 3: knee, shin, ankle, mid foot, metatarsal and toe. These scores were then compared to the injury profile. Table 4.3 shows the grouping of injuries into the lumbar-pelvic stability index with

lowering of the right leg. Table 4.4 shows the grouping of injuries into the lumbar-pelvic stability index with lowering of the left leg.

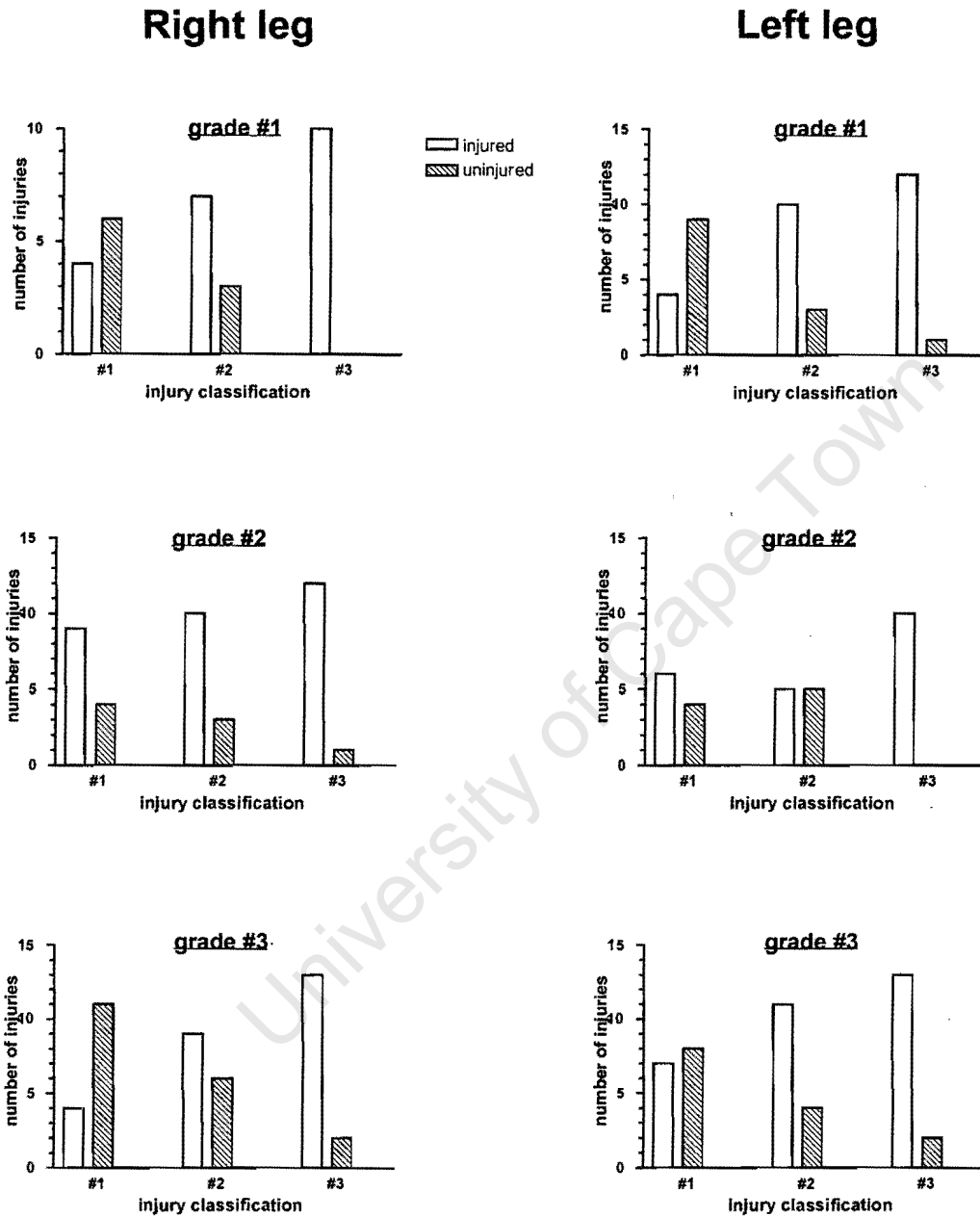
Table 4.3: Grouping of regional injuries into lumbar-pelvic stability index for lowering of the right leg.

AREA of INJURY	LUMBAR-PELVIC STABILITY INDEX during lowering of the right leg			
	<u>GRADE 1</u>	<u>GRADE 2</u>	<u>GRADE 3</u>	<u>TOTAL</u>
<u>Group 1</u>				
with injury	4	9	4	17
no injury	6	4	11	21
<u>Group 2</u>				
with injury	7	10	9	26
no injury	3	3	6	12
<u>Group 3</u>				
with injury	10	12	13	35
no injury	0	1	2	3

Table 4.4 Grouping of regional injuries into lumbar-pelvic stability index for lowering of the left leg.

AREA of INJURY	LUMBAR-PELVIC STABILITY INDEX during lowering of the left leg			
	<u>GRADE 1</u>	<u>GRADE 2</u>	<u>GRADE 3</u>	<u>TOTAL</u>
<u>Group 1</u>				
with injury	4	6	7	17
no injury	9	4	8	21
<u>Group 2</u>				
with injury	10	5	11	26
no injury	3	5	4	12
<u>Group 3</u>				
with injury	12	10	13	35
no injury	1	0	2	3

## Lumbar-pelvic stability index



**Figure 4.3:** The lumbar-pelvic stability index (grade 1, 2 or 3) of the right and left leg. The number of injuries, which have been divided into three regions (group 1- neck, shoulder, arm; group 2- rib, back, hip, groin, thigh or group 3- knee, shin, ankle, mid foot, metatarsal, toe), sustained in relation to the three degrees of lumbar-pelvic movement index.

However, no relationship was found on comparing the injury groups with lumbar-pelvic stability index.

### Discussion:

There are many ways of assessing transversus abdominis activity as an indicator of segmental lumbar spine stability. Fine-wire EMG and ultrasound imaging would be the most reliable methods of monitoring transversus abdominis activity when challenging segmental lumbar spine stability (Cresswell et al, 1992; Hodges et al, 1996 a; Hides et al, 1995; Teyhen et al, 2005). However, these methods are not freely available to clinicians in their practices. Hence a clinical test to assess transversus abdominis activity as an indicator of segmental lumbar spine stability was chosen.

Ultrasound imaging during the technique of abdominal hollowing ("draw in" manoeuvre) showed preferential recruitment of transversus abdominis, in subjects with lower back pain. (Teyhen et al, 2005). The "draw in" manoeuvre was monitored with a pressure biofeedback unit in prone and was found to be an indicator of transversus abdominis activity (Hodges et al, 1996 a). Eighty percent of low back pain subjects were identified on the basis of the pressure change data measured by the pressure biofeedback unit. It was therefore decided to use a pressure biofeedback unit in this study as a tool to assess the dancer's ability to isolate and activate transversus abdominis during the "draw in" manoeuvre in prone.

The mean pressure change recorded by the pressure biofeedback unit during the “draw in” manoeuvre by this group of dancers was  $4.1 \pm 2.5$  mmHg (- 2.0 – 9.0 mmHg). This compares well to a previous study where  $\geq 4$  mmHg was found to be expected pressure change during the correct execution of the “draw in” manoeuvre (Jull and Richardson, 1994).

In conjunction with the pressure biofeedback unit, EMG activity of certain muscles was measured. As surface EMG electrodes were used in this experiment and not fine-wire EMG, the EMG activity of internal oblique, external oblique and rectus abdominis and not transversus abdominis was measured. However, the EMG activation of internal oblique was similar to EMG activity of transversus abdominis during segmental lumbar spine stabilisation (Cresswell et al, 1992). Internal oblique maintained a constant level of activity regardless of trunk angle in most individuals during slow trunk flexion and extension (Cholewicki et al, 1997). This may suggest that internal oblique does have a stabilising affect especially the lower fibres of internal oblique which run horizontally, which is similar to that of transversus abdominis (Moore, 1992).

The electrodes were placed in such a position that the EMG activity of the lower fibres would be measured (Ng et al, 2002). Although there are some authors that disagree with the involvement of the transversus abdominis in segmental lumbar spinal stabilisation (De Troyer et al, 1990), this study used the EMG activity of internal oblique to reflect the activity of transversus abdominis and give an

indication of segmental lumbar spine stabilisation. This is supported by a number of studies (Cresswell et al, 1992; Cholewicki et al, 1997).

The greater EMG activity of internal oblique during the "draw in" manoeuvre in prone in comparison to rectus abdominis and external oblique activity was seen in this group of dancers. This is to be expected, as internal oblique is believed to assist transversus abdominis during segmental lumbar spine stabilisation (Cresswell et al, 1992).

The EMG activity of the external oblique and rectus abdominis has been demonstrated in a study where internal oblique was activated in all the subjects, external oblique in 50% of the subjects and rectus abdominis in less than 5% of subjects during the "draw in" manoeuvre in prone (Beith et al, 2001). This implies that different individuals use different muscle recruitment strategies to stabilise the lumbar spine (Cholewicki et al, 1997). This is possibly even more relevant to the sporting population as they may have to compensate to allow them to execute sport specific techniques. Very little research has been done to assess the recruitment strategies of sportsmen/women during segmental lumbar spine stabilisation.

The results of the pressure biofeedback unit and EMG activity would suggest that the dancers were able to achieve segmental lumbar spine stability with a neutral spine, as they were able to isolate and activate internal oblique during "draw in"

in prone. This however only monitored the activation of the internal oblique muscle and not the timing of the muscle contraction.

Gross lumbar-pelvic stability was measured by the ability to maintain a neutral spine whilst lowering a leg. A lumbar-pelvic stability index rating of three (the loss of ability to maintain a neutral spine on counts 4.0 – 5.0 was graded as a three during leg lowering) was seen by the author as essential for ballet dancers to be technically correct. If a ballet dancer is unable to maintain lumbar-pelvic stability in a position where gravity has been eliminated it is prudent to assume that lumbar-pelvic stability may not be maintained in standing. Therefore, the decision was made to use grade 3 as an indicator of adequate global lumbar-pelvic stability.

Only 15 out of 38 (39%) dancers were able to maintain a lumbar-pelvic stability of grade 3 during leg lowering in supine. The result is surprising, as one would expect the majority of ballet dancers to have strong lumbar-pelvic stability.

The test would have challenged both local and global spinal stabilising muscles. Although none of dancers had lower back pain during testing, which would have delayed onset of transversus abdominis activity when lumbar spine stability was challenged (Hodges et al, 1996 a; Hodges and Richardson 1997 a, b), they all had a history of injuries. Therefore no injury free control group of dancers was

tested for lumbar-pelvic stability and no comparison could be made or a norm established.

As all three grades of the lumbar-pelvic stability index demonstrated similar numbers of injuries, in all three groupings of injury, no relationship was found between injury prevalence and inadequate lumbar-pelvic stability. This may be due to several factors.

It would appear that some of the dancers with a group 2 injury history had adequate lumbar-pelvic stability whilst others did not. This may be due to effective rehabilitation post-injury in some and not in others. If the dancer did not follow an effective post back injury rehabilitation programme to retrain timeous contraction of transversus abdominis and internal oblique and strengthening of global muscle, lumbar spine stability may not have been achieved. However, some dancers did achieve lumbar spine stability. They may not have necessarily used transversus abdominis or internal oblique to achieve this, but used other strategies to stabilise the lumbar spine. Subjects with lower back pain have been shown to demonstrate different abdominal muscle recruitment strategies to stabilise the spine (Hublely-Kozey and Vezina, 2002).

Grade 2 and 3 lumbar-pelvic stability index showed similar numbers of group 3 injuries. There is no evidence to show how lower limb injuries in ballet dancers would effect lumbar spine stability. Compensating for pain, weakness or

decreased range of movement due to injury of a lower limb structure may well lead to numerous lumbar spine stabilising strategies. This is an area where research is lacking and deserves further investigation.

Due to the small number of available subjects and relatively low statistical power, it was difficult to differentiate between current injuries and old injuries and then to relate this to the lumbar-pelvic stability index. If the statistical power was greater a comparison between the current and old injuries may have resulted in interesting findings.

### Conclusion:

The first test showed that the internal oblique muscle is primarily responsible for the "draw in" manoeuvre of the three muscles tested. This would suggest it is working as a local stabilising muscle of the spine, which allows the rectus abdominis and external oblique to work as global spinal mobilisers and movers. This group of dancers showed limited compensation strategies using internal oblique almost exclusively during the "draw in" manoeuvre. This would indicate good segmental stability for this group.

The second test demonstrated global lumbar-pelvic stability in a group of ballet dancers, as assessed using leg lowering. The results showed a wide variation in lumbar-pelvic stability. This may suggest that ballet dancers have developed strategies using other trunk muscles to compensate for the decreased segmental control of the lumbar spine by transverses abdominis and internal oblique. No

specific relationship between global lumbar-pelvic stability and injury prevalence was found.

University of Cape Town

## **CHAPTER 5: SUMMARY AND CONCLUSION**

University of Cape Town

Ballet dancers are constantly aware of the threat of injury. This creates anxiety because an injury can affect the dancers' ability to perform and the ability to secure roles in a ballet, which may lead to a loss of earnings. However, dancers do not always seek medical attention because their schedules are too busy to allow them the time to attend appointments, they have financial constraints or they do not want management to know that they are injured.

Dancers injuries have been reviewed in the literature and it would appear that dancers incur lumbar spine and lower limb injuries in a greater frequency than upper limb injuries (Rovere et al, 1983; Hamilton et al, 1989; Garrick and Requa, 1993 and Nilsson et al, 2001). Lumbar spine injuries (23 %) were the most common in one group of dancers (Garrick and Requa, 1993) with ankle and foot injuries (54%) more dominant in a second group of dancers (Nilsson et al, 2001). Muscle injuries were the most common soft tissue injury (37%) in a dance company where 78% of the injuries were classified as chronic overuse injuries (Byhring and Bø, 2002).

This present study describes the injuries incurred by professional dancers of the Cape Town City Ballet and students of the UCT Ballet School. Thirty-eight dancers participated in this study of which 20 were professional (average age 27.7 years) and 18 were students (average age 19.4 years). A general injury questionnaire showed that, 139 injuries were sustained by this group of dancers. Of these injuries 16% were back, 12% knee, 12% shin and 10% ankle injuries.

One hundred and twenty six injuries were reported on in the questionnaire detailing the last 5 injuries sustained by each dancer. The most injuries ( $n = 40$ ) were sustained during the "Allegro" part of class with the middle of rehearsal being the period during which 36 injuries were sustained. Sixty-one of the injuries sustained were acute, 55 chronic overuse and 10 acute-on-chronic injuries. The distribution of soft tissue injuries showed muscles to be injured the most at 28%, followed by joint injuries at 22%, ligament 19%, bone 14%, tendon 12% and 5% neural.

Anterior pelvic tilt with lumbar extension is a compensatory movement often used by ballet dancers. This may predispose the dancer to developing muscle imbalances (Kendall et al, 1993). Muscle imbalances have been observed in dancers that may be related to anterior pelvic tilt, increased strength of the psoas muscle (Peltonen et al, 1998) and weakness of abdominal muscles (Liederbach, 2000). The research demonstrates that the transversus abdominis and internal oblique muscles are activated in an attempt to stabilise the lumbar spine (Hodges and Richardson, 1996 b; Cresswell et al, 1992 and Cholewicki et al, 1997).

Two tests were designed to:

(i) establish whether or not a group of ballet dancers were able to isolate and activate internal oblique as a reflection of transversus abdominis activity during a "draw in" manoeuvre,

(ii) establish if this group of dancers were able to stabilise the lumbar-pelvic region during a leg lowering movement. Once a lumbar-pelvic stability index had been established a relationship between this index and injury prevalence was sought.

The first test showed that the internal oblique muscle is primarily responsible for the "draw in" manoeuvre of the three muscles tested. This would suggest it is working as a local stabilising muscle of the spine, which allows the rectus abdominis and external oblique to work as global spinal mobilisers and mobilisers.

The second test demonstrated that on challenging lumbar-pelvic stability in dancers during leg lowering in supine, only 15 out of 38 (39%) dancers were able to maintain a lumbar-pelvic stability of grade 3. This result is surprising, as one would expect the majority of ballet dancers to have strong lumbar-pelvic stability.

No relationship between lumbar-pelvic stability and injury prevalence was found. All three grades of the lumbar-pelvic stability index demonstrated similar numbers of injuries, in all three groupings of injury.

Due to an inability of a number of dancers to maintain global stability during leg lowering, it would be ideal for the ballet company to have a resident physiotherapist and/or biokineticist to introduce rehabilitative strengthening. The Cape Town City Ballet Company however, is unable to afford this and the

dancers therefore have to leave the premises to seek medical attention. This is time consuming especially for the dancers that are largely dependant on public transport. Many of the dancers have the most basic medical aid, which only covers limited physiotherapy and rehabilitation of injuries. They are unable to afford to pay for treatment themselves and although Workman's Compensation claims are submitted, these claims are slow to be processed and caregivers are not always guaranteed payment. The dancers are aware of this and are reluctant to use Workman's Compensation unless they sustain a severe injury that may need costly medical investigations or surgery followed by intensive rehabilitation.

The practical application of the findings of this thesis is that it is important for management and medical staff to monitor ballet dancer's injuries especially in respect to the mechanism and type of injury. This will allow the management of the ballet company to implement a plan to minimise the risk of injury and hereby play a preventative role in the incidence of injuries. This will enable the medical staff to assess ballet dancer's injuries timeously and to treat effectively, allowing restricted dancing under supervision, to minimise time off dancing.

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## APPENDICES

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University of Cape Town



Appendix A

FACULTY OF HEALTH SCIENCES

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11 November 2002

Miss M Swart  
14 The Fields  
Field Close  
Pinelands  
7405

Dear Miss Swart

MSc PROPOSAL

Candidate	Swart M (SWRMIC003)
Degree:	Bsc in Physiotherapy
Department:	Allied Health Sciences
Qualifications:	BSc Physio (Hons) (1998) OFS
Title:	Differences in the prevalence of lower limb injuries in classical ballet dancers with or without trunk stability
Supervisor:	Mrs J Gray, Prof M Lambert

I am pleased to advise that chairperson of the Dissertations Committee has approved your candidature for the above degree on behalf of the Committee. Formal approval will be obtained by publication in the next Dean's Circular (MED06/02).

If you have any further queries, please do not hesitate to contact me.

With best wishes.

Sincerely

A handwritten signature in cursive script, appearing to read 'M de Vries'.

MARILYN DE VRIES  
POSTGRADUATE OFFICER

c.c. Mrs J Gray, Prof M Lambert

## Appendix B

**MRC / UCT**  
**Research unit for Exercise Science and Sports Medicine**  
**(ESSM)**  
**Department of Human Biology**

Dear Volunteer,

The MRC / UCT Research Unit for Exercise Science and Sports Medicine will be conducting a study to investigate the prevalence of lower limb injuries in ballet dancers and the strength of abdominal stabiliser muscles to establish whether there is a relationship between lower limb injuries and abdominal stabiliser strength.

The study will involve:

- Answering of a questionnaire to attain an injury history
- Height, body mass and skin folds will be measured.
- The muscle strength of abdominal stabilisers using the pressure biofeedback unit will be measured.

I confirm that the nature and testing procedure of the tests have been fully explained to me. I understand that I may ask questions at any time during the testing procedure. I agree to comply with any instructions given during the study. I realise that I am free to withdraw from the study without prejudice at any time, should I choose to do so.

I accept that the results of the study may be published in a research manuscript, and understand that my identity as a subject in this study will always be kept anonymous.

I have carefully read this form. I understand the nature of this study. I agree to participate in this study of the MRC / UCT Research Unit for Exercise Science and Sports Medicine.

Name of volunteer: \_\_\_\_\_  
 (in full)      Signature: \_\_\_\_\_  
                     Date: \_\_\_\_\_

Name of Witness: \_\_\_\_\_  
 (in full)      Signature: \_\_\_\_\_  
                     Date: \_\_\_\_\_

Name of researcher: \_\_\_\_\_  
 (in full)      Signature: \_\_\_\_\_  
                     Date: \_\_\_\_\_

## Appendix B

**MNR / UK  
Research Unit for Exercise Science and Sports Medicine  
(ESSM)**

Department of Human Biology  
Geagte Vrywilliger,

Die MNR / UK Research Unit fo Exercise Science and Sports Medicine gaan 'n studie uitvoer om die prevalensie van beserings van die onderste ledemaat in balletdansers en die sterkte van abdominale stabiliseerders te ondersoek en om te bepaal of daar 'n verhouding bestaan tussen beserings van die onderste ledemaat en die spiersterkte van abdominale stabiliserende spiere.

Die studie sal die volgende insluit:

- Die beantwoording van 'n vraelys om 'n geskiedenis van beserings te verkry en
- Lengte, ligaam massa en velvou sal gemeet word.
- Spiersterkte van abdominale stabiliseerders sal getoets word deur gebruik te maak van die druk-beheerde bioterugvoer eenheid.

Ek bevestig dat die aard en toetsprosedures van die toetse volledig aan my verduidelik is. Ek verstaan dat ek mag vrae vra enige tyd tydens die toetsprosedure. Ek stem in om te voldoen aan enige instruksies wat tydens die studie gegee word. Ek besef dat ek vry is om van die studie te onttrek sonder vooroordeel te enige tyd, indien ek sou kies om dit te doen.

Ek aanvaar dat die resultate van hierdie studie moontlik gepubliseer sal word in 'n navorsings manuskrip. Ek verstaan dat my identiteit anomien sal bly.

Ek het hierdie vorm sorgvuldig gelees. Ek verstaan die aard van die studie. Ek stem in om aan hierdie studie van die MNR / UK Research Unit for Exercise Science and Sports Medicine deel te neem.

Naam van Vrywilliger: \_\_\_\_\_  
(voluit) Handtekening: \_\_\_\_\_  
Datum: \_\_\_\_\_

Naam van Getuie: \_\_\_\_\_  
(voluit) Handtekening: \_\_\_\_\_  
Datum: \_\_\_\_\_

Naam van Navorser: \_\_\_\_\_  
(voluit) Handtekening: \_\_\_\_\_  
Datum: \_\_\_\_\_

## Appendix C

**Anthropometric Assessment**Name: \_\_\_\_\_ Male  Female 

Date of birth \_\_\_\_\_

Height \_\_\_\_\_ m

Weight \_\_\_\_\_ kg

**Skinfolds (mm)** \_\_\_\_\_

Triceps: \_\_\_\_\_

Biceps: \_\_\_\_\_

Subscapular: \_\_\_\_\_

Suprailiac: \_\_\_\_\_

Calf: \_\_\_\_\_

Thigh: \_\_\_\_\_

Abdominal: \_\_\_\_\_

**Injury Questionnaire:**

**Appendix D**

Date: \_\_\_\_\_

Name : \_\_\_\_\_ Male  Female

Date of birth: \_\_\_\_\_ (Day/ Month/ Year)

Ballet status 1: Student \_\_\_\_\_  
2: Professional \_\_\_\_\_

Corps de Ballet  Soloist  Principals

Age started dancing \_\_\_\_\_

Which technique RAD  Cechetti

**Ballet schedule First and second week**

Discipline	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Hours of class							
Hours of pointe work							
Hours of rehearsal							

**Ballet schedule 1 week before performance**

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Hours of class							
Hours rehearsal							

**Week of performance**

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Hours of class							
Hours rehearsal							
Hours performance							

How many seasons in a year? \_\_\_\_\_

How long does a season run for ? \_\_\_\_\_

**Participation in other dance forms:**

	Type (tick)	How many years ? (dates)	How many hours per week ? If still participating.		
			last 3 months	3 to 6 months	6- 12 months
Modérn					
Contemporary					
Jazz					
African					
National					
Spanish					
Tap					

**Other exercises to compliment ballet:**

	Type (tick)	How many years ? (dates)	How many hours per week ? If still participating.		
			last 3 months	3 to 6 months	6- 12 months
Pilates					
Gym					
Aerobics					
Water activities					

**Do you now have, or have you ever had, any of the following conditions?**

	<i>Fill in all 3 columns</i>	Please tick for yes	Duration	
			Within the last year	More than a year ago
1	Frequent headaches (1 per weeek)			
2	Fainting spells/ dizziness			
3	Frequent colds (1 per month)			
4	High Blood pressure (> 150mmHg)			
5	Allergies			
	Food that should not be taken			
	Skin allergies			
	Medication:			
6	Asthma			
7	Weight loss/ gain : (3kg either way)			
8	Indigestion/ Hearburn			
9	Hereditary conditions			
10	Any other? Please state.			

**Current and Previous Injuries**

Do you have, or have you ever had, any of the the following conditions ?

(Please tick)

No		Number : from recent to oldest	Current and Previous		
			Current (last month)	Previous (1-12 months ago)    >12 months ago	
1	Neck injuries				
2	Shoulder injuries				
3	Arm/ Wrist / hand injuries				
4	Ribcage injuries				
5	Back injuries				
6	Hip joint injuries				
7	Hip Muscle injuries				
8	Groin injuries				
9	Thigh injuries				
10	Knee injuries				
✓ 11	Lower limb / shin splints				
✓ 12	Ankle injuries				
✓ 13	Midfoot injuries				
✓ 14	Metatarsal injuries				
✓ 15	Big Toe injuries				
✓ 16	Muscle strains				
✓ 17	Tendon injuries				
18	Abdominal injuries				
19	Any other				

**Injury No:**  **Date of injury :** \_\_\_\_\_

**Activity during which injury sustained ? (please tick below)**

Class                      Barre                                            Other dance forms                        
    Allegro                        
    Pas de deux                     

	Beginning	Middle	End
Rehearsals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mechanism of injury	Acute <input type="checkbox"/>	Chronic <input type="checkbox"/>	Acute on chronic <input type="checkbox"/>

Diagnosis: \_\_\_\_\_

**Treatment:**

Medication                        
 Physiotherapy                                            Electrotherapy                                            Manual therapy                        
 Strapping                                            Special tests                                            Specify : \_\_\_\_\_  
 Rehabilitation                        
 Surgery                                            Rest                     

Time off dancing: \_\_\_\_\_ (How many days/ weeks)

Did you see a Doctor?                      Yes                       No   
 Did you see a physio?                      Yes                       No   
 Complete recovery ?                      Yes                       No

If NO, what are your symptoms? \_\_\_\_\_