

**Injury incidence and the use of the Movement Competency Screen  
(MCS) to predict injury risk in full-time dance students at the New  
Zealand School of Dance (NZSD): A prospective cohort study.**

**Linda Lee**

Supervisors: Associate Professor Duncan Reid

Jill Caldwell

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## ATTESTATION OF AUTHORSHIP

“ I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been accepted for publication for the qualification of any other degree or diploma of a university or other institution of higher learning”.

Signed:



Date: 30 October 2015

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## **ETHICAL APPROVAL**

The University of Technology Ethics Committee (AUTEC) granted ethical approval for this research on the 23 September 2013. AUTEC Reference Number: 13/245.  
(see Appendix A)

## ABBREVIATIONS USED THROUGHOUT THIS THESIS

Variable Nomenclature	Variable definition
CI	Confidence Interval
OR	Odds Ratio
B	Unstandardized coefficient
DE	Dance exposure
DEhr	Hours of dance exposure
FMS	Functional Movement Screen
HPSNZ	High Performance Sport New Zealand
IPAIRS	International performing arts injury reporting system
MCS	Movement Competency Screen
NZSD	New Zealand School of Dance
SD	Standard Deviation

# **ABSTRACT**

## **Objective**

To establish the injury incidence and characteristics amongst pre-professional ballet and modern dance students undertaking full-time training, as well as the relationship between dance exposure and injury risk. This study also aimed to establish the relationship between the Movement Competency Screen (MCS) outcomes and injury risk.

## **Introduction**

Dancers undertaking pre-professional training are of an age considered to be high risk for injury, which can have long-term implications on participation and performance. There is a need for research utilising standardised injury and exposure measures so as to better understand the injury profile of this specific population. The growth of dance medicine has seen an associated rise in pre-participation screening to identify those at risk of injury. Screening an athlete's functional movement patterns is hypothesised to be an effective strategy, by which athletes at risk of injury may be identified. The MCS is a time effective tool for this purpose, with proven reliability in uninjured subjects. There is currently no literature investigating the utility of the MCS for assessing injury risk within the dance population.

## **Methods**

Sixty-six pre-professional dance students (40 females, 26 males) attending a full-time pre-professional training school in New Zealand were recruited to take part in a longitudinal cohort study. Prospective injury surveillance was undertaken over a full academic year. Reported injury data was collected via the in-house physiotherapist using the International Performing Arts Injury Reporting System (IPAIRS), and

self-reported injury data was collected every three weeks using an on-line questionnaire. Dancers undertook the MCS at the start of the academic year.

## **Results**

Eighty-six per cent of dancers reported at least one injury over the 2014 academic year. Fifty-nine per cent of all reported injuries were time-loss. The average number of days off dance due to injury was 5.85 (SD 6.37). The injury incidence rate was 2.27 per 1000 hours of dance exposure (DEhr) and 3.35 per 1000 dance exposures (DE). The clinical incidence was 1.92 injuries per dancer. Sixty-eight per cent of injuries were lower limb. There was a significant association between the total number of injuries and total dance exposures (DE) per month ( $p=0.016$ ). Dancers were more likely to sustain an injury in term one, reducing with each subsequent term ( $p=0.018$ ). Dancers who had a MCS score  $< 23$  were more likely to be injured than those who scored  $\geq 23$  ( $p=0.035$ ). This was most likely attributed to a greater number of trunk injuries ( $p=0.036$ ). Lower limb injuries were more likely to result in time-loss ( $p<0.001$ ), as well as require a greater number of full days off dance ( $p=0.002$ ).

## **Conclusion**

The injury prevalence amongst pre-professional modern and ballet dancers in this cohort was high, although injury incidence was comparable to other similar cohorts. There is a strong relationship between dance exposure (DE) and injury risk. There was a positive relationship between the mean MCS outcome score and injury risk. This indicated that dancers who scored lower than the average, and who therefore, had reduced or altered movement competency were more likely to be injured.

# **Chapter 1**

## **Introduction**

### **1.1 Statement of the problem**

Dancers are consistently described as artistic athletes (Allen, Nevill, Brooks, Koutedakis, & Wyon, 2013; Koutedakis & Jamurtas, 2004; Russell, 2013). The range of motion, strength, aerobic power and endurance required by a dancer to achieve an effortless aesthetic is as physically demanding as any traditional sport. Similarly, to achieve excellence, dancers require the freedom of a strong and healthy body to be successful and sustain a long career.

Each dance genre has, by definition its own unique demands, and as a consequence its own specific risks with regard to injury. Ballet is distinctive in that it has several factors intrinsic to the genre. Namely: demi pointe and pointe, the five primary positions in maximal external rotation, and the high repetition of what are considered non-physiological movement patterns (Nilsson, Leanderson, Wykman, & Strender, 2001). Likewise, modern dancers have their own set of challenges, including a more variable syllabus, often involving more than one style and a greater degree of improvisation (Weigert & Erickson, 2007). Modern dancers tend to vary more markedly in body shape and size, with strength and flexibility patterns also differing to the ballet dancer (Weigert & Erickson, 2007). However, the requirements of modern-day choreography mean dancers have to be versatile and able to easily transition between genres, resulting in significant physical demands. Further to this, training and performance schedules also push dancers to capacity. Subsequently, injury prevalence rates amongst dancers are high, with 82-94% of



dancers reported to sustain injuries across their careers (L. H. Hamilton, Hamilton, Warren, Keller, & Molnar, 1997; Negus, Hopper, & Briffa, 2005; Steinberg, Aujla, Zeev, & Redding, 2013). Injury prevalence specifically amongst adolescent pre-professional dancers is also high, indicating dance related injuries to be a significant issue from an early age (Crookshanks, 1999; Laws, 2010; Steinberg et al., 2011). Injuries sustained by pre-professional dancers can have a considerable impact on training and potential career opportunities, and for some can be career ending. Injuries can also have significant financial consequences for dance students who may have to repeat a year, resulting in extra fees, as well as pay the costs associated with their rehabilitation.

As the overall demands on dancers evolve, so too has the need to optimise their health and wellbeing (Russell, 2013). However, in order to achieve this, it is essential to firstly understand the extent of the problem (Finch, 2006; van Mechelen, 1997). The lack of standardised injury reporting and exposure methods utilised within the dance medicine literature mean the injury profile of dancers is not yet fully understood. The use of more consistent measures is necessary to enable a better understanding of the aetiology of dance injuries. This will also help guide future development and implementation of evidence based injury prevention strategies, so that those entrusted with the care of dancers will be better placed to prevent injuries occurring in the first instance (Finch, 2006; van Mechelen, 1997). There are, however, no current epidemiological studies of dancers undertaking pre-professional training in New Zealand.

Dance medicine research has identified a number of intrinsic and extrinsic risk factors that may contribute to dance related injury, although many require more

focused research to establish their true significance (Jacobs, 2010; Russell, 2013; Wanke, Mill, et al., 2014). Dance exposure (hours and events) is one factor reported to contribute to injury risk, yet there is currently a paucity of research evaluating the role this plays. High training volumes and/or number of exposures have been shown in other sports to also contribute to injury risk (Drew, 2015; Newlands, 2013; Rogalski, Dawson, Heasman, & Gabbe, 2013). Pre-professional dancers undertaking full-time training are exposed to a high volume of dance exposure (hours and events) at an age where injury risk has been reported to increase (Caine, Maffulli, & Caine, 2008; Roberts, Nelson, & McKenzie, 2013). Evaluating the relationship between dance exposure and injury in this specific population is, therefore, of interest and will possibly highlight this specific risk factor as a focus for future research.

Pre-participation or pre-season screening within dance schools and professional companies has become more widely accepted as the need to optimise dancers' health is recognised as a critical factor in both developing and maintaining talent. Current screening protocols promoted for dancers utilise considerable resource, yet their efficacy in establishing injury risk has not yet been proven. The Movement Competency Screen (MCS) is a screening tool that is used clinically in New Zealand and has been adopted by High Performance Sport New Zealand (HPSNZ) as part of an overall risk assessment strategy (Reid & Kearney, 2013). Recent research has demonstrated the MCS to be a reliable tool, although the relationship between outcome scores and injury risk remains unclear (Kritz, 2012; Newlands, 2013; Vanweerd, 2013). The utility of functional movement screening and, more specifically, the MCS, as a means of detecting dancers at risk of injury has not yet been reported (Allen et al., 2013; Schmieg, 2012). The relationship between

functional movement competency outcomes and injury data may help identify factors contributing to dance injury, and as such help guide future evidence based injury prevention strategies.

## **1.2 Purpose of the study**

This research will firstly aim to establish the injury incidence and characteristics amongst elite pre-professional modern and ballet dancers attending a full-time training school in New Zealand. Utilising standardised injury reporting methodology and the International Performing Arts Injury Reporting System (IPAIRS) survey, will contribute good quality injury data to the growing body dance research. Secondly, the relationship between dance exposure (hours and events) and injury risk will be examined. The third aim of this study is to determine the relationship between the Movement Competency Screen (MCS) outcome scores and injury risk, location and severity.

## **1.3 Significance of the problem**

There is currently no epidemiological data on full-time pre-professional ballet and modern dance students training within New Zealand. This will be the first study to establish the injury incidence and prevalence within this specific population in New Zealand, and is the first necessary step in determining the significance of the problem. This study will utilise standardised injury surveillance and reporting, which will help to better inform future injury prevention strategies. Reported injury data obtained using the International Performing Arts Injury Reporting System (IPAIRS) survey will also contribute towards to a larger international dance injury database. The outcomes of this study will be of interest not only to the New Zealand School of Dance but also to other dance training institutes, teachers, healthcare

professionals and to dancers themselves, by providing a better understanding the injury profile of dancers.

This study will examine the relationship between dance exposure and injury risk amongst pre-professional dancers. This will be of interest to those who are involved in managing training and performance loads for dancers. Determining the relationship between dance exposure and injury will help establish if this risk factor requires future focused research, and potentially result in modifications to dancers' training and performance schedules. This information may also assist healthcare professionals in planning training volumes when dancers return after injury.

Establishing the most effective and efficient tools to identify dancers at risk of injury is essential. This is the first study to examine the efficacy of the MCS for this purpose within the dance population. Simple screening tools such as the MCS have the potential to be utilised by dance teachers, trainers and other health professionals. This may, therefore, enable screening to be more widely implemented in dance, as well as promote communication and a common understanding between those involved in optimising dancers' wellbeing. The MCS may also help to identify risk factors for dance related injury and, therefore, better guide injury prevention strategies.

## **Chapter 2**

### **Review of Literature**

#### **Introduction**

This review of literature has been divided into four sections. The first section is a literature review of dance injury incidence and characteristics in pre-professional modern and ballet dance students. The second section reviews current trends in injury surveillance and reporting in dance medicine research. The third section is an overview of risk factors for musculoskeletal injury in pre-professional dancers pertinent to this study. The fourth section reviews the current literature pertaining to functional movement screening tools utilised within sports and dance, as well as their ability to predict injury risk.

#### **2.1 Injury Incidence and Characteristics in Pre-professional Ballet and Modern Dance Students**

Injuries sustained by young adolescent dancers may have long-term implications on participation and performance. However, these injuries are comparatively poorly reported compared to their professional counterparts (DiFiori et al., 2014; Steffen & Engebretsen, 2010; Steinberg, Aujla, et al., 2013). Dancers undertaking pre-professional training are typically of an age (16 – 20 years) considered to be high risk for injuries, which also differ in nature and frequency compared to both younger and older athletes (Caine et al., 2008; Gallagher, Finison, Guyer, & Goodenough, 1984; Garrick & Requa, 1997). Injuries sustained during adolescence, such as patella-femoral pain syndrome (PFPS) and meniscal or anterior cruciate ligament

(ACL) injuries, potentially have lasting effects that persist into adulthood (Brukner & Khan, 2007; Riegger Kugh & Keysor, 1996; Thomas, Wood, Selfe, & Peat, 2010; Utting, Davies, & Newman, 2005). Increasing our understanding and awareness of injury characteristics and risks factors for this specific population is, therefore, an important ongoing task and will better guide the development and implementation of injury prevention strategies and optimise long-term health and wellbeing. The purpose of this section is to examine the current literature in relation to injury incidence and characteristics in pre-professional ballet and modern dance students.

### **2.1.1 Literature review.**

#### ***2.1.1.1 Methodology.***

The primary source of literature was electronic databases and included: SPORTdiscus with full text, Cinahl Pulse with full text, Medline, Scopus, Proquest Direct, and Google Scholar. Search terms used to access relevant research studies included: dance\*, ballet, contemporary, modern, pre-professional, elite, young, student, training, school\*, injur\*, incidence, prevalence, severity and characteristics. Specific injury types (stress fractures, tendinopathies, tendinitis, muscular strains and sprains) and locations were also used in combination with search terms. Keywords were used separately and also in various combinations. Reference lists of relevant studies were examined for additional literature. The results of the search strategy are outlined in Figure 2.1. The electronic database search identified 142 relevant articles. Titles and abstracts were screened, and all duplicates, non-English, literature/systematic reviews and current concept papers were excluded. Relevant articles were reviewed and included based on the following criteria: (1) full text articles in peer reviewed journal or full conference proceedings, (2) studies examining injury prevalence, incidence, characteristics or other aspects of

musculoskeletal injury specific to pre-professional modern and ballet dance students, (3) studies which included a mixed cohort i.e. pre-professional dancers and professional and/or recreational dancers, (4) relevant masters or doctoral research theses (5) all years from 1969 – October 2014 were included.

#### **2.1.1.2 Results.**

A total of 142 relevant articles were retrieved. After applying the exclusion criteria 27 articles were included in the final review. Injury prevalence, incidence and dance exposure reported in the studies reviewed are presented in Table 2.1.

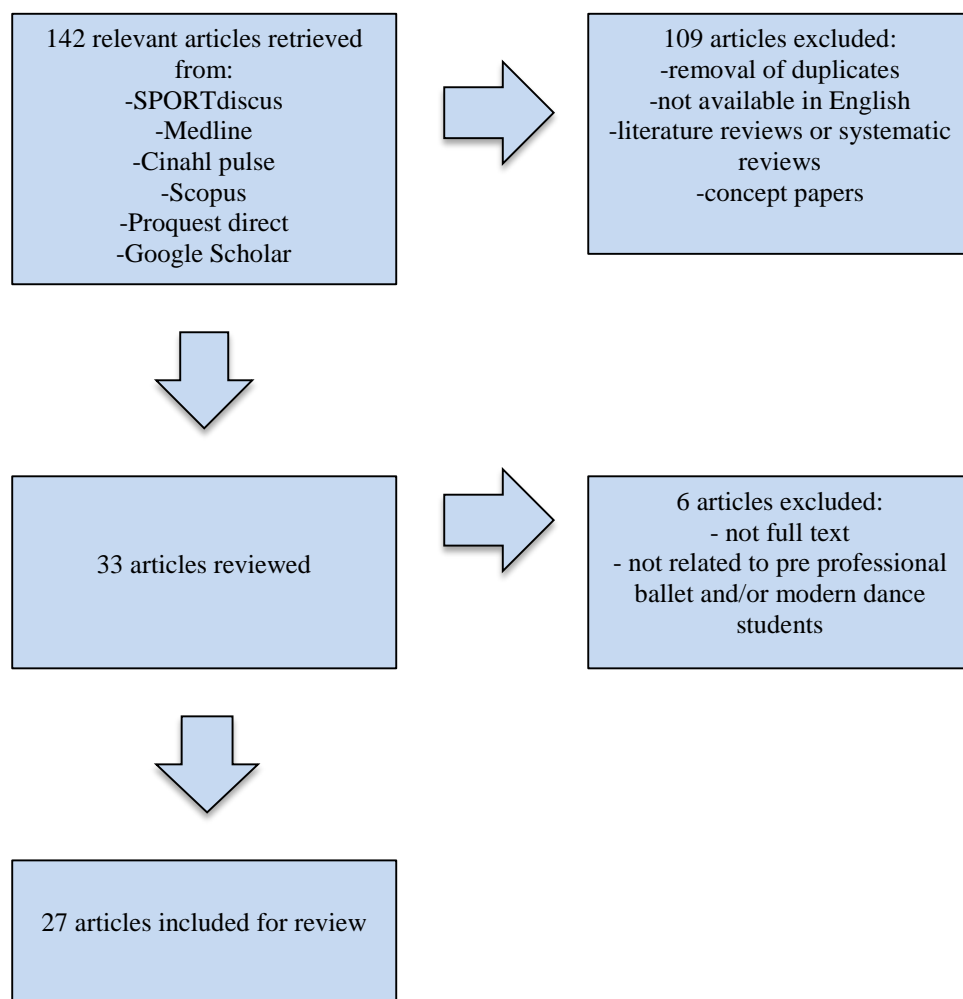


Figure 2.1 Database search strategy

### **2.1.2 Injury prevalence.**

Lifetime injury prevalence amongst pre-professional dancers has been reported to be as high as 82%-94% (L. H. Hamilton et al., 1997; Negus et al., 2005). There are, however, limited prospective studies reporting the prevalence of injuries in elite pre-professional dancers. Reported prevalence rates within this population currently range from 32-93% (see Table 2.1). Prospective studies of elite pre-professional ballet dancers have reported injury prevalence rates to be 76-77% (Ekegren, Quested, & Brodrick, 2014; Luke et al., 2002). In comparison, a five-year retrospective study of 359 elite pre-professional ballet dancers found only 32-51% of dancers reported injuries (Gamboa, 2008). However, this study included dancers from the age of nine who are likely to have less dance exposure and, hence, may contribute to the lower prevalence in this study. Studies utilising self-reported injury data have reported some of the highest injury prevalence rates amongst pre-professional ballet students ranging from 90-94% (Krasnow, Mainwaring, & Kerr, 1999; Luke et al., 2002; Negus et al., 2005). This may, in part, be reflective of this method of data collection, which is more likely to also capture those injuries either left untreated, unreported or treated by off-site healthcare providers not employed by the school.

Injury prevalence amongst modern dance students is similar to those of ballet students, ranging from 30-89% (refer to Table 2.1). Weigert and Erickson (2007) in a study of female modern dance students over two semesters had a self-reported injury prevalence of 67% and 77%, in semesters one and two respectively. Reported injury rates were somewhat lower (30% and 36%) in this same cohort. In contrast, Baker, Scott, Watkins, Keegan-Turcotte, and Wyon (2010) reported a higher prevalence rate of 89% (reported and self-reported injury data) in a mixed cohort of



both male and female first year contemporary dance students. The dance curriculum in this study included a significant amount of ballet exposure (n=144hrs/year), while the previous study did not define components of the curriculum. Variable training demands is one factor limiting conclusions within and between genres.

Overall, it is evident from the current literature that injury prevalence is high amongst dancers. Injury is commonly cited as a cause of attrition in sport and, similarly, in dance has the potential to cut short a promising career (L. H. Hamilton et al., 1997; Steffen & Engebretsen, 2010). For those who make it into the competitive world of professional dance many are likely to begin their career with a history of previous dance related injury.

In comparison to pre-professional dancers, injury prevalence reported within the professional dance population is consistently high, albeit reported rates do range from 54-95% (Allen, Nevill, Brooks, Koutedakis, & Wyon, 2012; Allen et al., 2013; Bowling, 1989; Bronner, Ojofeitimi, & Rose, 2003; Byhring & Bo, 2002; Crookshanks, 1999; Fredriksen & Clarsen, 2014; Jacobs, 2010; Nilsson et al., 2001; Ojofeitimi & Bronner, 2011; Shah, Weiss, & Burchette, 2012). Injury prevalence rates between genres are comparable, ranging from 46-82% for professional contemporary dancers and 49-96% in professional ballet dancers (Allen et al., 2012, 2013; Bowling, 1989; Bronner et al., 2003; Byhring & Bo, 2002; Crookshanks, 1999; Jacobs, 2010; Nilsson et al., 2001; Ojofeitimi & Bronner, 2011; Shah et al., 2012). The higher prevalence rates reported overall amongst professional dancers compared to pre-professional dancers, may be a reflection: of greater dance exposure, technical demand, rigours of performance and touring schedules, as well as intrinsic factors such as age and previous injury history.

### **2.1.3 Injury incidence.**

Reporting of injury incidence rates within dance medicine research, either relative to the number of exposures (per/1000 DE) or hours of exposure (per/1000 DEhr) is not yet common practice. Less than 50% of reviewed studies of pre-professional ballet and modern dancers reported overall injury incidence rates which varied between 0.56 – 4.7/1000hrs (see Table 2.1).

Amongst studies of pre-professional ballet dancers, Luke et al. (2002) reported the highest injury incidence of 2.9 (reported injuries) and 4.7 (self-reported injuries/1000hr). Injuries in this study were not defined but rather categorised according to history, location, mechanism, severity, and course. Exposure was based on the average reported hours of dance per week. In comparison, Ekegren et al. (2014) included only time-loss injuries (utilising the injury definition proposed by the International Association of Dance Medicine and Science (IADMS, 2012)). They reported a lower injury incidence of 1.38/1000hr DE amongst a larger cohort of 266 elite pre- professional ballet dancers. This lower rate may reflect the use of this more specific injury definition, resulting in fewer injuries being included in analysis. Comparable studies amongst pre-professional modern students are lacking, with only one study identified reporting injury incidence within this specific population. This study by Echegoyen, Acuña, and Rodríguez (2010) reported an injury incidence of 4/1000hr over a three-year period amongst modern dance students. The use of a broad injury definition, exposure data based on number of training hours only (no performance hours were reported) and the average age of dancers being older (23.85yr), may contribute to the higher incidence rate in this cohort compared to that of pre-professional ballet or other mixed cohorts.

Only three studies were identified within current dance medicine literature reporting injury incidence via the number of dance exposures (DE) (Bowerman, Whatman, Harris, Bradshaw, & Karin, 2014; Ekegren et al., 2014; Gamboa, 2008). Therefore, dance medicine still has some way to go to build a comparable body of research utilising this method of reporting. Ekegren et al. (2014) and Gamboa (2008) reported incidence rates amongst pre-professional ballet dancers to be, 1.87 and 1.09 injuries/1000DE respectively. Comparatively, Bowerman et al. (2014) reported a much higher incidence rate of 3.52/1000DE. This incidence is particularly high given only overuse injuries of the lower limb and lumbar spine were included. The broad injury definition used, short inception period (six months), small sample size (n=46) and estimation of exposure across the six months (based on a sample weekly timetable) are all factors possibly contributing to the higher incidence found this cohort.

There are few studies reporting injury incidence amongst professional dancers with which to make comparisons with the pre-professional population. One recent, well designed study by Allen et al. (2013) indicates the injury incidence amongst professional ballet dancers to be higher than those at pre-professional level (Allen et al., 2013). In this three year study of professional ballet dancers (n=52-58) injury incidence was 4.4/1000hr DE in year one, reducing to 2.02/1000hr DE after the introduction of individualised conditioning programmes (Allen et al., 2013). This is in contrast with earlier studies of professional dancers that have reported lower injury incidence rates (0.18 – 0.67/1000hr), which may be partly due to variations in injury reporting and study methodologies (Bronner et al., 2003; Nilsson et al., 2001; Ojofeitimi & Bronner, 2011; Shah et al., 2012).

While further research investigating injury incidence in pre-professional dancers is necessary, current well-designed studies indicate the incidence rates to be similar to or lower than those reported in other adolescent athletes. Injury incidence amongst adolescent athletes across multiple sports has been reported to be on average between 3.1 - 3.5/1000hrAE (Steffen & Engebretsen, 2010). A closer comparison may be made with gymnasts, who traditionally also have high training loads and aesthetic requirements that are comparable to dancers. Gymnasts, overall, have a slightly higher injury incidence, although like pre-professional dancers a wide range of injury incidence has been reported (0.5 – 3.7/1000hr) (Caine et al., 2008). This wide range is also likely, in part, due to differing levels of involvement as well as variations in study methodologies.

In summary, although injury prevalence amongst pre-professional dancers is high, injury incidence is similar to or, indeed, at times lower than those reported amongst adolescent athletes in comparable aesthetic sports, and also lower than that of professional dancers. However, the limited number of studies reporting injury incidence restricts generalisation across the broader pre-professional dance population, between genres or, indeed, comparisons with the professional dance population. Future studies incorporating standardised units of exposure alongside standardised injury definitions are required so as to enable a better understanding the injury profile of pre-professional dancers.

Table 2.1 Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Fulton et al (2014)*</b>	Retrospective cohort (6wk course 1x/yr for 3 yrs)	Mixed genre - summer intensive programme (USA)	2010: N=100 2011: N=96 2012: N=124  F/M = NR  Age: 12 -50yr	NR	<b>RI:</b> on-site physiotherapists	Incident leading to self-referral to the clinic	<b>P: number of reported injuries</b> 2010 = 101 2011 = 96 2012 = 124 <b>Other: number of visits per dancer reporting an injury</b> 67% 1 evaluation 18% 1 follow up 10% 3 visits 2% up to 6 visits
<b>Wanke et al (2014)*</b>	Retrospective cohort (17yrs)	Students at state ballet school and professional dancers from 6 theatres (Germany)	Professional: N= 1339 F=658 M=681 Age: 21-35yr  Students: N= 612 F=421 M=191 Age: 12-18yr	NR	<b>RI:</b> examined by medical doctor	Traumatic injuries: time-limited accident that mainly acts on the body of the insured person from the outside during work or on the way to work or home resulting in physical damage or death	<b>IR:</b> Students: 0.14/1000WH  Professional: Theatre= 0.33/1000WH Revue= 0.22/1000WH Classical= 0.22/1000WH Neo-classical=0.16/1000WH Musical performers= 0.09/1000WH
<b>Ekegren et al (2014)</b>	Prospective longitudinal study (1yr)	Elite pre-professional ballet students from 3 different dance schools (London, UK)	N=266  F=144 M=112  Age: 15 -23yr	Avg: 30.3hr/per wk (1030hr/academic yr)	<b>RI:</b> on-site physiotherapists	Anatomic tissue-level impairment diagnosed by licensed health-care practitioner resulting in full time loss of activity for one or more days beyond the day of onset.  Activity= participation in a 'class, rehearsal or performance.	<b>P:</b> 76% injured over 1 year Avg: 1.42 injuries/dancer  <b>IR:</b> Overall: 1.38/1000hrDE 1.87/1000 DE  Per year: Yr1: 1.34/1000hr DE Yr2: 1.76/1000hr DE Yr3: 1.38/1000hrDE No significant difference in IR across different year levels

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Bowerman (2014)</b>	Prospective cohort (6 months)	Elite ballet dancers Australian Ballet School (ABS) (Melbourne, Australia)	N=46 F= 30 M=16  Age: 16 +/- 1.58yr	Estimated from dance timetables total hours not reported	<b>RI:</b> on-site physiotherapist	Physical harm resulting in pain or discomfort that requiring modified activity during one or more classes, or which required a dancer to cease all dance related activity	<b>IR: Overuse injuries of Lsp /LL only</b> All: 2.4/1000hr 3.52/1000DE  F: 2:19/1000hr 3.21/1000DE  M: 4.12/1000hr 2.81/1000DE
<b>Steinberg, Aujla, et al (2013)</b>	Retrospective cohort (2yr)	Elite dancers at Centres for Advanced Training (CAT) (part-time) Mixed genre (contemporary, ballet, hip hop, creative, other) (UK)	N=806 F=588 M=218  Age: 8 – 18yr	Avg Training hrs: CAT 7.5 +/- 2.7hr + Other dance school 4.7 +/- 4.5hr	<b>SRI:</b> via survey	Any injury sustained in last 12 months  Injuries categorised by date, type, location	<b>P:</b> Overall: 43.1% injured over 2yr 8-10yr = 45.3% 11-12yr = 41.5% 13-15yr = 43.1% 16-18yr = 48.2%  <b>IR:</b> 8-10yr = 1.32/1000hr 11 -12yr = 1.55/1000hr 13-15yr = 1.24/1000hr 16-18yr = 1.17/1000hr
<b>Steinberg, Sievner et al (2013)</b>	Descriptive epidemiology study	Recreational dancers at Israel Performing Arts Centre Mixed Genre (Tel Aviv, Israel)	N=569 F=569  Age: 8 -16yr	NR	<b>RI:</b> Orthopaedic surgeon	Excluded if no pain during the clinical examination or no signs of injury	<b>P:</b> 42.4% dancers sustained at least one previous injury  <b>IR:</b> not reported
<b>Baker-Jenkins et al (2013)</b>	Prospective cohort study (10mths)	Contemporary dance students studying BA in Dance Theatre at a UK dance conservatoire (London, UK)	N=47 F=47  Age: 19.9 +/- 2.5yrs	180hrs of timetabled contemporary and 144hrs of ballet	<b>SRI:</b> via questionnaire  <b>RI:</b> retrieved from physiotherapy records	Physical damage to the body or body part which prevented completion of one or more entire curriculum class	<b>P:</b> 74% reported injuries  <b>IR:</b> not reported

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Leanderson et al (2011)</b>	Retrospective longitudinal open cohort (7yr)	Elite pre-professional ballet dancers at Royal Swedish Ballet school (Stockholm, Sweden)	N=476 F= 297 M=179  Age: 10-21yr	Gd 4: 6hr/wk Gd 5 -7: 10.5hr/wk Gd 8: 11.5hr/wk Gd 9 -11: 15hr/wk	<b>RI:</b> Orthopaedic consult. Collected from clinic records from 1988 - 1995	Injuries receiving orthopaedic care.	<b>P:</b> 44% (210 injuries)  <b>IR:</b> Avg (all ages) 0.8/1000hr DE <u>10yr:</u> Female .3/1000hr Male .5 /1000hr <u>11-14yr:</u> F: 0.7/1000hr M: 0.6/1000hr <u>15 -21yr:</u> F: 0.9/1000hr M: 1.1/1000hr
<b>Steinberg et al (2011)</b>	Descriptive cross-sectional/longitudinal cohort study (15yr)	Non-elite dancers at Israel dance schools Mixed genre (ballet, modern jazz) (Israel)	N=1336  F= 1336  Age: 8-16yrs	Avg hours: 8.7  Range: 2.5 – 11.4hr  (hrs danced increase with age)	<b>SRI:</b> via interview	Injury not defined	<b>P:</b> 42.6% dancers sustained an injury  <b>IR:</b> per/1000hr 8yr =1.05 9yr =0.79 10yr =1.00 11yr =2.23 12yr =1.31 13yr =1.40 14yr =1.25 15yr =1.28 16yr =1.29
<b>Baker et al (2010)</b>	Retrospective longitudinal cohort (1yr)	First year dance undertaking BA degree in dance theatre at UK contemporary dance conservatoire (UK)	N= 57  F=47 M=10  Avg age: 20-21 +/- 3yrs	Contemporary: 180hr/year Ballet: 144hr/year	<b>SRI:</b> survey <b>RI:</b> clinic notes	Physical damage to the body or body part, which prevented completion of one or more entire curriculum class.	<b>P:</b> 89% reported 1 or more injuries over 1 academic year  <b>IR:</b> not reported

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Echegoyen et al (2010)</b>	Prospective longitudinal cohort (2004 -2007)	Dance students - Escuela Nacional de Danza Genres: modern, Mexican folkloric Spanish (Mexico)	N=444 F/M= NR Age Modern Avg= 23.1yr Mexican Avg =23.8yr Spanish Avg = 22.5yr	Class Modern: 11.6hr/wk Spanish/Folk 13.3hr/wk  Rehearsal: Modern/Mexican 1.6hr/wk Spanish 5hr/wk	<b>RI:</b> recorded by physician	Medical condition due to dance activities resulting in at least one absence from a dance class or rehearsal	<b>P:</b> Total injuries: 1168 Average injuries per dancer Modern: 4 Mexican: 2 Spanish: 2  <b>IR:</b> per 1000 training hours Modern: 4/1000hr Spanish: 1.5/1000hr Mexican: 1.8/1000hr
<b>Laws (2010)*</b>	Retrospective survey (1 year)	Professional dancers and elite vocational dance students Mixed genre (UK)	Total (professional + students) N = 1056  Students Only: N=791  Students Only: F=618 M=173	Students Avg: 27.1 +/- 14.6hr /week  Professional Avg: 36 +/- 18.2hr /week	<b>SRI:</b> via survey	Physical problem (stress or other) to do with performance, rehearsal, training, touring or the circumstances of dance lift, affecting ability to participate fully in normal training, performance or physical activity	<b>P:</b> 80% of all dance students sustained an injury over the last 12mth  <b>IR:</b> not reported
<b>Sides et al (2009)</b>	Prospective cohort (1 semester – 16wk)	Collegiate modern dance students (USA)	N= 51 F=47 M=4  Age Ave 22.4 +/- 3.7yrs	NR	<b>RI:</b> Athletic trainer	Any injury reported to athletic trainer at the dance medicine clinic	<b>P:</b> 51 reported injuries over 16 weeks

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours



Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Gamboa J et al (2008)</b>	Retrospective descriptive cohort (5yrs)	Elite pre-professional ballet dancers (Washington, USA)	N = 359 F= 288 M= 71  Age: 9 – 20yr	20hr/wk ballet 2hr/wk x-training	<b>RI:</b> retrospective review of the physiotherapy records at the end of each school year	At least 1 treatment session from a physical therapist	<b>P:</b> 32 -51% of dancers injured/yr 0.41 – 0.67 injuries per dancer (Avg 0.55/dancer)  <b>IR:</b> 1.09/1000AE's 0.77/1000hr (Annual Rate: 0.56 – 0.93/1000hr)
<b>Hiller et al (2008)*</b>	Prospective single cohort (13 months)	Non-elite adolescent dancers - performing arts secondary school and local dance school (Sydney, Australia)	N=114 F = 94 M = 21  Avg Age: 14.2yr	Not supplied (used average hours that occurred in the week of baseline data collection)	<b>SRI:</b> interview, participants contacted monthly	<u>Ankle injuries only:</u> Any inversion injury that had resulted in either swelling or bruising in the area and limping for more than one day	<b>P: Ankle Sprains ONLY</b> 28.9% dancers sustained an ankle sprain  <b>IR:</b> Ankle sprain 0.21/1000hr  <b>Other:</b> Previous ankle sprain associated with increase risk of future sprain in contralateral ankle
<b>Weigert et al (2007)</b>	Prospective observational cohort study (2 semesters)	Female dance majors and minors - University led modern dance curriculum (Wisconsin, USA)	N=30  F = 30  Age: 18 – 26yr	Avg: 13.24hr/wk	<b>RI:</b> clinic data <b>SRI:</b> self-reported injuries and self reported time off dance	Any problem that caused pain and/or limited their participation in dance activities	<b>P: RI</b> S1 30% S2 36.4% <b>SRI</b> S1 67% S2 77%
<b>Negaus et al (2005)</b>	Descriptive retrospective correlation study (2yr)	Elite pre-professional ballet dancers: Western Australia Academy of Performing Arts (Australia)	N=29  F= 24 M=5  Age: 15- 22yr	NR	<b>SRI:</b> via interview	Any pain, discomfort or other musculoskeletal problem which required modification of, or time away from, dance, training, examinations, or performance	<b>P:</b> Lower limb injury in last 2yrs 93.1% non traumatic 41.4% traumatic 93.1 % currently injured at time of study (continuing ongoing issues affecting dance)

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Schmitt et al (2005)*</b>	Prospective cohort (5mth)	Elite pre-professional dancers at German dance academy (Germany)	N=42 F=31 M=11  Age: 14 -23yr	NR	<b>SRI:</b> via questionnaire	Injury not defined	<b>P:</b> 12% cumulative incidence (ankle injuries)
<b>Luke et al (2002)</b>	Prospective cohort (9mth)	Elite pre-professional ballet dancers at Liberal Arts High School dance program (Natick, Massachusetts)	N=39 F= 34 M=5  Age:14 -18yr	Avg hrs: 3.2hr/day (over a 2wk block)  Female: 3.3hr/day Male: 2.7hr/day	<b>SRI:</b> survey every 2 weeks  <b>RI:</b> on-site physiotherapist	Injury not defined  Injuries categorised by location, history, mechanism, severity and course.	<b>P:</b> SRI = 90% Total 112 injuries (2.8 injuries/dancer) RI = 77% Total 71 injuries (1.4 injuries/dancer)  <b>IR:</b> SRI: 4.7/1000hr Female SRI: 4.2/1000hr Male SRI: 8.4/1000hr  RI: 2.9/1000hr Female RI: 2.6/1000hr Male RI: 5.5/1000hr
<b>Coplan (2002)*</b>	Retrospective cohort study	College level ballet dancers and instructors (Baltimore, USA)	N=30 F= 27 M= 3 Age: 16 -50	NR	<b>SRI:</b> via interview	Any dysfunction or pain in lower back or lower extremities that impacted on the dancers ability to practice or perform	<b>P:</b> 47% low back and lower limb injury  <b>IR:</b> not reported

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Askling et al (2002)*</b>	Retrospective cohort (10yr)	Ballet Academy in Stockholm – modern and classical (Sweden)	N= 99 F= 76 M= 22  Age: 17-25yrs	NR	<b>SRI:</b> via questionnaire	Acute injury: sudden sharp pain or pop that the dancer could relate to a specific situation Overuse Injury: insidious onset that continued to bother the dancer during a period of at least 2 weeks	<b>P:</b> 34% sustained acute rear thigh injuries  17% overuse injuries to rear thigh  <b>IR:</b> not reported
<b>Garrick (1999)</b>	Prospective cross-sectional (20mth)	Non elite ballet dancers at ballet school (California, USA)	N=38  Age: 13 – 18yr	20-28hr/wk	<b>RI:</b> On-site clinic (Physio/orthopaedic surgeon) and Community Dance Medicine Clinic records	Any complaint about which a dancer has questions  Injuries classified by type and location	<b>P:</b> 64% (38 of 59 dancers sought care)  <b>IR:</b> not reported
<b>Krasnow et al (1999)*</b>	Retrospective cross-sectional cohort	Elite artistic gymnasts, modern/ballet dancers - full time students (Canada)	N= 30 gym 16 ballet 19 modern F=65  Age: 12 -18yr	NR	<b>SRI:</b> via questionnaire	Physical harm resulting in pain or discomfort that causes one or more of the following 1. Cessation of activity 2. A need to modify activity 3. Negative effect on training 4. Sufficient distraction or emotional distress	<b>P:</b> Lifetime prevalence:  94% ballet dancers 79% modern dancers 100% gymnasts

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

Table 2.1 continued. Studies reporting injury incidence in pre-professional ballet and modern dance students

Study Reference	Study Type	Sample population and genre	Sample size/gender/age	Exposure (DE or DEhrs)	Injury recording protocol	Injury Definition/Criteria	Outcomes
<b>Miller &amp; Moa (1998)</b>	Retrospective cohort (1yr)	Dance (ballet), theatre, music and visual arts students attending Performing Arts School (USA)	N= 210  Dancers only N=42  F/M and age not specifically reported for dance students	NR	<b>RI:</b> retrospective review of medical notes	Injury not defined	<b>P:</b> ballet dancers 43%
<b>Hamilton et al (1997)</b>	Prospective cohort (1yr)	Dancers at the School of American Ballet (USA)	N= 40  F= all  Avg age: 14.92yrs +/- 0.96yr	17hr/wk	<b>SRI:</b> reported to Orthopaedist	Injury not defined	<b>P:</b> 82% reported a history of dance related injury  64% developed further injuries over the year
<b>Wiesler et al (1996)</b>	Prospective cohort study (1yr)	Ballet and modern dance students at the North Carolina school of the Arts (USA)	N = 148  F= 119 M= 29  Age: 12 – 28yr	NR	<b>RI:</b> Physiotherapist and sports medicine Physician	Acute or chronic lower limb problem that warranted attention by health care personnel	<b>P: Lower Limb Injuries Only</b> 63.5% had 1 or more injuries  <b>IR:</b> Not reported
<b>Rovere et al (1983)</b>	Prospective cohort (1yr)	North Carolina School of the Arts - mixed genre (USA)	N= 218  F= 162 M=56  Age = NR	NR	<b>RI:</b> Physician	Injury not defined	<b>P:</b> 84.9% sustained an injury 87% of injuries sustained were dance related

\* Mixed cohorts including pre-professional dance students and professional or young dancers

N = number of subjects M = male F = female yr = year/s hr = hour/s Avg = average Gd = grade S1=semester 1 S2=semester 2 NR = not reported P = prevalence

IR = incidence rate SRI = self reported injuries RI = reported injuries DE= dance exposure AE= athletic exposure WH= work hours

#### **2.1.4 Injury severity.**

Establishing the severity of injuries is essential so appropriate and timely prevention measures can be implemented to reduce and prevent significant harm to athletes (Goldberg, Morox, Smith, & Ganley, 2007; van Mechelen, 1997). The prevalence of injuries amongst dancers as previously highlighted is high. However, less is known about the impact these injuries have on participation and performance, specifically amongst pre-professional dancers. As depicted in Table 2.2, injury severity is infrequently reported and measures utilised within the dance research to quantify severity have been inconsistent.

Injury severity was defined in three of the studies reviewed by the number of full days off dance (Angioi, Metsios, Twitchett, Koutedakis, & Wyon, 2009; Ekegren et al., 2014; Wanke, Koch, Leslie-Spinks, & Groneberg, 2014). In these studies ‘time-loss’ ranged from 2.4-28 days. Angioi, Metsios, Koutedakis, Twitchett, and Wyon (2009) reported the lowest of these (2.4 days). However, this study was hampered by a small sample size (n=16), involved a mixed cohort of pre-professional and professional dancers, and did not report the injury type or distribution. By comparison, Ekegren et al. (2014) found the average number of days lost to injury in a group of 266 elite pre-professional ballet dancers was somewhat higher (28 days/injury). This study also reported tibial stress fractures, foot stress reactions/stress fractures, and ankle synovitis/impingements/bursitis took the longest total time to return to dance (Ekegren et al., 2014). Another study, which included pre-professional and professional ballet dancers classified injury severity as mild, moderate or severe depending on the number of days off dance (Wanke, Koch, et al., 2014). Although Wanke, Koch, et al. (2014) did not report the average number of days lost (or range) to injury, thus limiting comparisons with previous studies,

they found 45.5% of ballet students required >3 days off dance due to injury. In other studies reviewed, injury severity measures included both the number of days lost and/or modified, with one study of pre-professional modern dancers reporting an average of 7-8 days lost/modified per semester (over two semesters) (Weigert & Erickson, 2007). In an earlier study, Krasnow et al. (1999) reported the percentage of injuries requiring training modification. In this study 31% of injuries sustained by modern dancers required <2 days of modified training, with 31% needing 1-3 months. In comparison, no ballet dancers required <2 days of modified training with the majority taking either 3-7 days (29%) or 3-4 weeks (35%). While the differing severity measures make comparisons between studies difficult, it is evident from these studies that dance injuries do have a significant impact on dance participation, both individually and cumulatively, particularly given the high prevalence of injuries within this population.

Time-loss from dance is comparatively more widely reported within the professional dance population, due to legal and insurance requirements as well as contractual obligations (Allen et al., 2012; Crookshanks, 1999; Jacobs, 2010; Laws, 2010). In an international cross-sectional study of nine professional ballet and modern dance companies, the majority of injured dancers took either no time off work or 1-7 days over the 12 month study period, despite the majority of injuries being described as moderate to severe in nature (Jacobs, 2010). In this same study, ballet dancers reported higher frequencies of days off work compared to modern dancers, and also sustained a greater percentage of more severe injuries i.e. those injuries requiring 3-6 months and >6 months off work. Allen et al. (2012) undertook a prospective study of 52 professional dancers and defined severity as the “number of days a dancer took to return to full fitness” (p. 783). In this study dancers averaged 30.2 days off

per/1000hrs of dance (mean = 7 days time-loss), with over 50% of time-loss injuries being overuse in nature. They also noted those injuries resulting in the greatest 'time-loss' included; stress fractures of the tibia and metatarsals, ankle instability and lumbar facet joint/nerve root pathology. A larger retrospective study of 139 professional dancers reported a higher average time-loss, with dancers returning to a full workload on average 14 days after injury (range 1-42 days) (Crookshanks, 1999). Although these studies indicate injuries sustained by professional dancers result in the average of number of days off dance being similar to or indeed slightly higher than those at pre-professional level, any comparisons must be made cautiously, given the limited literature involving pre-professional dancers and variations in severity measures. Current literature from professional and pre-professional populations indicate lower limb injuries and stress fractures in particular, result in the most time loss from dance, thus highlighting the need for targeted injury prevention strategies.

Other scales utilised in dance literature to define injury severity include: the Self Estimated Functional Inability because of Pain scale (SEFIP), Visual Analogue Scale (VAS), World Health Organization Disability Scale, and the Likert Scale (Gamboa, 2008; Luke et al., 2002; Negus et al., 2005; Weigert & Erickson, 2007). The SEFIP is a validated questionnaire measuring intensity of pain as well as the ability to dance on a five point scale across 14 body sites (Ramel, 1999). Weigert and Erickson (2007) in a study of modern dance students reported SEFIP scores across four sub-groups, with the total score averaging between 4.9-5.64. A lack of other comparative studies utilising the SEFIP amongst pre-professional dancers limits conclusions, while comparisons with professional dancers are also limited due to variations in scoring methodology (Jacobs, 2010).

Table 2.2 Studies reporting injury type, severity and location in pre-professional ballet and modern dance students

Study Reference	Injury Type: traumatic/overuse	Injury Severity Classification	Severity Outcome	Injury Location						
				LL	Foot Ankle	Knee	Hip	UL	Lsp	Neck
<b>Wanke et al (2014)*</b>	<u>Traumatic Injuries</u> <u>Ballet Students:</u> Head/Neck F: 6.2% M: 9.4% UL: F: 12.6% M: 18.7%	UKB Classification Mild: < 5 days off Mod: > 5 days – 6wk off Severe: > 6wk off	45% dancers > 3 days absent due to injury	All 67.7%				15.5%	Spine 7.4% Trunk 0.8%	7.3%
<b>Ekegren et al (2014)</b>	Overuse: 72% Traumatic: 28%  joint/ligament 46%, muscle /tendon 30% bone 19% other tissue 5%	Time-loss (full days lost from full participation)	Total days lost due to injury: 10548 Avg: 28 days/injury Avg: 7.02 Physio treatments per injury	77%	Ankle 33% Foot 20%	13%	Hip & Groin10%  Thigh 2%	3% (Shoulder 64%)	Trunk 16% (Low back 60%)	3%
<b>Bowerman (2014)</b>	<b>Only overuse injuries of LSP and LL collected</b>	Injury severity coded S1 = modified class S2= off class ≤ 7 days S3= off class > 7 days	“Majority of injuries” = S1	Other LL 9%	Foot: 31% Ankle 15%	7%	7%		24%	
<b>Steinberg, Aujla et al (2013)</b>	NR	NR	NR	Other LL 22.6%	Foot and ankle 19.3%			4.8 - 10.7%		

\* Mixed cohort \*\* Non elite dance students \*\*\*professional NR = not reported Lsp = lumbar spine Tsp = thoracic spine Csp = cervical spine LL = lower limb UL = upper limb  
Avg = average SRI=self-reported injuries SR=reported injuries mth=month/s yr=year/s UKB= German Social Accident Insurance Institute Berlin B = ballet M = modern



Table 2.2 continued. Studies reporting injury type, severity and location in pre-professional ballet and modern dance students

Study Reference	Injury Type: traumatic/overuse	Injury Severity Classification	Severity Outcome	Injury Location						
				LL	Foot Ankle	Knee	Hip	UL	Lsp	Neck
<b>Steinberg, Sievner et al (2013)**</b>	NR	NR	NR		Ankle/ foot 17.0%	40.4%			19.2%	
<b>Leanderson et al (2011)</b>	Overuse: 77% Traumatic: 23%	NR	NR	76%	Foot & Leg 53%	21%	Hip & Thigh 11%	4%	13%	
<b>Steinberg et al (2011)**</b>	NR	NR	NR		<u>YR8-9</u> 43.1%	<u>YR8-9</u> 10.9%			<u>YR8-9</u> 28.3%	
					<u>10-11</u> 25.2%	<u>10-11</u> 29.9%			<u>10-11</u> 15.0%	
					<u>12-13</u> 21.8%	<u>12-13</u> 35.6%			<u>12-13</u> 12.5%	
					<u>14-16</u> 23.1%	<u>14-16</u> 33.7%			<u>14-16</u> 18.9%	
<b>Echegoyen et al (2010)</b>	Overuse: 29%	NR	NR	70.47%					8.7% (mod)	1.29% (mod)
<b>Baker et al (2010)</b>	Perceived cause overuse and jumping	NR	NR	RI=73% SRI = 78.6%	Ankle 17.46%	20.63%		13%	9.1%	

\* Mixed cohort \*\* Non elite dance students \*\*\*professional NR = not reported Lsp = lumbar spine Tsp = thoracic spine Csp = cervical spine LL = lower limb UL = upper limb Avg = average SRI=self-reported injuries SR=reported injuries mth=month/s yr=year/s UKB= German Social Accident Insurance Institute Berlin B = ballet M = modern

Table 2.2 continued. Studies reporting injury type, severity and location in pre-professional ballet and modern dance students

Study Reference	Injury Type: traumatic/overuse	Injury Severity Classification	Severity Outcome	Injury Location						
				LL	Foot Ankle	Knee	Hip	UL	Lsp	Neck
<b>Laws (2010)*</b>	NR	Time-loss (full days lost from participation)	Avg days lost over 12 mths (professional): 13+/- 32.9 days off class/rehearsal/performance  14% sustained long-term injuries keeping them off dance for up to 18months.		Foot B: 23% M: 11% Ankle B: 30% M: 20%	34%	10%		31%	13%
<b>Angioi et al (2009)*</b>	Highest number of injuries muscular (46.6%), tendon 20%, multiple 26.6%)	Time-loss (full days lost from full participation)	Avg days lost due to injury: 2.4 +/- 1.3 days							
<b>Sides et al (2009)</b>	NR	NR	NR	60.8%	Foot 13.7% Ankle 9.8%	27.5%	5.9%	All 17.7% Sh 13.7%)	13.7%	2%
<b>Gamboa et al (2008)</b>	Overuse > across the 5 years Yr 1 88%, Yr 2 86% Yr 3 69% Yr 4 77% Yr 5 55%	World Health Organization Disability Scale modified for dancers	Significant difference identified between injured and non-injured dancers for median current disability		53.4%	16.1%	21.6%		9.4%	
<b>Hiller et al (2008)</b>	Ankle sprains only	NR	NR		Ankle sprain 28.9%					

\*Mixed cohort \*\* Non elite dance students \*\*\*professional NR = not reported Lsp = lumbar spine Tsp = thoracic spine Csp = cervical spine LL = lower limb UL = upper limb  
Avg = average SRI=self-reported injuries SR=reported injuries mth=month/s yr=year/s UKB= German Social Accident Insurance Institute Berlin B = ballet M = modern

Table 2.2 continued. Studies reporting injury type, severity and location in pre-professional ballet and modern dance students

Study Reference	Injury Type traumatic/overuse	Injury Severity Classification	Severity Outcome	Injury Location						
				LL	Foot Ankle	Knee	Hip	UL	Lsp	Neck
<b>Weigert et al (2007)</b>	S1: Overuse 55% (5/9) Traumatic 45% (4/9)  S2: Overuse 88% (7/8) Traumatic 12% (1/8)	Time-loss (Number of days missed or modified)  SEFIP Scores “Self-estimated functional inability because of pain”	Avg: S1 = 7.27 days S2 = 8.73 days Avg in previous 12 months: 13.89 days (0 -120 days, SD 24.45) Avg SEFIP: 4.9 – 5.64							
<b>Negaus et al (2005)</b>	Overuse: 93.1% (27/29) Traumatic 41.5% (12/29)	Total severity index <u>Duration of injury</u> (wks) transformed into an ordinal scale (0-3) <u>Perceived impact</u> at peak of injury on VAS 0-10	Severity data not provided.  Severity of non-traumatic injuries were associated with reduced functional turn out	Other lower leg 19.5%	Foot 11% Ankle 25.6%	7.3%	Hip 25.6% Thigh 1.2%		9.8%	
<b>Coplan et al (2002)</b>	NR	NR	NR	81.6%	Foot 4.5% Ankle 13.6%	36.3%		4.5%	13.6%	
<b>Luke et al (2002)</b>	Overuse: SRI=54% RI = 49.3% Acute Strain: SRI=14% RI = 39.4%	Likert Scale 1 – 5 scored by: Dancers for SRI and by Physiotherapists for RI	Avg: 2.8 +/- 1.1 Median: 3  Fair correlation between dancers and physiotherapists		Ankle 31%				29.5%	

\* Mixed cohort \*\* Non elite dance students \*\*\*professional NR = not reported Lsp = lumbar spine Tsp = thoracic spine Csp = cervical spine LL = lower limb UL = upper limb  
Avg = average SRI=self-reported injuries SR=reported injuries mth=month/s yr=year/s UKB= German Social Accident Insurance Institute Berlin B= ballet M = modern

Table 2.2 continued. Studies reporting injury type, severity and location in pre-professional ballet and modern dance students

Study Reference	Injury Type traumatic/overuse	Injury Severity Classification	Severity Outcome	Injury Location						
				LL	Foot Ankle	Knee	Hip	UL	Lsp	Neck
Askling et al (2002)	<b>Hamstring Injuries Only:</b> Overuse: 17% Acute: 34%	NR	NR				51% rare thigh			
Garrick (1999)	Overuse: 42.4 - 53.6% Acute: 20 – 43.5% Acute injuries most common in ankle	NR	NR		Foot 28% Ankle 19.9%	16.1%	11%		5.3%	
Krasnow et al (1999)	NR	Days of modified training	% Ballet/Modern/Gym <2days: 0%/31%/0% 3-7days: 29%/0%/5% 1-2wk: 12%/0%/38% 3-4wk: 35%/15%/18% 1-3mth: 6%/31%/34% >3mth: 18%23%/5%		Foot/ Ankle B27% M26%	B22% M24%	B30% M10%		B12% M18%	Csp/ Tsp B5% M8%
Weisler et al (1996)	NR	NR	NR	63.5%	Foot (23%) Ankle (39%)	(18%)	(20%)			

\* Mixed cohort \*\* Non elite dance students \*\*\*professional NR = not reported Lsp = lumbar spine Tsp = thoracic spine Csp = cervical spine LL = lower limb UL = upper limb  
Avg = average SRI=self-reported injuries SR=reported injuries mth=month/s yr=year/s UKB= German Social Accident Insurance Institute Berlin B= ballet M = modern

Table 2.2 continued. Studies reporting injury type, severity and location in pre-professional ballet and modern dance students

Study Reference	Injury Type traumatic/overuse	Injury Severity Classification	Severity Outcome	Injury Location						
				LL	Foot Ankle	Knee	Hip	UL	Lsp	Neck
<b>Hamilton et al (1997)</b>	Overuse: 49%	Severity based on: 1. Medical diagnosis 2. Nature and duration 3. Frequency  Reported as either 1. major or minor injuries 2. duration of disability	51% minor injuries 21% major injuries  Avg length of disability 54 days							
<b>Miller &amp; Moa (1998)</b>	NR	NR	NR	Leg 10%	Ankle 16%	4%	Hip 6%		4%	CSP + UL 2%
<b>Rovere et al (1983)</b>	NR	Time-loss for specific injuries (full days lost from participation)	Hip tendonitis: 6.9days Low back strain: 4.7 days Chondromalacia patella: 4.1 days Achilles: 2.5 days Ankle Sprain: 2.1 days		Ankle 22.2% Foot 14.8%	14.5%	Hip 14.2%		Csp/Tsp/Lsp 17.6%	

\* Mixed cohort \*\* Non elite dance students \*\*\*professional NR = not reported Lsp = lumbar spine Tsp = thoracic spine Csp = cervical spine LL = lower limb UL = upper limb  
Avg = average SRI = self-reported injuries SR=reported injuries mth = month/s yr = year/s UKB = German Social Accident Insurance Institute Berlin B = ballet M= modern

### **2.1.5 Characteristics of musculoskeletal injury in pre-professional ballet and modern dance students.**

The characteristics of dance injuries are like those of other sports. However, the distribution and nature of these injuries are considered to be specific to the demands of dance (Motta-Valencia, 2006). Characteristics of dance related injuries including nature (traumatic or overuse) and location are reported in Table 2.2. The purpose of this section is to examine the literature reporting the characteristics of dance injuries amongst pre-professional ballet and modern dance students.

#### ***2.1.5.1 Traumatic and overuse injuries***

Overuse injuries occur over time due to repetitive micro-trauma to tendons, bones and joints (Malkogeorgos, Mavrovouniotis, Zaggelidis, & Ciucurel, 2011). As can be seen in Table 2.2, overuse injuries are more common than acute traumatic injuries in pre-professional dancers. This is consistent with what is also seen in the professional dance population and in other non-contact sports involving highly repetitive movements and/or training/competition that are of longer duration (Allen et al., 2012; Byhring & Bo, 2002; Nilsson et al., 2001; Ojofeitimi & Bronner, 2011; Shah et al., 2012; Yang et al., 2012). The reported prevalence of overuse injuries amongst pre-professional dancers ranges from 29% - 93% (see Table 2.2) with the majority of these injuries occurring in the lower limb (Ekegren et al., 2014; Leanderson et al., 2011). Echegoyen et al. (2010) reported the lowest rate (29%) of overuse injuries in a cohort of 444 pre-professional dancers (modern, folk, Spanish). However, this only included five overuse injury diagnoses: low back pain, tendinitis (location not specified), patellofemoral pain, osteitis pubis and plantar-fascia. The limited categories for overuse injury, along with a mixed cohort of dancers, may

account for the lower rates found in this study compared to other studies of pre-professional dancers where prevalence of overuse injuries is consistently higher.

While the prevalence of overuse injuries in pre-professional dancers is high, the types and distribution of injuries making up these figures have been less commonly reported (Gamboa, 2008; Leanderson et al., 2011; Wanke, Koch, et al., 2014; Weigert & Erickson, 2007). Bowerman (2013) in a cohort of pre-professional ballet dancers, found the greatest number of overuse injuries occurred in the foot followed by the lumbar spine and ankle which is consistent with the demands on ballet dancers. Within the sports medicine literature, females have been reported to have a higher incidence of overuse injuries than males, although the reasons behind this are not fully understood (Yang et al., 2012). Similarly, Nilsson et al. (2001) in a study of professional ballet dancers, found that female dancers were more likely to sustain overuse injuries compared to males. However, amongst pre-professional dancers no significant difference between genders has been consistently reported (Leanderson et al., 2011; Steinberg, Aujla, et al., 2013). Overall, pre-professional dancers appear to have higher prevalence rates of overuse injuries compared to other adolescent sporting populations, which are estimated to vary between 45.9 – 54% (DiFiori et al., 2014). Gymnasts, who also have high training volumes, have reported prevalence rates of overuse injury ranging from 33% - 40.6% (Caine et al., 2003; DiFiori et al., 2014). These are, on average, lower than those found in pre-professional dancers who are routinely exposed to highly repetitive training and performance demands. This difference may also reflect the broad injury definitions commonly used within dance medicine, which potentially capture a wider range of injuries.

The demands of dance mean acute injuries are still an inevitable part of the dance injury profile. Traumatic/acute injuries refer to those injuries which are the result of a single episode of excess stress or strain that results in micro-trauma (Motta-Valencia, 2006). Ankle injuries are reportedly the most common acute injury across both pre-professional and professional dancers, with a higher risk of ankle sprains amongst younger dancers (Baker et al., 2010; Leanderson et al., 2011; Negus et al., 2005; Nilsson et al., 2001). At the professional level dancers  $\leq 26$  years were shown to have higher rates of acute ankle sprains than dancers older than 26 years (Nilsson et al., 2001). This is considered, in part, to be due to greater experience, better technique, strength and/or a well-developed routine of self-care such as warm up and conditioning (Leanderson, 2012; Nilsson et al., 2001). Acute upper body and knee injuries have been reported to be more common in professional male dancers (Motta-Valencia, 2006; Nilsson et al., 2001; Wanke, Mill, et al., 2014). This difference has been attributed to specific technical demands including lifting, and jumping and landing (Motta-Valencia, 2006; Nilsson et al., 2001). Interestingly, male and female professional dancers have been shown to have the same level of risk for acute non-contact ACL injuries, although female modern dancers had a higher risk than female ballet and male dancers (Liederbach, Dilgen, & Rose, 2008). This is in contrast to other sporting populations where female athletes have a higher risk of non-contact ACL injury (Sutton & Bullock, 2013). The lack of gender difference for non-contact ACL injuries is thought to reflect the fact dancers practise hundreds of jumps each day with specific focus on precision and balance, possibly having a protective effect (Liederbach et al., 2008). Comparative studies within the pre-professional population however are still required.



### ***2.1.5.2 Injury location***

The distribution of dance injuries is similar in pre-professional and professional dancers, with the greatest number of injuries occurring in the lower limb followed by the back/trunk and then upper body (Allen et al., 2012; Jacobs, 2010; Ojofeitimi & Bronner, 2011; Shah et al., 2012). Despite some variability in prevalence rates, as depicted in Table 2.2, the foot and ankle are particularly susceptible to injury and are the most commonly reported lower limb injuries in both pre-professional modern and ballet dancers. A combination of technical demand, high training levels, selected physical characteristics i.e. cavus foot and hypermobility, and inadequate recovery time post injury are cited as significant contributory factors for lower limb injury in this population (Allen et al., 2012; Conti & Wong, 2001; Ekegren et al., 2014). The rates of lower limb injury seen in pre-professional dancers appear higher than the rates seen in adolescent athletes involved in team sports (53.7 -53.8%) as well as gymnasts (57.81%) (Caine et al., 2003; Hootman, Dick, & Agel, 2007). By comparison, upper limb injury rates tend to be lower in dancers (ballet and modern) compared to gymnasts (21.36%) (Caine et al., 2003) and across multiple sports (18.3 – 21.4%) (Hootman et al., 2007). Pre-professional modern dancers typically have higher rates of upper body injury compared to their ballet counterparts, reflecting the demands of the genre (Baker et al., 2010). Hip hop is one dance genre that has reported significantly higher upper body injury prevalence (32%), and is likely the result of consistently high loads on the upper body, and at times performed on less than ideal flooring (Ojofeitimi, Bronner, & Woo, 2012).

The lumbar spine is also vulnerable to injury in both professional and pre-professional dancers with factors such as repetitive hyperextension, and for males high lifting demands, contributing to injury risk (Alderson, Hopper, Elliott, &

Ackland, 2009; Dunn, Proctor, & Day, 2006; Nilsson et al., 2001). Injury rates amongst pre-professional dancers for the low back ranged from 5.4% - 25.3% (see Table 2.2). Luke et al. (2002) reported the highest rate of low back injury (18 out of 71 injuries, 25.3%). The high number of dancers reporting a previous history of low back injury at the start of the study (25.6%) may contribute to this finding. The only study reporting a higher rate was in a mixed cohort of pre-professional and professional dancers (31%), which may reflect the higher rates of low back injury generally noted in the professional population (12%-33%) (Allen et al., 2012; Bowling, 1989; Crookshanks, 1999; Jacobs, 2010; Nilsson et al., 2001; Shah et al., 2012; Solomon, Solomon, Micheli, & McGray, 1999).

#### ***2.1.5.3 Injury type***

The distribution of specific injuries, beyond location/region and type of onset (acute or overuse) are limited within the dance literature. Studies that have categorised injuries according to diagnosis have often used variable reporting strategies. Several studies have reported the tissue type affected by injury with either joints/ligaments or muscles the most commonly affected structures (Baker et al., 2010; Ekegren et al., 2014; Laws, 2010; Steinberg, Aujla, et al., 2013). Bone injuries, specifically stress reactions/fractures, are also common amongst pre-professional dancers, with one study reporting these accounted for 19% of all injuries and also resulted in the greatest time off dance (Ekegren et al., 2014). Limited studies have utilised a standardised injury diagnoses system, such as the Orchard Sports Injury Classification System (OSICS), to report injuries. One study that did, found the most common injuries were tenoperiostitis of the tibia, ankle and tendon injuries, and ankle synovitis/impingement/bursitis (Ekegren et al., 2014). Leanderson et al (2011) reported the most common injuries in a cohort of pre-professional ballet

dancers to be ankle sprains, tendinosis pedis, chondromalacia patella, hip tendinosis and low back pain, although the OSICS were not used. Three other studies reviewed reported the prevalence of a single injury type, including hamstring strains (Askling, Lund, Saartok, & Thorstensson, 2002), patellofemoral pain (Steinberg et al., 2012b), and ankle sprains (Hiller, Refshauge, Herbert, & Kilbreath, 2008). However, as no other comparable studies were identified to compare findings, this limits possible conclusions across the broader pre-professional dance population.

#### ***2.1.5.4 Timing of dance injuries.***

Large-scale studies of sports injuries have reported higher injury rates during games in the competitive season than during training (with the exception of gymnastics) (Hootman et al., 2007). There have been mixed reports within the dance literature as to when dancers are most at risk of injury. The variable technical demands, frequency, intensity and duration of classes, rehearsals and performances reported across each cohort possibly contributes to this lack of consistent results (Allen et al., 2012; Bowling, 1989; Bronner et al., 2003; Crookshanks, 1999; Shah et al., 2012; Steinberg et al., 2011).

Several studies of professional dancers have reported higher rates of new injuries to occur during performances (range 37- 54%) compared to rehearsals (range 3 -37%) and classes (10%) (Bronner et al., 2003; Crookshanks, 1999). Factors such as difficult costuming, lighting, crowding backstage, increased work load, fatigue, and high repetition of specific choreography have been cited as contributing to injury risk at these times (Bowling, 1989; Bronner et al., 2003; Crookshanks, 1999; Steinberg et al., 2011; Wanke, Koch, et al., 2014). Pre-professional dancers, in comparison, spend more of their time attending classes with less overall exposure to

rehearsals and performances (Ekegren et al., 2014). As such, injury risk has been shown to be greater during class time (Wanke, Koch, et al., 2014). In pre-professional dance cohorts, injury rates have also been found to increase with each year of dance training, which is thought to coincide with greater technical demand and increased training demands associated with performance and rehearsals (Ekegren, Quested, & Brodrick, 2011; Ekegren et al., 2014; Leanderson et al., 2011; Steinberg et al., 2011).

#### **2.1.6 Conclusion.**

The availability of consistent comparable research on injury incidence and severity in pre-professional modern and ballet dancers is limited. Although progress has been made in recent years, variable injury definitions, severity measures, and lack of exposure data, has at times limited meaningful comparisons. Overall, dancers sustain injuries with similar characteristics to other athletes. However, the demands of dance make the frequency and distribution of these injuries specific to this population. Future intervention studies focusing on reducing overuse lower limb injuries, and specifically those injuries resulting in significant time-loss from dance such as stress fractures is indicated.

## **2.2 Injury Surveillance and Reporting in Dance Medicine.**

### **Introduction**

The current literature highlights musculoskeletal injuries to be a significant ongoing health issue for dancers (Jacobs, 2010; Jacobs, Hincapié, & Cassidy, 2012). Successful injury prevention requires consistent and ongoing collection of reliable and relevant injury data (Finch, 2006; Liederbach & Richardson, 2007; Maffey & Emery, 2011; van Mechelen, 1997). The injury surveillance model proposed by van Mechelen (1992), where the extent of the injury problem (incidence and severity) is initially established, followed by aetiology and risk factors, set the benchmark for injury surveillance and prevention for sporting populations (Maffey & Emery, 2011). More recently, this was further developed by Finch (2006) who proposed an extended framework, Translating Research into Injury Prevention and Practice (TRIPP). While the first two stages of the TRIPP model mirror those of van Mechelen's, stages 3-6 involve identification, development and implementation of injury prevention strategies, establishing their uptake and efficacy both in ideal conditions and 'real world' environments (Finch, 2006).

Dance medicine is a developing field with an associated increase in research reporting the incidence and characteristics of dance injuries. However, several confounding factors exist within the current dance literature often limiting conclusions and comparisons across the dance population, and hence also robust research focusing on TRIPP stages 3-6. The purpose of this section is to examine current status of injury surveillance and reporting trends within dance medicine.

### **2.2.1 Injury reporting in dance research.**

The reliance on retrospective injury data, either via dancers recall of injury or medical notes, is a prominent limitation of the current body of literature, as can be seen in Table 2.1. Retrospective data is inherently associated with well known limitations, including recall bias and use of non-uniform injury reporting methods (Portney & Watkin, 2009). Comparisons and conclusions across the body of available studies must, therefore, be made cautiously.

Another primary confounding factor within dance medicine literature is the variability in injury definitions utilised (refer to Table 2.1). More recently, authors have made recommendations to promote standardised injury reporting methodology in dance research (Bronner, Ojofeitimi, & Mayers, 2006; IADMS, 2012; Liederbach & Richardson, 2007). Bronner et al. (2006, p. 72) proposed the injury definition, “any physical complaint sustained by a dancer resulting from performance, rehearsal or class and resulting in a dancer injury report and triage, irrespective of the need for medical attention or time-loss from dance activities”. This is consistent with definitions used for other sports and recommendations made by the International Olympic Committee (IOC) (Finch, 2006; Junge et al., 2008). The International Association of Dance Medicine and Science’s (IADMS) Standard Measures Consensus Initiative (SMCI), a guide for injury reporting in dance, goes a step further proposing the use of a time-loss definition: “any anatomic tissue-level impairment as diagnosed by a licensed health care practitioner that results in full time loss of activity for one or more days beyond the day of onset” (Liederbach, Hagins, Gamoba, & Welsh, 2012, p. 144). In this instance ‘activity’ refers to “participation in a class, rehearsal or performance” (Liederbach, Hagins, Gamoba, & Welsh, 2012, p. 144). The use of a ‘time-loss’ injury definition is recommended for

use in epidemiological research as it is considered to achieve the most consistent and reliable injury data (Liederbach et al., 2012; National Collegiate Athletic Association (NCAA), 2013). The application of this new definition is, however, only just becoming evident within recent dance medicine literature, with only one study of pre-professional dancers using this definition (Ekegren et al., 2014) (Table 2.1). As such, dance medicine has some way to go to build a comparable body of reported time-loss injury data (Finch, 2006; Liederbach et al., 2012; NCAA, 2013).

Reliance purely on time-loss definitions is, however, considered to result in the under-reporting of injuries, specifically those injuries that are overuse in nature (Clarsen, Myklebust, & Bahr, 2013). In dance, as in many sports, activity modification or simply continuing to dance with an injury is common practice (Bronner et al., 2006; Jacobs, 2010). Non time-loss injuries are common in dance and, therefore, important to capture as a distinct group in order to obtain a more complete injury profile (Bowerman, 2013; Krasnow et al., 1999; Liederbach & Richardson, 2007).

Reported injury data whereby injuries are diagnostically confirmed by qualified medical staff is considered the most valid and comparable means by which injury characteristics can be obtained (International Association of Dance Medicine & Science (IADMS), 2012; Junge et al., 2008). The use of reported injury data is common in dance research, in part due to the development of wellness programmes and availability of in-house medical care now common in pre-professional dance schools. However, failure to report injuries or delayed reporting is a well-recognised issue in dance (Baker et al., 2010; Jacobs, 2010; Luke et al., 2002; Nordin-Bates et al., 2011; Weigert & Erickson, 2007). Reported injury data relies on the dancer

considering that their ‘problem’ requires some level of healthcare attention. Instead, dancers often simply accept pain as part of the process (Andersen & Hanrahan, 2008; Baker et al., 2010). Under reporting of injuries may also be due the dancer wanting to avoid time-loss or seeking healthcare off-site. The use of self-reported injury data within dance research has the capacity to capture a unique insight into the culture of injury reporting within a dance school, including injury characteristics, without the obvious consequences of reporting to in-house staff (Baker et al., 2010; Baker-Jenkins, Wyon, & Nevill, 2013; Luke et al., 2002; Portney & Watkin, 2009; Weigert & Erickson, 2007). Nevertheless, this method has well documented limitations which must be considered when interpreting results (Portney & Watkin, 2009).

Quantifying the volume of exposure during which dancers may be at risk of injury is required to put injury prevalence into context (C. W. Fuller et al., 2006; Liederbach et al., 2012). The use of injury incidence rates has been poorly utilised in dance research with inconsistent reporting methods and exposure definitions. Current recommendations define dance exposure (DE) as: “any participation in a class, rehearsal, or performance in which the dancer was exposed to the possibility of a dance injury” (Liederbach et al., 2012, p. 145). Reporting injury rates per 1000/DE’s is considered to achieve a higher level of reliability as well as comparability between sports genres, and is consistent with other international sporting bodies (Junge et al., 2008; Liederbach et al., 2012; NCAA, 2013). Only three reviewed studies of elite pre-professional ballet dancers used this methodology, allowing some comparison within this specific population (Bowerman, 2013; Ekegren et al., 2014; Gamboa, 2008). The use of time to define exposure is more commonly used within dance medicine, and is typically reported per 1000hrs of dance exposure (DEhr). This



method has recognised limitations, particularly in dance, where the actual time spent dancing will vary from class to class, and dancer to dancer depending on the choreography and role of each dancer (Liederbach & Richardson, 2007).

Comparisons between studies of pre-professional dancers are also limited by the nature of institutes providing dance training. These may vary from elite pre-professional dance schools to university led dance degrees; hence, so too does the volume of dance exposure, syllabus, intensity and opportunity to perform. The age of dancers attending training institutes also spans a wide age range. Elite level training may begin from as young as eight years old (Steinberg, Siev-Ner, et al., 2013) with young dancers specifically selected to attend training schools on a part-time basis while they continue their schooling. Such variations inherently have an influence on research outcomes. Current studies are now beginning to better identify the population at risk, depicting narrower age bands and/or specific year of study, thereby, enabling more meaningful and specific comparisons to be made (Ekegren et al., 2014; Leanderson et al., 2011; Steinberg, Siev-Ner, et al., 2013).

### **2.2.2 Injury surveillance systems in use in dance.**

The use of injury surveillance as advocated by IADMS (2012) is now more common within dance schools and professional companies. Two recently promoted online tools developed for this purpose; the Dancers Wellness Project (DWP) and the International Performing Arts Injury Reporting System (IPAIRS) have the potential to provide training schools and companies, as well as researchers, a more consistent means by which injury data may be collected. The use of these injury surveillance tools is still relatively new in dance research, outside of that undertaken by the developers (Baas & Galbraith, 2005; Liederbach, 2013). Liederbach (2013)

developed the IPAIRS, an online standardised and secure injury reporting system. This enables dance clinicians and researchers to gather both quantitative and qualitative injury data utilising diagnostic nomenclature consistent with the National Collegiate Athletic Association Injury Surveillance System (NCAA ISS) (Kreha, 2013).

### **2.2.3 Conclusion**

The development of the Standard Measures Consensus Initiative (SMCI) by the International Association of Dance Medicine & Science (IADMS) (2012) has been an important step in beginning to address the lack of standardised injury reporting within dance medicine. Together with the development of injury surveillance systems that can be utilised both nationally and internationally, a larger more comparable body of injury data for pre-professional adolescent dancers can be established. This will then also better guide future research and injury prevention strategies (Finch, 2006; Jacobs, 2010; Liederbach et al., 2012)

## **2.3 Risk Factors for Musculoskeletal Injury In Dancers**

### **Introduction**

Dance injuries, like those of other sports, are considered to occur as a result of the interplay between multiple risk factors. A wide range of risk factors for dance related injuries have been reported in the dance literature, as depicted in Table 2.3. There is a continuing need to develop a better understanding of the nature and interaction of these risk factors within the dance population, more specifically amongst pre-professional dancers who due to their age and training demands inherently differ from those at professional level. While some risk factors like age and gender cannot be modified, many more can be, and therefore so too can the overall risk of injury. Identifying modifiable risk factors within this specific population will better guide future research, whereby the implementation and efficacy of evidence based injury prevention strategies can be established. The purpose of this section is to provide an overview of the current evidence for those intrinsic and extrinsic risk factors for dance related injury that are most pertinent, and provide background to this current study.

Table 2.3 Summary of potential intrinsic and extrinsic risk factors for dance related injury

Intrinsic Risk Factors	Extrinsic Risk Factors
Demographics <ul style="list-style-type: none"> <li>- age</li> <li>- gender</li> <li>- height</li> <li>- weight</li> <li>- body mass index (BMI)</li> <li>- body fat % (BF%)</li> </ul>	Environmental <ul style="list-style-type: none"> <li>- floors (sprung versus un-sprung)</li> <li>- raked stage</li> <li>- poor and variable lighting</li> <li>- space constraints</li> <li>- poor ventilation</li> <li>- cold or hot studios/theatres</li> </ul>
Medical History <ul style="list-style-type: none"> <li>- previous injury history</li> <li>- onset of menarche</li> <li>- growth</li> <li>- RED-S (reduced energy deficiency syndrome)</li> </ul>	Training <ul style="list-style-type: none"> <li>- volume (high, low and rapid changes)</li> <li>- intensity</li> <li>- poor warm up /cool down practices</li> <li>- training and performance schedules</li> </ul>
Physical condition of dancer <ul style="list-style-type: none"> <li>- CV fitness/fatigue</li> <li>- capability</li> <li>- nutrition/fluids</li> </ul>	Equipment/Clothing <ul style="list-style-type: none"> <li>- footwear (pointe, flats, character, jazz, tap, barefoot)</li> <li>- difficult costuming</li> <li>- props</li> </ul>
Anatomical-physiological <ul style="list-style-type: none"> <li>- range of motion</li> <li>- strength</li> <li>- motor control (functional and dance specific)</li> <li>- hypermobility</li> </ul>	Choreography <ul style="list-style-type: none"> <li>- beyond the dancers capacity</li> <li>- repetitive overloading</li> <li>- intensity</li> </ul>
Training <ul style="list-style-type: none"> <li>- faulty technique</li> <li>- year of study</li> </ul>	Services <ul style="list-style-type: none"> <li>- lack of access to healthcare services and conditioning facilities</li> <li>- lack of education on strategies to reduce injury risk and optimise self-care</li> </ul>
Psychology <ul style="list-style-type: none"> <li>- risk taking behaviours</li> <li>- competitive pressures</li> <li>- self-esteem</li> <li>- psychosocial coping</li> </ul>	Regulatory and organisational aspects <ul style="list-style-type: none"> <li>- poor remuneration</li> <li>- contract obligations</li> <li>- culture of organisation</li> <li>- competition and status within company/school</li> </ul>

Note: Adapted from (Jacobs, 2010; Liederbach et al., 2012; Motta-Valencia, 2006; Russell, 2013; Steinberg et al., 2012a; Wanke, Mill, et al., 2014)

### **2.3.1 Intrinsic risk factors**

#### ***2.3.1.1 Demographics.***

Demographic factors including: age, gender, height weight and body mass index (BMI) have been commonly reported within the dance literature with regard to injury risk, albeit with variable results. Sports injuries amongst young athletes are well documented, with both the incidence and the severity of injuries reported to increase during adolescence (El-Metwally, Salminen, Auvinen, McFarlane, & Mikkelsen, 2010; Gallagher et al., 1984). Likewise, the risk of dance injury, and specifically lower limb injury has been demonstrated to increase during adolescence, with the highest rates found in 15 – 19 year olds (Roberts et al., 2013). Although pre-professional dancers are often of an age considered at high risk of injury, the relationship between age and injury risk across this specific population has been inconsistent (Baker et al., 2010; Bowerman, 2013; Caine et al., 2008; Campoy, Bastos, Vanderlei, & Padovani, 2011; Gamboa, 2008; Garrick & Requa, 1997; Leanderson et al., 2011; Luke et al., 2002; Steinberg, Aujla, et al., 2013; Steinberg, Siev-Ner, et al., 2013). Significant differences in maturation and growth in dancers of the same age, coupled with other risk factors such as differences in technical demands and exposure, are thought to explain why chronological age is not always a reliable indicator of injury risk (Bowerman, 2013; Caine et al., 2008; Malkogeorgos et al., 2011). Gender has also been considered to contribute to the variability in age related injury risk. Luke et al. (2002) in a study of pre-professional dancers aged 14-18 years found males had an injury rate twice as high as female dancers, which was thought to reflect the fact males are considered to reach physical maturity later than females. However, the study only included five males who were reported by the authors to have less technical experience, a greater degree of technical demand and

were required to do more partnering and lifting. Other comparable studies of adolescent dancers have found no association with gender and overall injury risk (Baker et al., 2010; Ekegren et al., 2014; Leanderson et al., 2011; Steinberg, Aujla, et al., 2013). Further to this, there is a lack of consistent association between gender and injury location and/or type amongst pre-professional dancers within the current research. (Baker et al., 2010; Gamboa, 2008; Garrick & Requa, 1997; Leanderson et al., 2011; Steinberg, Aujla, et al., 2013).

Low BMI amongst dancers, in particular amongst female dancers, has been well documented within the dance literature, and in some cases has been implicated with an increased risk of injury (Burckhardt, 2011; Crookshanks, 1999; Doyle-Lucas, 2010; Laws, 2010; Wyon, Hutchings, Wells, & Nevill, 2014). An association between low BMI and dance injuries was reported in an early study by Bensen, Geiger, Eiserman, and Wardlaw (1989) who found those with a lower BMI spent more days off dance due to injury. In comparison, studies involving younger dancers from 8-16 years have found no association between BMI and injury risk (Steinberg et al., 2012a; Steinberg, Siev-Ner, et al., 2013). This younger age group is likely to have a lower muscle mass, and in some cases will be yet to reach the age of menarche, and therefore may not be comparable to older pre-professional dancers (Wyon et al., 2014). In studies of pre-professional dancers, a low body fat percentage (BF%) has also been significantly correlated with increased time off from acute injury, total time off from any injury, and the length of time for which activity was modified due to injury (Twitchett, Angioi, Metsios, Koutedakis, & Wyon, 2008; Twitchett et al., 2010).

A low BMI or BF% may also be associated with other clinical disorders such as disordered eating and menstrual dysfunction. Previously known as the Female Triad, this is now referred to as Reduced Energy Deficiency Syndrome (RED-S), and is characterised by low energy availability as a result of an imbalance between energy intake and energy expenditure (Mountjoy et al., 2014). While menstrual dysfunctions (specifically primary and secondary amenorrhea) have been well documented amongst pre-professional dancers, the relationship with injury risk in dancers is unclear due to inconsistent findings (Gamboa, 2008; Hincapie & Cassidy, 2010; Kadel, Teitz, & Kronmal, 1992; Luke et al., 2002; Mountjoy et al., 2014; M. P. Warren, Brooks-Gunn, Hamilton, Warren, & Hamilton, 1986). Overall, there is a lack of literature investigating the prevalence of RED-S and the relationship to injury risk within the dance population; hence this requires further focused research (Doyle-Lucas, 2010).

#### ***2.3.1.2 Medical history.***

Previous injury is a well documented risk factor for future injury across many sports, and has been reported to increase an athlete's risk of further injury by up to a fivefold (Thein-Nissenbaum, Rauh, Carr, Loud, & McGuine, 2011). Dancers are sustaining injuries at young ages, with one study of 569 dancers reporting that 46.2% had sustained a dance related injury by the age of 16 years (Steinberg, Siev-Ner, et al., 2013). The result is a high number of dancers entering pre-professional training with a previous injury history (D. Hamilton et al., 2006; Negus et al., 2005; Steinberg et al., 2011). An increased risk of injury has been reported in dancers with a previous history of ankle injury (Hiller et al., 2008; Wiesler, Hunter, Martin, Curl, & Hoen, 1996) and low back pain (Gamboa, 2008; Laws, 2010; Wiesler et al., 1996). Gamboa (2008), in a study of 204 adolescent ballet dancers, found those that

sustained an injury were 56% more likely to have had a previous history of low back pain than the non-injured group. However, in studies where all types of previous injury have been included in analysis, no association with injury risk has been found (Gamboa, 2008; Luke et al., 2002; Steinberg et al., 2011). The high injury prevalence, and the fact that a significant number of dancers have a history of previous dance injury make this a relatively homogenous group, and hence may contribute to these later findings.

#### ***2.3.1.3 Anatomical and physiological factors.***

The relationships between specific anatomical and physiological variables (generalised joint hypermobility [GJH], range of motion [ROM], strength, dance and/or functional movement control) and injury risk have been investigated within the dance population, with mixed results. A high prevalence of GJH is well documented within the dance population, specifically amongst ballet dancers (Day, Koutedakis, & Wyon, 2011; McCormack, Briggs, Hakim, & Grahame, 2004; Scheper et al., 2013). While some studies have reported no association between GJH and injury risk (Roussel et al., 2013; Roussel et al., 2009; Ruemper & Watkins, 2012), the weight of the literature indicates that dancers with GHJ are more susceptible to injury and greater time-loss, and have higher rates of attrition from junior to professional levels (Briggs, McCormack, Hakim, & Grahame, 2009; Leanderson, 2012; Ruemper & Watkins, 2012; Scheper et al., 2013; Scheper, de Vries, Nollet, & Engelbert, 2014).

In comparison to GJH, the relationship between joint range of motion (ROM) and injury risk is unclear. It is hypothesised that inadequate or excessive ROM may lead to compensatory movement patterns and, thereby, may contribute to increased risk



of injury (Mottram & Comerford, 2008). Reduced ankle dorsiflexion (Gamboa, 2008), reduced hip external rotation and increased hip abduction (Steinberg et al., 2012a), and greater range of compensated turnout (Coplan, 2002) have been associated with increased injury risk amongst dancers. However, these findings have not been consistent across the pre-professional population with several other studies reporting no association between ROM (including hip and ankle) and injury risk (Coplan, 2002; Gamboa, 2008; Hiller et al., 2008; Luke et al., 2002; Steinberg et al., 2012a, 2012b; Wiesler et al., 1996). Confounding factors such as the variability in measurement techniques, injury definitions, age and number of participants, and the degree of exposure may also contribute to the lack of consistency noted within the dance literature. Another factor may be that those individuals who are attracted to dance and reach an elite level are a relatively homogenous group in that their ROM does not markedly differ; hence large cohorts are necessary to detect any significant association.

Similarly, reduced strength, altered agonist:antagonist ratios, and power are thought to lead to altered biomechanics and control of motion, placing the athlete at risk, especially when the musculoskeletal system is stressed such as when fatigued or at extreme ranges of motion (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004; Nalder, Malanga, DePrince, Stitik, & Feinberg, 2000). There is limited research investigating muscular strength and injury risk within the dance medicine literature from which to draw any solid conclusions (Gamboa, 2008). Although altered strength ratios in both the ankle (dorsiflexors and plantarflexors) and hip (abductors and adductors) have been identified amongst dancers, the role this has on injury risk is unknown (W. G. Hamilton, Hamilton, Marshall, & Holnar, 1992). There is some good evidence within the dance research indicating that reduced lower limb

muscular power (measured utilising vertical jump or isokinetic dynamometer) is predictive of injury severity in both pre-professional and professional dancers and therefore may be a useful component to include as part of an overall injury screening protocol (Angioi, Metsios, Twitchett, et al., 2009; Koutedakis, 1997; Koutedakis, Clarke, Wyon, Aways, & Owolabi, 2009).

Optimal alignment and neuromuscular control (interaction between the nervous and musculoskeletal systems to achieve a desired outcome) is cited within the sports medicine literature as a critical factor in relation injury prevention, particularly the lower limb (Gutierrez, Kaminski, & Douex, 2009; Hewett et al., 2005). Authors have demonstrated significant changes in neuromuscular control and postural stability during dance specific movements (grand plie, sissonne ferme, first position, fifth position and en pointe) in dancers with a previous history of injury (Lee, Lin, Wu, Wu, & Lin, 2012; C. F. Lin, Lee, Liao, Wu, & Su, 2011; C. W. Lin, Su, & Lin, 2014). There are, however, only limited studies investigating the relationship between altered neuromuscular control of dance specific or functional movement and risk of future injury in dancers (Gamboa, 2008; Karim, Millet, Massie, Olson, & Morganthaler, 2011; Liederbach, 2010; Poggini, Losasso, & Iannone, 1999; Wilson & Deckert, 2009). A 5-year retrospective study of 359 elite pre-professional ballet dancers investigated the association between three measures for dance movement and posture (relevè balance time, developpè test and pliè turnout alignment) and risk of injury (Gamboa, 2008). No significant differences were noted between injured and non-injured dancers. Another retrospective study of young non-elite dancers aged 8-16 years examined three primary ballet movements (relevè, turnout position, and pliè in first position) that were scored as either correct or incorrect (Steinberg et al., 2012a). They found dancers who had the specific fault of 'rolling in' at the

foot/ankle sustained a greater percentage of injuries than those dancers assessed as having correct technique. A more recent study by Bowerman (2013) utilised 2D video to examine the reliability of knee and pelvic alignment measures in elite adolescent dancers performing single leg dance specific movements (fondu and temps levé) and their association with risk of overuse injuries of the lower limb and lumbar spine. In relation to injury risk, improved knee angles on the right side during fondu and temps levé showed a small to moderate decrease in overuse injury risk (Bowerman, 2013). No significant findings for the left leg or pelvic angles were reported. Limb dominance, measurement error, and small sample size were factors cited by the author to have potentially influenced results. Dancers were also only asked to perform the two movements three times; hence factors such as fatigue and endurance, which may influence alignment control, would not have been tested. Other studies reviewed have investigated landing mechanics and strategies in dancers in relation to: gender, ground reaction forces, floor, shoe type, neuro-mechanics, and compared to other athletes (Ambegaonkar et al., 2011; Orishimo, Kremenich, Pappas, Hagins, & Liederbach, 2009; Reeve, Hopper, Elliott, & Ackland, 2013). However, none of these examined the relationship to injury risk. Poor control of functional movement patterns has been associated with both a previous injury and future injury risk in dancers. The supporting research is, however, limited to two studies by the same author who utilised only a one functional movement pattern (standing bow) amongst its battery of tests (Roussel et al., 2013; Roussel et al., 2009).

### **2.3.2 Extrinsic injury risk factors for pre-professional dancers.**

#### **2.3.2.1 Dance exposure.**

The negative effects of relative training loads (changes in training load), and or training loads beyond an athlete's capacity are apparent from the sports medicine literature (Brenner, 2007; Brink, Nederhof, Visscher, Schmikli, & Lemmink, 2010; Drew, 2015; Kellmann; Koutedakis, 2000). Dancers are inherently an at risk group, often training 5-6 days per week, at times up to 7 hours per day, with classes lasting up to 120 minutes (Koutedakis, 2000; Wyon & Koutedakis, 2013). Periodization within dance, unlike other elite sports is poorly utilised if at all (Murgia, 2013).

In reviewed studies, pre-professional dancers danced on average from between 7.5 – 30.3 hours per week, as shown in Table 2.1. The variations in hours of exposure noted are likely due to differences in age, full-time versus part-time training programmes, and in many cases are likely to be under reported. Only limited studies were identified investigating dance exposure (volume) in relation to injury risk. Purnell, Shirley, Crookshanks, and Adams (2006) in a study of 75 dance students and 73 gymnasts aged between 16 and 19.5 years, found a training volume greater than 8.5 hours per week was a significant risk factor for injury. Comparatively, Steinberg, Siev-Ner, et al. (2013) in a cohort of non-elite dancers aged 8-16 years reported no association between hours of dance practice and injury risk. This younger cohort is, however, less comparable to elite pre-professional dancers who are older, and are exposed to a greater training load (hours and units) with more technically demanding choreography. Overuse injuries, in particular bony stress reactions/fractures common amongst dancers, are considered to occur as a consequence of excessive training volume. In the professional population, Kadel et al. (1992) found that dancers who danced more than five hours per day had a greater

risk of sustaining a stress fracture. Although stress fractures have been identified as resulting in significant time-loss amongst pre-professional dancers, no comparable studies were found in relation to training load and stress fracture risk amongst pre-professional dancers (Ekegren et al., 2014).

#### ***2.3.2.2 Type of dance exposure***

Studies investigating the association between exposure (hours or units) to a specific demand i.e. genre or technique, and increased injury risk, are similarly limited. Elite dancers (8-18 years) undertaking part-time training who undertook a greater number of hours training in contemporary dance (Steinberg, Aujla, et al., 2013) and non-elite ballet dancers (8 -16 years) undertaking more than 60 minutes dancing en pointe per week (Steinberg, Siev-Ner, et al., 2013), have been shown to have increased risk of injury. No similar findings were identified pertaining specifically to pre-professional dancers undertaking full-time training with which to make comparisons.

#### ***2.3.2.3 Changes in dance exposure.***

Rapid increases or decreases in training load (hours, intensity, frequency) are also considered to contribute to injury risk in pre-professional dancers. A study of 204 pre-professional ballet dancers reported increased injury incidence at times of increased training intensity such as: at the start of the academic year, during rehearsals, and prior to exams (Gamboa, 2008). Similar findings, including increased injury rates closer to assessment times and in the period immediately after students returned from holiday, were reported in a study of contemporary dance students (Baker et al., 2010). This is consistent with findings from other sports where rapid increases or variability in exposure have been reported to precede injury and are

associated with an increase in specific injuries, namely tendinopathies (Drew, 2015; Orchard et al., 2015)

### **2.3.3 Conclusion**

While current literature indicates that injury risk in dancers increases during adolescence, this is likely also influenced by variations in maturation, technical demand and increased exposure. There is good evidence that female dancers have a high risk of low BMI and menstrual dysfunction. Further research investigating the interaction of these variables and other markers of RED-s in relation to injury risk within the pre-professional population is needed. Overall, research focused on specific isolated anatomical and physiological factors in relation to injury risk is limited, and thus far has produced inconsistent results. Evaluation of neuromuscular control (functional and dance specific) whereby the interaction of independent variables (strength, range of motion, proprioception) may be established has the opportunity to provide a more efficient and effective means by which to identify those individuals at risk of injury. There is, however, only limited focused research on neuromuscular control and the relationship to injury risk in the pre-professional dance population; hence further investigation is warranted. Dance exposure/training load is a primary extrinsic risk factor also requiring focused research in order to establish optimal training volumes/frequencies for pre-professional dancers to better optimise training outcomes and minimise the risk of injury.

## **2.4 Functional Movement Screening**

### **Introduction**

Pre-participation or pre-season screening is widely used within organised sport to establish an athlete's readiness to participate in sport, training and competition, with the overall aim to promote the health and safety of the athletes (Sanders, Blackburn, & Boucher, 2013). Although, also promoted as a means of identifying those athletes at risk of injury, there is limited empirical evidence that broad spectrum pre-participation musculoskeletal screens assessing intrinsic risk factors are effective in predicting future injury risk in both in the sporting and dance arenas (Brumitt, Heiderscheit, Manske, Niemuth, & Rauh, 2013; Carpenter, Donner, Hoff, & Johnson, 2011; M. Fuller & Peirce, 2009; Gamboa, 2008; Garrick, 2004; Mottram & Comerford, 2008). The growing field of dance medicine has seen an associated rise in pre-participation and/or pre-season screening for dancers at both pre-professional and professional levels. Implementation of screening programmes have been associated with reduced injury rates in professional dancers (Solomon, 1997; Solomon et al., 1999). While this indicates that screening has the potential to play an important role in injury reduction, this is likely to be in part due to the secondary benefits that come from screening, including: ready access to a visible integrated healthcare team, positive influence on injury reporting behaviour, and promotion of healthcare education (Brumitt et al., 2013; M. Fuller & Peirce, 2009; IADMS, 2008; Potter, Galbraith, & Baas, 2011; Wilson & Deckert, 2009).

While advocated by international dance organisations, pre-participation screening for dancers at this time is not standardised nor regulated (Crookshanks, 1999; IADMS, 2008; Laws, 2010; Owens, 2009). Screening protocols currently recommended to assess a dancer's physical or musculoskeletal status have followed

an orthopaedic sports medicine model and include lengthy assessments of posture, joint range, flexibility, strength, and more recently cardiovascular fitness and dance specific movement control (W. G. Hamilton, 2006; Liederbach, 1997; Liederbach & Richardson, 2007; Morgan, 2010; Potter et al., 2011; Siev-Ner, Barak, Heim, Warshavsky, & Azaria, 1997; Solomon, 1997). Such comprehensive pre-participation screens can utilise considerable resource and can be time consuming to undertake. Further to this, their efficacy in establishing injury risk is not proven.

Functional movement screening tools utilising a battery of 'tests' to assess neuromuscular control have become a popular alternative to previously lengthy pre-participation screens. It is hypothesised that alterations in functional movement patterns due to asymmetrical and/or reduced muscular strength or joint range of motion, poor dynamic balance and alignment may predispose athletes to injury and impact performance (Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Cook, Burton, & Hoogenboom, 2006; Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2012; Kiesel, Pilsky, & Voight, 2007). Alterations in neuromuscular control of functional movements have been associated with patella-femoral pain syndrome (Willson & Davis, 2009), ACL injury (Hewett et al., 2005) and low back pain (Rickman, Ambegaonkar, & Cortes, 2012). Further to this, neuromuscular training has also been shown to reduce injury incidence and severity, as well as improve specific performance measures (Hewett, Lindenfeld, Riccobene, & Noyes, 1999; LaBella, Huxford, Smith, & Cartland, 2009; Myer, Ford, Khoury, Succop, & Hewett, 2010; Myer, Ford, Palumbo, & Hewett, 2005). Functional movement screening tools are reported to identify athletes who demonstrate specific deficits in an efficient manner, and who may then benefit from onward referral for more in depth assessment, targeted conditioning and/or modifications to training and



performance loads (Brumitt et al., 2013; Cook et al., 2006). The purpose of the following section is to review functional movement screening tools reported in the literature, and the efficacy of these tools in establishing injury risk in athletes and dancers.

## **2.4.1 Literature Review**

### **2.4.1.1 Methodology**

The literature reviewed was sourced from electronic databases and included: SPORTdiscus with full text, Cinahl Pulse with full text, Medline, Scopus, Proquest Direct and Google Scholar. All years from 1969 – May 2015 were included in the search. Search terms used to access relevant research studies included: pre-participation, move\*screen, functional, screen\*, movement\*competency, reliability, injury, risk and risk factors. Keywords were used separately and also in various combinations. Reference lists of all articles were checked for further relevant studies. Also included in the search were names of known movement screening tools including: functional movement screen (FMS), movement competency screen (MCS), star excursion balance test (SEBT), lower extremity score system (LESS), lower extremity functional screen (LEFS), lower extremity functional test (LEFT), and drop vertical jump (DVJ). Inclusion criteria included: (1) English and full text available (2) original research, systematic reviews, and full conference proceedings (3) studies examining functional screening tools in relation to sports, dance, injury risk/incidence and reliability. Excluded studies included: (1) unavailable in English or full text.

### **2.4.1.2 Results.**

After applying the exclusion criteria, 37 studies were included in the review. Eleven different screening tools assessing functional or dance specific neuromuscular

control, were identified. Nineteen studies reviewed specifically examined the relationship between the functional movement screening tools and injury risk and these are presented in Table 2.4.

## **2.4.2 Functional movement screening tools.**

### ***2.4.2.1 Movement Competency Screen (MCS).***

The Movement Competency Screen (MCS) is a screening tool used clinically by physiotherapists and strength and conditioning coaches within New Zealand. It is currently used by High Performance Sport New Zealand (HPSNZ), as part of the overall screening strategy for elite athletes. Developed by Dr Matthew Kritz (2012) as part of his doctoral thesis, the MCS was designed to offer a battery of tests that were reliable and valid in their ability to establish an individual's movement competency, and thereby guide exercise prescription. The MCS was also developed as a way to achieve a more effective communication between strength and conditioning trainers, coaches and healthcare providers by promoting a common understanding of movement competency (Kritz, 2012). The MCS evaluates an athlete's mobility, stability, and proprioceptive control during fundamental movement patterns that are considered to be common to both sport and activities of daily living (Kritz, 2012). The MCS consists of five movements tasks (squat, lunge and twist, bend and pull, single leg squat, press up) that challenge eight fundamental movement patterns (Kritz 2012). In addition, the MCS has more recently been expanded to include three dynamic jump tests (counter movement jump and land, counter movement jump landing on one leg and broad jump landing on one leg), challenging eccentric and plyometric control (Kritz, 2013).

The inter-rater reliability of the MCS (five fundamental movement tasks) has been reported to range from ICC score of 0.70 to 0.85 (mean 0.79) representing substantial agreement (Kritz, 2012). These findings were supported by a more recent study by Reid, Vanweerd, Larmer, and Kingstone (2015) who found substantial inter-rater reliability (ICC 0.77, CI 0.49 – 0.91) for the overall MCS score between two raters in a study using 40 female high school netball players. Substantial inter-rater agreement was also reported for the individual movement patterns of squat, lunge and push up, with average kappa values of 0.61, 0.71, and 0.62 respectively. However, only moderate agreement was found for the bend, pull and single leg squat, and poor agreement for the twist component of the lunge. This study utilised two raters across forty subjects compared to the initial study by Kritz (2012) which had 58 raters and three athletes. Kritz (2012) also reported the intra-rater test-retest reliability of the MCS for 12 raters had almost perfect agreement (kappa = 0.93). Similarly, Reid et al. (2015) reported substantial intra-rater agreement for the overall MCS score (ICC = 0.88; SEM 0.14). However, for individual MCS tests, while substantial agreement was reported for the squat, lunge and push up, poor agreement was found for the twist with average kappa value 0.27. Moderate agreement was found for the bend, pull and single leg squat, with weighted kappa values of 0.66, 0.57 and 0.57 respectively. Reid et al. (2015) was the only study reviewed that had reported both the inter-rater and intra-rater reliability of the three dynamic jump tests. For the overall jump score, substantial inter-rater agreement was reported (ICC 0.65; SEM = 0.21), and kappa values for individual jump scores ranged from 0.62 – 0.70. Intra-rater reliability was also substantial for the overall score of three dynamic jump tests all three tests (ICC 0.88; SEM 0.16), and individual scores for the counter movement jump and broad

jump but moderate for the counter movement jump with single leg landing. The results of these studies demonstrate that the MCS produces consistent results between raters and testing sessions for the total MCS score. However, individual movement scores should be interpreted with caution.

Unlike other functional screens reviewed, the content of the MCS was peer reviewed as part of the development process (Kritz, 2012). Kritz (2012) reported an excellent percentage agreement (80% – 97%) by sports and health professionals in regard to the structure, movement tasks, and the criteria used for screening. The content validity specific to certain sports, particularly dance, has not been established.

#### ***2.4.2.2 Functional Movement Screen (FMS).***

The FMS developed by Cook et al. (2006) is one of the most reported functional screening tools within the literature. It is made up of seven movement tasks (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, push up and rotary stability), reportedly based upon “fundamental proprioceptive and kinaesthetic awareness principles” (Cook et al., 2006, p. 64). Unlike the MCS, the FMS does not include any dynamic jump/land tasks common to many sports. It may be argued that this limits the utility of the screen as athletes may not be sufficiently challenged so as to determine their capacity, particularly in areas considered high risk of injury (Frost, Beach, Callaghan, & McGhil, 2015). The FMS requires the use of specific equipment making this less accessible and user friendly compared to the MCS, which at most, requires a simple video camera. The FMS is by far the most researched functional screening tool with regard to reliability testing. The inter-rater and intra-rater reliability of composite FMS scores has varied from moderate to

excellent depending on the expertise of the tester (Gulgin & Hoogenboom, 2014; Onate, Cortes, Welch, & van Lunen, 2010; Parenteau et al., 2014; Schmieg, 2012; Schneiders, Davidson, Horman, & Sullivan, 2011). More specifically, within the dance population only one study investigating reliability of the FMS was identified, demonstrating moderate inter-rater reliability for composite FMS scores, and moderate to almost perfect inter-rater reliability for each of the seven FMS items (Schmieg, 2012). The FMS has demonstrated good to excellent inter-rater reliability in studies using relatively low numbers of raters (2 – 8) (Gulgin & Hoogenboom, 2014; Parenteau et al., 2014; Schneiders et al., 2011; Teyhen et al., 2012). However, one study demonstrated poor inter-rater reliability of the FMS composite score across five raters assessing 39 NCAA Division 1 university athletes (Shultz, Anderson, Matheson, Marcello, & Besier, 2013). This indicates FMS scores should still be used cautiously when multiple assessors are used to establish an athlete's injury risk. Like the MCS, individual movement patterns included in the FMS (specifically the inline lunge and hurdle step test) have been shown to be less reliable between raters and testing sessions (Onate et al., 2010; Schneiders et al., 2011; Teyhen et al., 2012). Individual movement scores should, therefore, be interpreted with caution. While the FMS has been well reported in terms of reliability, this author identified no published studies investigating or supporting the content validity of the FMS.

#### ***2.4.2.3 Other functional movement screens reported in the literature.***

Nine other screening tools that also included functional movement tasks were identified in the literature. Two studies reviewed utilised a battery of tests (including either the FMS or MCS) for use in sporting populations. The Nine-Test screening battery for athletes included movements selected from the FMS, the United State

Tennis Association High-Performance Profile (USTA HPP), and from the researchers own test battery (Frohm et al., 2012). This screening tool has demonstrated good inter-rater and intra-rater reliability (ICC 0.80 and 0.75) when assessed in an elite cohort of soccer players. However, further research across differing sporting codes using a variety of raters is needed (Frohm et al., 2012). Vanweerd (2013) developed the Netball Movement Screen Tool (NMST), which included the MCS, jump components, SEBT, and active SLR. This screening battery demonstrated excellent inter-rater (ICC=0.84; SEM=0.25) and intra-rater reliability (ICC=0.96; SEM=0.13) for overall NMST score. While the NMST requires further investigation across the broader netball population with regard to reliability, this research highlights the growing trend towards sport specific functional screens utilising a selection of screening tests relevant to each sport.

Another screening tool identified in the literature reported a battery of tests specific to dance that aimed to determine a dancer's readiness to begin dancing en pointe (Richardson, Liederbach, & Sandow, 2010). This group of tests was examined by Richardson et al. (2010) in study of 37 pre-pointe ballet students. They reported only three of the dynamic tests (airplane test, sauté test and topple test) were found to be the best predictors of pointe readiness, where the test results were closely associated with teacher subjective rating. However, no reliability testing was reported for this study.

With respect to assessing just lower limb alignment, four screening tools were identified in the literature. The Landing Error Scoring System (LESS) and Dynamic Knee Valgus (DKV) both assess lower limb alignment during a drop vertical jump (DVJ) off a 30cm high box. While individually these screening tools have

demonstrated high to excellent reliability they are limited in that they only assess one specific movement task (Ekegren et al., 2011; Onate et al., 2010; Padua, 2009; Padua et al., 2011; Smith et al., 2012). In comparison, the Lower Extremity Functional Scale (LEFS) was designed by its authors to identify specific biomechanical faults in female athletes during five movement tasks (Carpenter et al., 2011). However, no further studies examining the utility or reliability of the LEFS were identified. Whatman (2012) developed the lower extremity functional test visual rating screen to assess multiple body segments across multiple common functional movement patterns as part of his doctoral thesis. The utility of this screening tool across the broader sporting population and variety movement patterns still requires further research (Whatman, 2012).

The Star Excursion Balance Test (SEBT) and Y-Balance Test (YBT) are two screening tools that were specifically designed to test balance (Plisky, Rauh, Kaminski, & Underwood, 2006; Shaffer et al., 2013). The YBT is a modified version of the SEBT, and includes only three reach distances (compared to the original eight), with the aim of improving efficiency as well as reliability (Shaffer et al., 2013). While both the SEBT and YBT have proven reliability (inter-rater and intra-rater) and have been shown to effectively assess dynamic balance in single leg stance, the effect load and speed have on balance such as when landing from a jump would require further testing utilising alternate assessment strategies (Gribble, Kelly, Refshauge, & Hiller, 2013; Hyong & Kim, 2014; Shaffer et al., 2013; Shaikh & Walunjkar, 2014).

### **2.4.3 The efficacy of functional movement screening tools to predict injury risk**

The current body of literature indicates functional movement screening to be a valuable tool for the purposes of efficiently assessing an athlete's movement competency. While it is likely there is no one specific tool which will adequately identify all athletes at risk of injury, utilising those that are most reliable and effective for each sporting population as part of an overall screening strategy is necessary.

The efficacy of a screening tool may be established via its ability to improve performance measures, optimise training outcomes, and to predict and reduce injury risk. Functional movement screening tools involve a battery of tests that are scored against set criteria to provide an outcome score. It is hypothesised that those with higher outcome scores have better movement control and, therefore, are less susceptible to injury than those with lower scores. However, the utility of functional screening tools to predict injury risk and guide injury prevention and management remains unclear (Gamble, 2013). Studies investigating the relationship between functional movement screening tools and injury risk are presented in Table 2.4.



Table 2.4 Studies reporting the relationship between functional movement screening tools and injury risk

Study	Study design	Participants	Screening tool/s	Injury definition	Relationship to injury risk
<b>Brumitt et al (2011)</b>	Prospective Longitudinal Cohort	Division 3 University level athletes (N=193)	SLJ SLH for Distance LEFT	Reported - certified athletic trainer Injury = muscle, joint or bone problem/injury of the low back or lower extremity occurring during practice or competition requiring the athlete to be removed from that days event or to miss a subsequent practice or competition	SLJ - no association SLH - >10% difference = 4x increase risk of ankle/foot injury in females LEFT – increased risk of injury in females with slower scores and males with faster scores
<b>Smith et al (2012)</b>	Prospective cohort	High school and college athletes (N=3876)	LESS	Reported - Orthopaedic surgeon and confirmed with MRI  Injury= event with no direct contact to the ACL-injured knee from another athlete, the ground or extraneous structure	No association between LESS and risk of non-contact ACL injuries
<b>Kritz (2012)</b>	Prospective cohort – pilot study	Athletes across multiple sports (hockey, netball, basketball) (N=91)	MCS	Self reported  Injury= sustained during training or match preventing a player from taking full part in all training activities planned for that day and or match play for more than one day following the day of injury	MCS level 2 score versus level 3 score may predict risk of trunk injury

N = number of subjects FMS = functional movement screen MCS = movement competency screen LESS = lower error scoring system SLJ = single leg jump  
LEFT = lower extremity functional tests SJH = single leg hop LL = lower limb ACLR = anterior cruciate reconstruction OR=odds ratio SIMS = sports injury monitoring system  
AHLTA = armed forces health longitudinal technology application NCAA SS = national collegiate athletic association surveillance system

Table 2.4 continued. Studies reporting the relationship between functional movement screening tools and injury risk

Study	Study Design	Participants	Screening Tool	Injury Definition	Relationship to injury risk
<b>Newlands (2013)</b>	Longitudinal prospective cohort	NZ Rowing Squads (Elite, under 23 and junior) (N=76)	MCS	Self reported  Injury = pain, ache or discomfort in the low back with or without referral to the buttocks or legs that has been present for greater than one week and/or interrupted at least one training session	MCS score $\geq 16$ associated with increased risk low back pain (p=0.08)
<b>Warren et al (2014)</b>	Prospective cohort	Division 1 Collegiate Athletes (basketball, football, volleyball, cross-country, track and field, swimming/diving, soccer, golf, tennis) (N=167)	FMS	Self reported  Injury = musculoskeletal problem with a non-contact or overuse mechanism that caused the athlete to report to the athletic training room and required intervention	No association between FMS score and non contact injury OR: 1.01
<b>Weise et al (2014)</b>	Prospective longitudinal cohort	NCAA Division 1 football athletes (N=144)	FMS	Reported Injury = occurring as a result of participation in an organized intercollegiate practice or competition, requiring medical attention by certified athletic trainer or physician and results in restriction of participation or performance for 1 or more calendar days beyond the day of injury	No difference in FMS scores found between injured and uninjured participants for all sample stratifications (cut off score 17)

N = number of subjects FMS = functional movement screen MCS = movement competency screen LESS = lower error scoring system SLJ = single leg jump  
LEFT = lower extremity functional tests SJH = single leg hop LL = lower limb ACLR = anterior cruciate reconstruction OR=odds ratio SIMS = sports injury monitoring system  
AHLTA = armed forces health longitudinal technology application NCAA SS = national collegiate athletic association surveillance system

Table 2.4 continued. Studies reporting the relationship between functional movement screening tools and injury risk

Study	Study Design	Participants	Screening Tool	Injury Definition	Relationship to injury risk
<b>Hall (2014)</b>	Prospective longitudinal cohort (Thesis)	Intercollegiate football players (N=81)	FMS	Reported - athletic training staff  Classified as injured/non injured Classified via NCAA SS	No significant relationship between the FMS and injury risk
<b>Mohler (2014)</b>	Prospective cross sectional study (Thesis)	NCAA Division I female athletes (basketball, cheer, soccer, softball, tennis, volleyball) (N=99)	FMS	Reported - certified athletic trainer  Injury = non contact (acute or chronic) knee or lower extremity injury resulting in a minimum of 5 rehabilitation sessions with teams athletic trainer and/or modified activity during at least one practice or strength and conditioning session	No significant difference in FMS or subcomponent scores between injured and uninjured athletes Some trend towards more asymmetries in uninjured compared to injured athletes
<b>Padilla (2014)</b>	Prospective longitudinal study	Collegiate Division 1 Sprinters and cross country runners (N=64)	FMS	Reported  Injury= musculoskeletal injury resulting from participation in intercollegiate athletics that requires the attention of an athletic trainer, athletic training student or a physician	Significantly higher FMS scores in injured compared to un-injured athletes  One unit increase in FMS score associated with an increased risk of injury by 1.5 times NB: unable to identify cut points for injury prediction

N = number of subjects FMS = functional movement screen MCS = movement competency screen LESS = lower error scoring system SLJ = single leg jump  
LEFT = lower extremity functional tests SJH = single leg hop LL = lower limb ACLR = anterior cruciate reconstruction OR=odds ratio SIMS = sports injury monitoring system  
AHLTA = armed forces health longitudinal technology application NCAA SS = national collegiate athletic association surveillance system

Table 2.4 continued. Studies reporting the relationship between functional movement screening tools and injury risk

Study	Study Design	Participants	Screening Tool	Injury Definition	Relationship to injury risk
<b>Kiesel et al (2014)</b>	Prospective cohort	American professional football players – male (N=238)	FMS	Reported  Injury = any time-loss from practice or competition due to musculoskeletal injury	Combination of FMS $\leq 14$ and at least 1 asymmetry was highly specific for injury (relative risk 0.87)
<b>Shojaedin et al (2014)</b>	Prospective cross-sectional study	University students (handball, basketball, soccer) (N=100)	FMS	Injury not defined	Positive relationship between FMS scores and previous injury history FMS score $\leq 17$ = 4.7 times more likely to sustain lower limb injury (OR= 4.70)
<b>Lisman et al (2013)</b>	Prospective cohort	Marine Corps (N= 874)	FMS	Reported (AHLTA) Injury = subject who sustained physical damage to the body secondary to physical training and sought medical care one or more times during the study period	Slower run time and lower FMS scores increased risk of any injury or traumatic injury. (OR = 2.04, 1.92)
<b>O’Conner (2011)</b>	Prospective cohort study	Marine Corps (N= 874)	FMS	Reported (AHLTA) Injury = physical damage to the body secondary to physical training, sought medical care one or more times during the study period	Increased risk of injury with FMS scores $\leq 14$ Any injury: OR = 2.0 Traumatic injury: OR =1.92 No association with overuse injuries No association with previous history of injury

N = number of subjects FMS = functional movement screen MCS = movement competency screen LESS = lower error scoring system SLJ = single leg jump  
LEFT = lower extremity functional tests SJH = single leg hop LL = lower limb ACLR = anterior cruciate reconstruction OR=odds ratio SIMS = sports injury monitoring system  
AHLTA = armed forces health longitudinal technology application NCAA SS = national collegiate athletic association surveillance system

Table 2.4 continued. Studies reporting the relationship between functional movement screening tools and injury risk

Study	Study Design	Participants	Screening Tool	Injury Definition	Relationship to injury risk
<b>Brown (2011)</b>	Prospective cohort study (Thesis)	Division 1 women athletes (basketball, soccer, volleyball (N=55))	FMS	Injured or non injured  Injury Location: ankle, knee, no injury  Mechanism: contact, non-contact, no injury	No statistical difference between pre-season FMS scores of injured and non injured athletes FMS $\leq 16.5$ positive predictor for lower limb injury (OR: 4.5) No correlation between injury location, mechanism and FMS scores
<b>Schneiders et al (2011)</b>	Prospective cross-sectional study	Healthy active individuals (N=209)	FMS	Self reported  Injury not defined	No statistically significant difference in FMS scores between those with or without injury history.
<b>Wieczorkowski (2010)</b>	Prospective cohort	High school athletes (basketball) (N=82)	FMS	Self reported  Lower limb injury not defined	FMS score $\leq 14$ positive predictor of injury (OR: 2.26) FMS score $\leq 14$ positive predictor of LL injury (OR: 5.6) No association with FMS score and LL previous history of LL
<b>Chorba et al (2010)</b>	Prospective Cohort	Female collegiate athletes (mixed sports) (N=38)	FMS	Reported  Injury = musculoskeletal injury occurring as a result of participation in an organised intercollegiate practice or competition setting requiring medical attention	FMS score $\leq 14$ positive predictor of injury All subjects: OR= 3.85 Excluding ACLR: OR= 4.58 Significant correlation between low FMS score and injury (p= 0.0214, r= 0.76) No correlation between FMS scores and injury risk in those with previous ACLR

N = number of subjects FMS = functional movement screen MCS = movement competency screen LESS = lower error scoring system SLJ = single leg jump  
LEFT = lower extremity functional tests SJH = single leg hop LL = lower limb ACLR = anterior cruciate reconstruction OR=odds ratio SIMS = sports injury monitoring system  
AHLTA = armed forces health longitudinal technology application NCAA SS = national collegiate athletic association surveillance system

Table 2.4 continued. Studies reporting the relationship between functional movement screening tools and injury risk

Study	Study Design	Participants	Screening Tool	Injury Definition	Relationship to injury risk
<b>Sorensen (2009)</b>	Prospective longitudinal cohort	High school basketball players (N=112)	FMS	Reported  Injury = musculoskeletal impairments reported to and/or recognized by the school's coaching staff or certified athletic trainer	No association between FMS score and acute vs chronic injury No association between FMS scores $\leq 14$ and injury risk No significant difference between FMS scores for newly versus previously injured athletes
<b>Kiesel et al (2007)</b>	Retrospective descriptive	American footballers (professional males) (N=46)	FMS	Membership on the Injured reserve and time loss of 3 weeks	FMS score $\leq 14$ positive predictor of serious injury OR: 11.67

N = number of subjects FMS = functional movement screen MCS = movement competency screen LESS = lower error scoring system SLJ = single leg jump  
LEFT = lower extremity functional tests SJH = single leg hop LL = lower limb ACLR = anterior cruciate reconstruction OR=odds ratio SIMS = sports injury monitoring system  
AHLTA = armed forces health longitudinal technology application NCAA SS = national collegiate athletic association surveillance system

#### ***2.4.3.1 The Movement Competency Screen (MCS) and injury risk.***

Only two unpublished prospective cohort studies examining the relationship between MCS scores and injury risk in sporting populations were identified in the current literature. Kritz (2012) undertook a pilot study to examine the ability of the MCS to predict physical performance and injury over one prospective year. This study included screening 91 athletes across multiple sports (hockey, netball, basketball). The author found there was some evidence that the difference between a MCS Level 2 score versus a Level 3 for trunk movement would predict those athletes at risk of trunk injury. However, the heterogeneous sample and overall small sample size limits generalisation of these results (Kritz 2012). A more recent study investigated the relationship between MCS outcome scores (5 fundamental movement patterns only) and the risk of low back pain in rowers (Newlands, 2013). This study utilised a cut-off score of 16 (out of a possible 21), which was both the mean and the median MCS scores of the cohort. While findings did not reach statistical significance, those rowers whose composite MCS score was 16 or above were found to be 1.58 times more likely to have a new episode of low back pain than those with a score below 16 ( $p=0.08$ ), via longitudinal analysis. Cross sectional analysis found rowers with a MCS score of 16 or more were 2.57 times more likely to have at least one episode of low back pain ( $p=0.07$ ). Further to this, the researchers found no association between MCS scores and previous history of low back pain. While the sample size limited the ability of this study to detect small association in injury risk, the fact injury data only included low back pain also limits possible findings across the broader injury picture within this population. Hence, it may be the MCS is not sensitive in its ability to detect specific types of injury. Another factor possibly contributing to this result is the validity of the MCS tasks

for this specific population. Rowing is in essence a ‘seated’ sport, yet all MCS tasks are in standing postures, with only one task specifically loading the upper body.

#### ***2.4.3.2 The Functional Movement Screen (FMS) and injury risk.***

In comparison to the MCS, the relationship between the FMS and injury risk has been more widely reported within the literature, albeit with variable results, as is shown in Table 2.4. Kiesel et al. (2007) initially demonstrated a positive relationship between a FMS score  $\leq 14$  and an increased likelihood of sustaining a serious injury in 46 professional male football players (sensitivity=0.54, specificity=0.91, odds ratio=11.76). In a more recent follow up study, including a larger cohort of professional American football players (n=238), the combination of a FMS score  $\leq 14$ , and at least one asymmetry was reported to be highly predictive of injury risk (relative risk: 0.87) (Kiesel, Butler, & Plisky, 2014). Several other authors utilising the same cut off score in a variety of sporting cohorts have, similarly, reported FMS outcome scores  $\leq 14$  to be a positive predictor of injury, with odd ratios ranging from 2.26 - 3.85 (refer to table 2.4) (Chorba et al., 2010; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011; Wierzchowski, 2010). More specifically, FMS has been reported as a strong predictor of lower limb injuries (odds ratio = 4.5 – 5.6) but this was not consistent with regard to specific injury location (Brown, 2011; Chorba et al., 2010; Wierzchowski, 2010). While these findings appear promising, the inconsistent reporting of age, injury history or other risk factors in relation to FMS scores do impact on interpretation of results.

More recent studies have also reported no statistical relationship between the FMS and injury risk (location and mechanism) in mixed sporting populations (Hall, 2014; M. Warren, Smith, & N.J., 2014; Wiese, Boone, Mattacola, McKeon, & Uhl, 2014).



Further to this, a study by Padilla (2014) of Division 1 Track and Field NCAA athletes found an increased injury risk was associated with an increase in FMS scores, whereby a one unit increase in FMS score increased an athlete's injury risk by 1.5 times (Padilla, 2014). Comparatively, O'Connor et al. (2011) reported a bimodal distribution of FMS scores, whereby a higher injury risk was found amongst Marine Corp officer candidates whose FMS scores were  $\leq 14$  or  $\geq 18$ . The findings of these studies indicate that the relationship between outcome scores and injury risk may not be linear, and other factors such as movement variability or exposure (volume and intensity) may have an effect (Krumrei, Flanagan, Bruner, & Durall, 2014; Padilla, 2014).

The ability of the FMS to detect those with previous injury history is also inconsistent (Chorba et al., 2010; Schneiders et al., 2011; Shojaedin, Letafatkar, Hadadnezhad, & Dekhoda, 2014). More specifically, FMS scores have been unable to predict injury risk in those athletes with a history of significant lower limb injury (Chorba et al., 2010). This may indicate that the FMS tasks lack the necessary level of challenge and, therefore, validity required to identify those at risk. Emerging, albeit limited research suggests there is a positive relationship between low FMS scores, low cardiovascular fitness and injury risk (Lisman, O'Connor, Deuster, & Knapik, 2013). Overall, further multifactorial studies including known injury risk factors (age, exposure, level of competition, player position, fatigue, cardiovascular fitness and previous injury history) are still considered necessary in order to enable better interpretation of FMS scores in relation to injury risk (Kraus, Schütz, Taylor, & Doyscher, 2014).

#### **2.4.3.3 Conclusion**

There is currently a lack of consistent evidence as to the efficacy of functional movement screening tools in identifying athletes at risk of injury. The MCS is the only functional movement-screening tool reviewed that assesses whole body movement during functional movement patterns and also includes dynamic jumping and landing tasks. Furthermore, it does not require specialised equipment and is a time efficient means of screening. The MCS has not been utilised within the dance population and its ability to predict injury risk requires further investigation.

### **2.5 Conclusion**

Dancers like other athletes experience substantial physical demands related to movement and impact. These factors coupled with the aesthetic demands provide a unique set of challenges for those involved in dance medicine and injury prevention. High injury prevalence rates reported within the dance literature indicate musculoskeletal injury is a significant health issue within the pre-professional dance population. There is, however, only limited comparative literature examining injury incidence with which to gauge injury risk. The lack of standardised methodology for injury reporting and exposure/training are key confounding factors contributing to variable findings. This study will utilise uniform injury and exposure reporting methodology. The IPAIRS will enable the consistent documentation of dance injury events as well as contribute towards a larger international body of research. There is no current injury incidence or characteristics data for pre-professional dancers in New Zealand.

Similarly, there is limited comparable research investigating the association between risk factors (intrinsic and extrinsic) and injury. Although current literature highlights potential relationships between injury risk and specific risk factors, inconsistent results and limited studies prevent the generalisation of findings to the broader pre-professional dance population. Furthermore, no studies were identified that examined risk factors for injury within the New Zealand dance population. Future research utilising more consistent and reliable surveillance methods is necessary to add strength to current findings and further establish the significance and interaction risk factors have on injury. This will also better assist the development and implementation of evidence based injury prevention strategies.

As with other sporting codes, pre-participation screening is now more commonplace within dance medicine, although the ability to consistently identify those dancers at risk of injury remains elusive. Functional movement screening tools are promoted as a means by which those athletes at risk of injury can be identified. Overall, there is good evidence that functional movement screening tools demonstrate good inter-rater and intra-rater reliability. There is however, a lack of consistent evidence supporting their ability to predict injury risk across a wide range of different sporting populations. Further investigation is warranted as to their utility specifically within the dance population (Allen et al., 2013). This study will therefore investigate the injury incidence and characteristics, and the role of the MCS to predict injury risk in pre-professional dancers in New Zealand.

## **Chapter 3**

### **Methods**

#### **Introduction**

This study involved injury surveillance of students at the New Zealand School of Dance (NZSD) over one full academic year. Reported and self-reported injury incidence and associated characteristics were collected as well as total dance exposure over the academic year. Dancers at the NZSD were assessed using the Movement Competency Screen (MCS). MCS outcome scores and their relationship to injury incidence, location and severity over the prospective year were examined via an online survey tool and in-house hard copy survey tool.

#### **3.1 Study Design**

This study was a prospective longitudinal cohort design.

#### **3.2 Subjects**

All students enrolled in the NZSD (n=86) for the 2014 academic year were invited to participate in the study. A total of 66 dancers were recruited (40 females, 26 males) aged between 16 -24 years old (mean 18.15yrs). The NZSD is a full-time tertiary level dance school, which offers both a two-year Certificate in Dance Performance and a Diploma in Dance Performance requiring one additional year of study (equivalent to an undergraduate degree). Dancers are recruited via an audition process for a place to study at the NZSD, and must complete and achieve the requirements of each year in order to progress to the following year. Dancers are selected to major in either classical or modern dance, although they still attend classes in both genres.

Recruitment for the current study took place via an information session in which the primary researcher (LL) outlined the study. This was held during the first week of introductory classes for 2014, which all students were timetabled to attend. Students were given an information sheet (Appendix 2) and consent form (Appendix 3). They were assured at this time that participation was entirely voluntary and that they would not be personally identified to anyone external to the school nor within the school. The inclusion criteria for the study was:

- Enrolled full-time student at the NZSD (Years 1-3). Enrolment requires meeting all the entry requirements outlined by the NZSD (NZSD 2015).

All consent forms and questionnaires were screened after the information session, and subjects were excluded if they were:

- Not able to fully participate in training or performance demands at the time of screening.
- Deemed medically unfit for study participation by a doctor.
- Indicated on the initial dancer's questionnaire they had a current injury, which would limit participation in the MCS screening session.
- Did not return the consent form.

Each participant was assigned a unique identifier, to protect his or her identity during the study. The Auckland University of Technology Ethics Committee granted ethical approval for this study (AUTEC 13/245) (Appendix 1).

### **3.3 Sample Size Justification**

Eighty-six dancers were enrolled at the NZSD for the 2014 academic year. Based on previous studies, the expectation was to recruit 75 - 80% of the target sample of 86

dancers, i.e. 64 - 69 dancers (Byhring & Bo, 2002; Hiller et al., 2008). Initial recruitment achieved a sample size of 74 dancers. However, due to various factors only 66 dancers completed the necessary documentation and screening. Those who did not participate in the study are accounted for below:

- Two dancers were away on the day of recruitment
- Four dancers consented to the study but were away on secondment on the day of screening
- Three dancers consented to the study. However on the day of screening they were deemed unfit to participate due to injury
- One dancer was under 16 years old and required parental consent which was unable to be achieved by the time of screening
- Ten dancers chose not to participate in the study

During the course of the study, one dancer opted out of the reported injury data collection and another dancer opted out of completing the online surveys. A further four dancers who enrolled in the study left the NZSD over the course of the year. Those who opted out or left during the course of the study have been accounted for within the data analysis.

### **3.4 Study Location**

The physical components of this study (information session, initial injury questionnaire, reported injuries data collection and the MCS) were conducted at the New Zealand School of Dance, Te Whaea: National Dance & Drama Centre, 11 Hutchison Road, Newtown, Wellington, New Zealand. All other self-reported injury data was completed online.

### **3.5 Injury Surveillance**

Prospective injury surveillance was undertaken over a full academic year, excluding the holiday period (n=38 weeks).

#### **3.5.1 Dancers' Initial Questionnaire**

Dancers who completed the consent form at the information session also completed an initial questionnaire (Appendix 4). This was based on the NZSD Orthopaedic Intake form (New Zealand School of Dance, 2014) and the New York University Langone Medical Center Patient Medical History Form (personal communication with authors, 2013). The questionnaire collected categorical variables (age, gender, year of study, dance major) as well as baseline data regarding medical, injury and dance history. Each dancer's questionnaire was checked for completeness and any history of injury that could limit participation in the study. Any incomplete or unanswered questions were completed with the dancer when he/she attended the MCS screening session. The primary researcher (LL) clarified the injury status of all dancers who indicated they had a 'current injury' to ensure they met the inclusion criteria prior to undertaking the MCS screening session.

#### **3.5.2 Reported injuries**

Reported injury data was collected by the in-house physiotherapist who is contracted to provide physiotherapy services at the NZSD for 14 hours per week. The NZSD physiotherapist has over 20 years experience as a musculoskeletal physiotherapist and holds a Bachelor of Physiotherapy (BPhty) and Post Graduate Diploma in Manipulative Therapy. All students are encouraged to see the physiotherapist for assessment and management of any injuries. For all injuries reported to the in-house physiotherapist that met the injury criteria, an Injury Summary Sheet (Appendix 5) and International Performing Arts Injury Reporting

System (IPAIRS) form were completed (Appendix 6). All injury data was then entered into a coded Excel spread sheet and analysed using SPSS Version 22.

The IPAIRS data (de-identified) for **reported time-loss injuries only** was entered into the Harkness Center for Dance Injuries (HCDI) RedCAP database by the primary researcher (LL). The RedCAP is a secure electronic database that is fully privacy-protected and Health Insurance Portability and Accountability Act (HIPAA) compliant, protected by a firewall (no data is stored on local drives). The data collected from this research will in time contribute to a larger international research database at the HCDI. The HCDI will not identify any participating institutions beyond the type and major geographical location pertinent to a geographical trend in results. No disclosure of the name of the institution, city, and directors was made.

### **3.5.3 Self-reported injuries**

Dancers were asked to complete an online questionnaire relating to their injury status (Appendix 7) three times per term. They received the questionnaire via email using an online survey tool, Survey Monkey ([www.surveymonkey.com](http://www.surveymonkey.com)). This enabled collection of self-reported injury incidence, type, location and related variables. Reminders to complete the survey were sent to students via the Survey Monkey website as well as via text message. Some students were also followed up with phone calls. Hard copy surveys were given to those students who had not completed the online survey after two weeks.

### **3.5.4 Injury definitions**

Definitions utilised for injury recording and associated variables are defined below:

**Injury:** Any physical complaint sustained by a dancer resulting from performance, rehearsal or class, and resulting in a dancer injury report or triage, irrespective of the



need for medical attention or time-loss from dance activities (Bronner et al., 2006, p. 72).

Time-Loss Injury: “an anatomic tissue-level impairment as diagnosed by a registered health care practitioner that results in full time loss from activity for one or more days beyond the day of onset” (Liederbach et al., 2012, p. 144).

Non Time-Loss Injury: An injury that does not rise to the level of a reported time-loss injury (Liederbach et al., 2012).

Reported Injury: Any injury (time-loss or non time-loss) meeting the injury definition which was triaged, assessed or managed by the NZSD physiotherapist.

Self-Reported Injury: Any injury meeting the injury definition (time-loss or non time-loss), reported via online questionnaire directly from the dance student.

Traumatic/Acute Injury: “An injury that results from a specific identifiable event” (C. W. Fuller et al., 2006, p. 194).

Overuse Injury: “An injury caused by repeated micro-trauma without a single identifiable event responsible for the injury” (C. W. Fuller et al., 2006, p. 194).

Recurrent Injury: An injury with the same diagnosis as a previously recorded injury and that occurs within two months after the dancer’s return to full participation (Allen et al., 2012; C. W. Fuller, Bahr, & Dick, 2007). Recurrent injuries were further categorised according to Fuller et al (2007) as either:

*1. Exacerbations*: “worsening state of a non-recovered injury such that the dancer is unable to take a full part in dance related activities that would normally be required” (Allen et al., 2012, p. 783).

2. *Re-Injury*: “an injury of the same type and at the same site as the first episode, occurring after a dancers return to full participation from the initial injury within two months” (Allen et al., 2012, p. 783).

### **3.6 Injury Severity**

Dancers were asked to rate the level of their pain due to their current injury using the Numeric Pain Rating Scale (NPRS). Injury severity was also measured by time-loss or degree of activity modification and were defined as:

Time-loss: is the total number of full days off dance, from the date of injury to the date of the dancer returning to participation (Dick, Agel, & Marshall, 2007).

Activity Modification: is the extent to which a dancer had to modify or reduce their training load due injury. This was rated using a descriptive scale, describing the degree of activity modification the dancer had to undertake as a result of the injury as listed below.

1. *Not at all*: dancer is able to attend all classes/rehearsals/performance, without any limitations
2. *Minor*: dancer is able to attend all classes/rehearsals/performance with only minor limitations
3. *Moderate*: dancer is able to attend all classes/rehearsals/performance but with moderate limitations such as; participating in petite allegro but not grand allegro, keeping legs below 45 degrees
4. *Major*: dancer is unable to participate in significant components of classes/rehearsals/performance, including having to sit out some but not all

timetabled classes over a normal school day or avoiding significant components such as jumping or pointe work

Injury severity was further categorised based on the impact the injury had on dance participation, and is detailed below. This scale was modified from that used in earlier studies by Dick et al. (2007) and Bowerman (2013).

S0 No days off or modified

S1 Activity modification only

S2  $\leq 7$  days off dance

S3  $> 7$  days off dance

S4 Year ending - if a dancer was unable to return to training due to injury

### **3.7 Exposure**

Dance exposure (DE) was defined as “one dancer participating in one class, rehearsal or performance in which he or she is exposed to the possibility of dance injury regardless of the time associated with that participation” (Liederbach et al., 2012, p. 144). Dance exposure (DE) (hours and events), was calculated for each year of study, major and gender to enable comparisons within the current dance and sports literature. This was calculated each week from the school timetables (over one full academic year) and then tallied to provide the total dance exposure (hours and events) for each group. Conditioning sessions, such as attending the gym and pilates, were not included in the exposure calculations.

### **3.8 Movement Competency Screen (MCS)**

#### **3.8.1 Reliability study.**

Prior to this study, a pilot study was undertaken to assess the intra-rater reliability of the primary researcher utilising the MCS. A convenience sample, comprising of ten dancers (aged range 11 - 24 years) from the primary researchers workplace were approached to participate in the pilot study. Dancers were directed to perform the MCS as per the protocol outlined by Kritz (2012). This was recorded on an iPhone 5 and uploaded onto the primary researchers (LL) computer for analysis. The MCS scoring was undertaken utilising the 0-3 point scale as described by Kritz (2012), using the High Performance Sport New Zealand scoring sheet (Appendix 8). Scoring was then repeated one week later. Intra-rater reliability was established using average measures intra-class correlation coefficient (ICC). The ICC  $_{(2,1)}$  for the overall MCS scores in ten subjects was excellent (ICC  $_{(2,1)}$  0.99, CI 0.98 - 0.99).

#### **3.8.2 Screening protocol**

All the study subjects were screened with the MCS over a period of two days during the first week of term one. Two experienced physiotherapists, with over 18 years' experience and post-graduate qualifications, undertook the screening. Both physiotherapists had training on how to undertake the MCS. Dr Mat Kritz the creator of the MCS, and a physiotherapist at HPSNZ were consulted with regard to the protocol for undertaking MCS screening sessions. The following procedures were used for each subject:

1. The primary researcher and research assistant confirmed with each subject that they had read the information sheet and understood the requirements of

study participation prior to the undertaking of the MCS assessment. Any questions were answered at this time if they arose.

2. Dancers wore standard dance class attire and bare feet.
3. Subjects attended for screening in groups of four. On the day of screening the dancers were given verbal instructions on how to perform each MCS movement patterns. Each movement was demonstrated by the researcher or assistant (LL/RG). Subjects had the opportunity to practise the movement patterns once during the demonstration before undertaking the screen.
4. MCS verbal instructions and images given to subjects during the screening process were standardised as per the MCS protocol (Appendix 9)
5. If during the recording of the MCS the subject was performing an incorrect movement pattern, which would result in an invalid test, they were again shown a photograph image, given verbal cues as per the standardised protocol and a demonstration of the movement pattern. This was to ensure dancers fully understood what was required from them. No coaching on movement control or form was given to the subjects at any time.
6. The subjects were filmed using digital Panasonic (USA) cameras on a fixed tripod levelled with the floor, and 1.0m high. The MCS was filmed at 30 frames per second (fps). Video recording the MCS and video analysis is in line with current clinical practice.
7. Subjects were asked to start each movement from a designated starting point (three metres from the camera), allowing them to stay in frame during

jumping. For travelling jumps, they were asked to start one step back or to side from the marked start point.

8. Subjects were then asked to perform each movement pattern three times facing the front and three times facing the side (i.e. a total of six repetitions per movement). This is consistent with current clinical practice and was also as per recommendations of the MCS developer (M.Kritz, personal communication, September 9, 2013), and High Performance Sports New Zealand (HPSNZ) physiotherapist (L.Johnson, personal communication, October 9, 2013). For consistency, side views were taken from the left, and for unilateral movements, with the supporting leg closest to the camera.
9. The sequence of movements followed the protocol as outlined by its author (Kritz, 2013) (Appendix 9).

### **3.8.3 Movement Competency Screen (MCS) instructions**

The MCS is comprised of five fundamental movement patterns (body weight squat, lunge twist, single leg squat, bend and pull, push up) and three dynamic jump patterns (counter movement jump, counter movement jump with unilateral land, broad jump with unilateral land). Figures for the movement and jump patterns that were shown to the dancers can be seen in Appendix 9. The movement and jump patterns with verbal cues given to each subject were undertaken in the following order (Kritz, 2013):

### 1. Body Weight Squat

Perform a body weight squat with your fingertips on the side of your head and your elbows held in line with your ears. Squat as low as you comfortably can at your own pace. Repeat this three times from the front and three times from the side.

### 2. Counter movement jump

With your fingertips on the side of your head and your elbows held inline with your ears, jump as high as you can. Repeat this three times from the front and three times from the side.

### 3. Lunge and Twist

Cross your arms and place your hands on your shoulders with your elbows pointing straight ahead. Perform a forward lunge then rotate toward the forward knee. Return to the centre, then push back, and return to the start position. Repeat this three times on the same leg facing the front and then three times from the side. Repeat this same movement on the opposite leg again three times from the front and three times from the side.

### 4. Broad jump with unilateral land

Perform a broad jump i.e. where you travel forwards. Take off with two feet and land on one foot. Do this three times on one leg facing forwards and three times on the same leg facing the side. Repeat this same movement on the opposite leg, again three times from the front and three times from the side.

### 5. Single leg body weight squat

Perform a single leg body weight squat with your fingertips on the side of your head and your elbows in line with your ears. Position the non-stance leg behind your body as you squat. Squat as low as you can at your own pace. Repeat movement on the same leg, three times facing the front and three times facing the side. Repeat this

same movement on the opposite leg, again three times from the front and three times from the side.

#### 6. Counter movement jump with unilateral land

Perform a squat jump in place with a two-foot take off. Jump as high as you can. Land only on one foot. Repeat this movement landing on the same leg, three times from the front and three times from the side. Repeat this same movement landing on the opposite leg, three times from the front and three times from the side.

#### 7. Bend and Pull

Start with your arms stretched overhead. Bend forward, allowing your arms to drop under your trunk. Pull your hands into your body as if you were holding onto a bar. Return to the start position with your arms stretched overhead. Repeat this three times facing the front and three times facing the side

#### 8. Push Up

Perform a standard push up. Repeat this three times facing the front and three times facing the side.

### **3.8.4 Movement Competency Screen (MCS) scoring.**

The primary researcher (LL) undertook analysis and scoring of each subject's MCS video, utilising QuickTime™ video software (Apple Inc., Version 10.2). Each movement pattern was assessed using a standardised screening criteria that was directly adapted from the original MCS 100 criteria described by Kritz (2012), and that used by Vanweerd (2013) for the Netball Movement Competency Screen (Appendix 10). Each movement was given a score from 0 – 3, based on identification of primary or secondary areas of concern as described by Kritz (2012). Primary areas of concern are those that are most likely to impact on the athlete's movement competency during the selected movement task (Kritz, 2012).



0 = unable to perform the movement pattern requested

1 = 2 or more primary's &/or 4 secondary

2 = 1 primary &/or 0-3 secondary

3 = 0 primary &/or 0-2 secondary

A score of one indicates poor movement competency, while a score of three indicates good movement competency. All unilateral movements were assessed and scored bilaterally (lunge and twist, single leg squat, counter movement jump with unilateral land, broad jump with unilateral land). The scores of all individual movements were then totalled to provide a composite outcome score (out of a possible 36). Scoring was recorded on a standardised form as used by the HPSNZ (Appendix 8). For the purposes of this study the individual scores for each of the three dynamic jump tasks were also totalled to provide a total jump score (out of a possible 15).

### **3.9 Data Collation**

A standard excel database (Microsoft Office Excel 2011) was created to record subject details (age, sex, injury history, dance history, medical history), as well as data collected from the online injury surveys. IPAIRS data (reported time-loss injuries) was loaded into the RedCAP secure online database by the primary researcher.

### **3.10 Statistical Analysis**

Descriptive analysis was initially undertaken on the data. For all continuous variables including: age, height, weight, BMI, injury prevalence, incidence and severity, means and standard deviations were calculated. For all categorical

variables including: injury location, gender, year of dance, and dance major, frequencies were recorded. To determine if any statistical differences existed between specific groups (gender, major, year of study) a t-test was undertaken for continuous variables and a chi-squared test was undertaken for categorical variables.

Descriptive analysis was performed to establish the injury prevalence and incidence.

Injury incidence was expressed as:

1. Injury incidence per 1000 dance exposures (DE)
2. Injury incidence per 1000hrs dance exposure (DEhr).

Injury incidence rates were calculated for each year of study (0-3), major (classical/contemporary), and gender as well as for time-loss and non-time loss injuries (Liederbach et al., 2012; Portney & Watkin, 2009).

A linear regression model was used to determine the relationship between dance exposure and injury incidence, and between the total MCS scores and the injury incidence data. A univariate linear regression model was also used to investigate the relationship between injury status and individual potential risk factors. A multivariate linear regression model was used to show the influence of a combination of risk factors for becoming injured. Covariates (refer to Table 3.1) were fitted into the model using a forward selection procedure and were retained in the final linear regression model if they reached a statistical threshold of  $p < 0.10$  or were deemed to be of clinical significance. A logistic regression was used to investigate the relationship between injury severity (time-loss or non time-loss injury) and possible risk factors. All analyses were performed using Statistical

Programme for Social Science (SPSS) software (SPSS V.22, IBM Corporation, New York, USA). Alpha levels were set at 0.05 (95% confidence level).

Table 3.1 Covariates used in statistical analysis

Outcome Variables	Predictors
Total number of injuries:	Age
- reported	Height
- self-reported	Weight
Total number of reported injuries via location:	BMI
- lower limb	Age started dancing seriously
- trunk,	Gender (male and female)
- upper limb	Major (modern and ballet)
- head/neck	Year of study (1 - 3)
Injury severity:	Previous injury history
- time-loss vs non time-loss	Current injury history
- total number of days off dance	Dance exposure (hours and units)
	Term of year (1 - 4)
	MCS score:
	- total MCS score (/36)
	- MCS score $\geq 23$
	- total jump score (/15)

## **Chapter 4**

### **Results**

#### **Introduction**

In this chapter the results of the study are presented. The first section details the demographics of the subjects who participated in the study. The second section outlines the injury prevalence, incidence and severity found in the study. The third section presents injury characteristics including type and location. The fourth section presents the relationship between dance exposure, time of year, and injury. The fifth section presents the results from the regression analysis between musculoskeletal injury and possible risk factors including the MCS.

#### **4.1 Subjects**

All students enrolled in the NZSD (n=86) for the 2014 academic year were invited to participate in the study. Of these 66 dancers (females = 40, males = 26) aged between 16-24 years old (mean 18.15yrs, SD 1.45) gave consent to participate. These dancers then completed the Dancers' Initial Questionnaire and the MCS. A descriptive analysis of the study variables collected showed no significant outliers and all continuous data was distributed normally. Levene's Test for Equality of Variances demonstrated homogeneity of variance. An independent t-test was undertaken to identify significant differences between male and female participants for age, height, weight, BMI, major, year of study, and previous injury history (refer to Table 4.1).

Table 4.1 Demographic data

	<b>Full Sample</b>		<b>Females</b>		<b>Males</b>		<b>p-value</b>
	<b>(SD)</b>		<b>(SD)</b>		<b>(SD)</b>		
<b>Subjects (n)</b>	66		40		26		
<b>Age (years)</b>	18.15	(1.45)	17.78	(1.18)	18.57	(1.72)	0.054
	(range:16 - 24)		(range: 16 - 20)		(range: 16 - 24)		
<b>Weight (kg)</b>	59.79	(9.67)	53.93	(6.04)	68.81	(6.29)	<0.001*
<b>Height (cm)</b>	171.17	(9.35)	165.63	(6.52)	179.75	(5.88)	<0.001*
<b>BMI</b>	20.25	(1.88)	19.54	(1.74)	21.33	(1.52)	<0.001*
<b>Age started dancing seriously (yrs)</b>	11.83	(3.39)	11.56	(3.16)	12.24	(3.76)	0.442

Table displays means and standard deviations

\* statistically significant at  $p < 0.05$

Significant differences were found by gender, with males being heavier and having a higher BMI than females ( $p < 0.001$ ) (Table 4.1). Female ballet dancers had a lower BMI (mean 18.35, SD 0.03) compared to female modern dancers (mean 20.67, SD 0.03). A similar trend was also found amongst males, with male ballet dancers having a lower BMI (mean 20.62, SD 0.32) compared to male modern dancers (mean 22.05, SD 0.04). Descriptive statistics for demographic data is presented in Table 4.1.

A chi-squared test was undertaken to examine if any significant difference existed between females and males for major, year of study and previous, and current injury history. The only significant difference that was found amongst these variables was that females had a greater history of previous injury compared to males ( $p = 0.011$ ).

Of the 66 subjects enrolled in the study, 32 were ballet majors and 34 were modern majors. Modern majors were slightly older than ballet majors ( $p < 0.043$ ). Modern

majors, on average, weighed more ( $p=0.035$ ), and had a higher BMI ( $p<0.001$ ) than ballet majors. Ballet majors began dancing seriously at an earlier average age than modern majors ( $p=0.01$ ). No statistically significant differences were found between ballet and modern majors for all other variables. Descriptive characteristics of these two groups are shown in Table 4.2.

Table 4.2 Descriptive characteristics of modern and ballet majors

	<b>Ballet</b>		<b>Modern</b>		<b>p-value</b>
	<b>Mean</b>	<b>(SD)</b>	<b>Mean</b>	<b>(SD)</b>	
<b>N</b>	32		34		
<b>Age (years)</b>	17.78	(1.28)	18.50	(1.52)	0.043*
<b>Weight (kg)</b>	57.22	(9.45)	62.20	(9.38)	0.035*
<b>Height (cm)</b>	172.09	(9.64)	170.31	(9.12)	0.442
<b>BMI</b>	19.25	(1.61)	21.19	(1.59)	<0.001**
<b>Age started dancing seriously (yrs)</b>	10.71	(3.22)	12.88	(3.26)	0.010*
<b>Previous injury history</b>	25	(78%)	32	(94%)	0.058†
<b>Current injury</b>	4	(12.5%)	7	(20.6%)	0.378†

\* statistically significant at  $p<0.05$  \*\* statistically significant at  $p<0.001$

† p-value calculated using chi-squared test

Of the 66 subjects, there were 28 in year one, 25 in year two and 13 in year three. Age of the dancers increased with each year of study with a significant difference found between year groups ( $p \leq 0.001$ ). Weight and BMI also increased with year of study, albeit these were not statistically significant ( $p > 0.05$ ). There were no other significant differences found between year groups for previous or current injury history or year started dancing seriously ( $p > 0.05$ ).

## 4.2 Lifetime Prevalence

At the start of the study 86.4% (n=57) of dancers reported a previous history of dance related injury.

## 4.3 Injury Prevalence and Severity

### 4.3.1 Reported injuries.

Sixty-five subjects were included in the reported injury data analysis. Of these, 56 dancers (86.2%) reported at least one new injury over the 2014 academic year. Thirty-five (53.8%) dancers sustained more than one new injury over the academic year. Figure 4.1 shows the number of injuries reported per dancer split via gender.

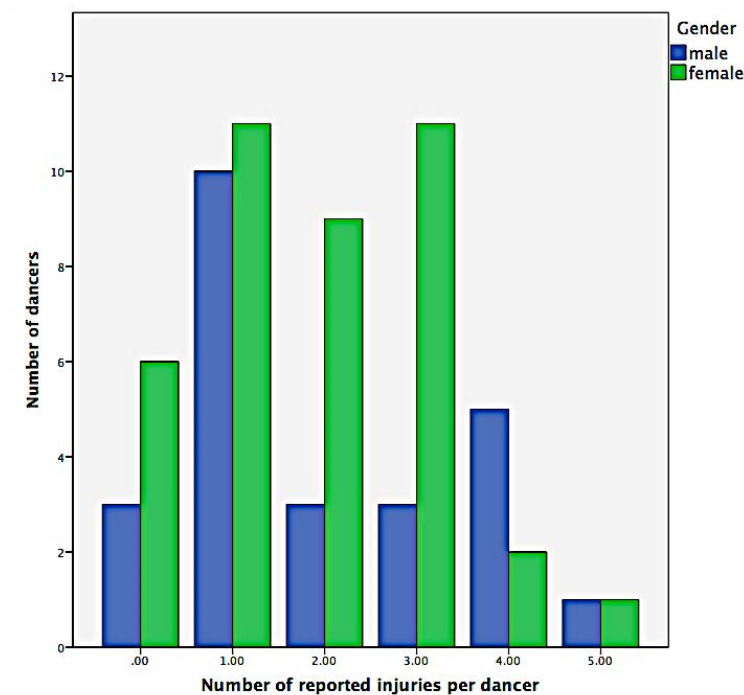


Figure 4.1 Number of reported injuries per dancer over the 2014 academic year

A total of 125 injuries were reported over the 2014 academic year. No significant differences were found between dancers who reported any injury or time-loss injuries and those that did not for variables of age, height, weight, BMI, gender, major, year of study or previous history of injury ( $p > 0.05$ ). Injury severity outcome measures for reported and self-reported injuries are presented in Table 4.3. Of all reported injuries 59.2% ( $n=74$ ) were time-loss injuries (one or more full days off participation). The mean number of full days off dance was 5.85 (SD 6.37, range 1-42 days). Eighty-six per cent ( $n=64$ ) of all time-loss injuries required the dancer to take  $\leq 7$  days off dance (S2), with 13.5% ( $n=10$ ) taking  $>7$  days off dance (S3). Injuries requiring the greatest time off dance included: lower limb stress fractures, posterior cruciate and meniscal injury, and foot and ankle tendinopathies. Fifty-one (40.8%) reported injuries were non-time loss, with all but one of these injuries requiring activity modification. The mean number of days of modified activity for non time-loss injuries was 7.14 (SD 5.49, range 0-28 days). The majority of non time-loss injuries (84%) were defined as requiring ‘moderate’ activity modification. No dancers were reported to require ‘major’ activity modification for non time-loss injuries. Modern majors had a greater number of reported injuries classified as S1 and S2 compared to ballet majors, while ballet majors had more injuries classified as S3 compared to modern majors. However, no significant differences were found between the total number of injuries per severity classification (S0 – S4) and any of the variables including: gender, major or year of study, age, height, weight or BMI ( $p > 0.05$ ). The distribution of injury severity via year of study and injury location is presented in Figures 4.2 & 4.3 respectively.



Table 4.3 Injury severity outcomes for reported and self-reported injuries

		Reported Injuries		Self-reported Injuries	
		(SD)		(SD)	
Time-loss injuries		74	(59.2%)	73	(42%)
Non time-loss injuries		51	(40.8%)	101	(58%)
Numerical pain score		5.29	(1.91)	5.99	(0.15)
Time-loss injuries:		5.85	(6.37)	4.01	(4.43)
mean full days off dance		(range: 1 - 42 days)		(range: 1 - 28 days)	
Non time-loss injuries:		7.14	(5.49)	NR	
mean days modified		(range: 0 - 28 days)			
Non time-loss	none	1	(2%)	13	(13%)
injuries: activity	mild	7	(14%)	53	(52%)
modification	mod	43	(84%)	22	(22%)
	severe	0	(0%)	12	(12%)
	NR			1	(1%)

NR = not reported SD = standard deviation

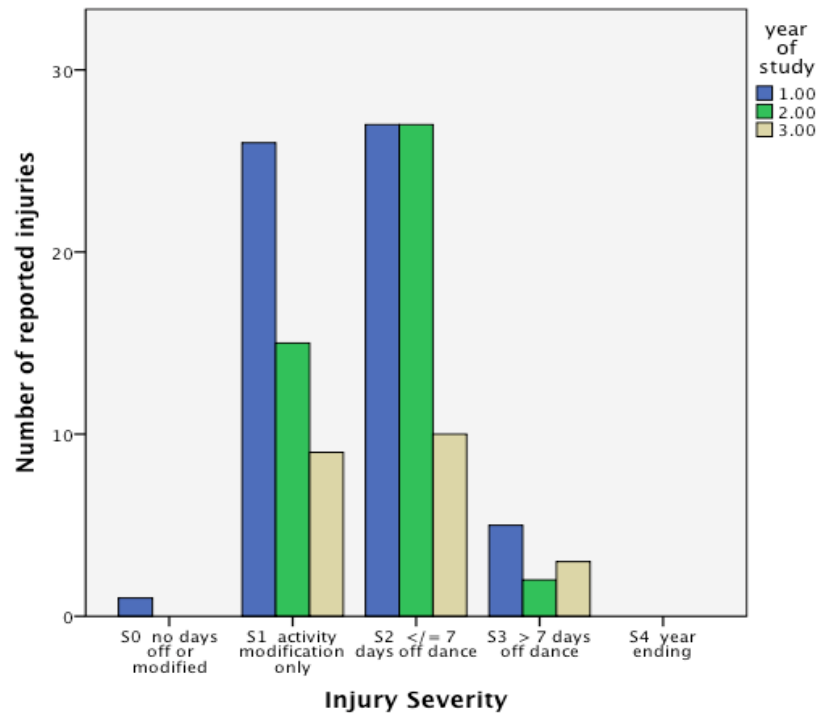


Figure 4.2 Distribution of injury severity via year of study

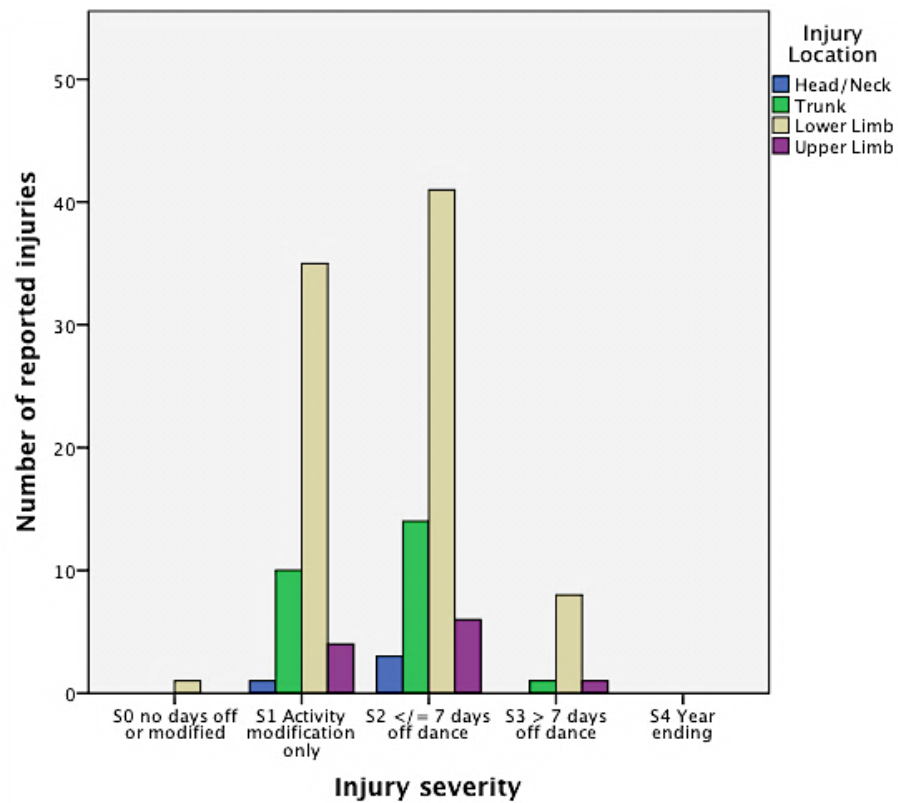


Figure 4.3 Distribution of injury severity via injury location

### **4.3.2 Self-reported injuries.**

A total of 61 subjects were included in the self-reported injury data analysis. Fifty-six dancers (91.8%) self-reported at least one injury during the year. Forty-two (68.9%) dancers reported more than one injury over the collection period.

A total of 174 injuries were self-reported over the 2014 academic year. Of all the self-reported injuries, 42% (n=73) were time-loss injuries requiring one or more full days off dance. No significant difference was found between those dancers who self-reported a time loss injury and those that did not for the variables of gender, major and year of study ( $p>0.05$ ). The average number of full days off dance due to injury was 4.01 (SD 4.43). Eighty-nine per cent (n=65) of all time-loss injuries required less than or equal to 7 days off dance (S2), while 11% (n=8) of all time-loss injuries required more than 7 days off due to injury (S3). One hundred and one injuries were self-reported as non time-loss (58%). Fifty-two per cent of these injuries required minor activity modification, 22% moderate activity modification and 12% major activity modification.

## **4.4 Injury Incidence**

### **4.4.1 Reported injury incidence.**

The clinical incidence of reported injuries was 1.92 injuries per dancer. The total injury incidence rate over the 2014 academic year was 2.27 (95% CI 2.25-2.28) per 1000 dance exposure hours (DEhr) and 3.35 (95% CI 3.33-3.37) per 1000 dance exposures (DE). The total injury incidence for time-loss injuries was 1.34/1000DEhr and 1.98/1000DE's. The total hours of dance exposure (DEhr) (class, rehearsal and performance), for the year were 55,162 hours (mean 848:33 DEhr, SD: 177:12). The total number of dance exposures (DE) (class, rehearsal, performance) was 37,314

(mean 574:06, SD 123:57). The injury incidence rates, for reported injuries were similar for males and females (2.39 and 2.19/1000DEhr), and ballet and modern dancers (2.11 and 2.17/1000DEhr). Year one students had the highest injury incidence rate for reported injuries (2.95/1000DEhr). Injury incidence also decreased term-by-term, with the highest incidence in term one (3.60/1000DEhr), followed by term two (2.33/1000DEhr), term three (1.59/1000DEhr) and term four (1.0/1000DEhr). Injury incidence data calculated via DEhr and DE for reported injuries is presented in Tables 4.4 and 4.5 respectively.

Table 4.4 Injury incidence rates for reported injuries per dance exposure hours (DEhr)

Variable	Subjects		Total Injuries	Total DEhr	Mean DEhr	Std Dev	95% CI	Reported Injuries per 1000 DEhr	
	N	%	RI						95%CI
<b>Year 1</b>	27	41.5	59	20021	741:30	180:00	670:16 – 812:43	2.95	2.92 – 2.97
<b>Year 2</b>	25	38.5	44	22733	909:19	148:22	848:04 – 970:33	1.94	1.92 – 1.95
<b>Year 3</b>	13	20.0	22	12408	954:26	86:58	901:52 – 1006:59	1.77	1.75 – 1.79
<b>Male</b>	25	38.5	50	20930	837:11	206:31	751:56 – 922:26	2.39	2.37 – 2.41
<b>Female</b>	40	61.5	75	34232	855:46	158:34	805:46 – 906:29	2.19	2.18 – 2.21
<b>Ballet</b>	31	47.7	58	27434	784:40	217:03	705:03 – 846:17	2.11	2.10 – 2.13
<b>Modern</b>	34	52.3	67	30836	906:57	103:32	870:44 – 943:04	2.17	2.16 – 2.19
<b>Time-Loss</b>	43	66.1	74	55162	848:33	177:12	804:43 – 892:32	1.34	1.33 – 1.35
<b>Non Time-Loss</b>	35	53.8	51	55162	848:33	177:12	804:43 – 892:32	0.92	0.91 – 0.93
<b>Total Cohort</b>	65	100.0	125	55162	848:33	177:12	804:43 – 892:32	2.27	2.25 – 2.28

N = number of subjects RI= reported injuries DEhr = dance exposure hours CI = confidence interval

Table 4.5 Injury incidence rates for reported injuries per number of dance exposures (DE)

Variable	Subjects		Total Injuries	Total DE	Mean DE	Std Dev	95% CI	Reported Injuries per 1000 DE	
	N	%	RI						95%CI
<b>Year 1</b>	27	41.5	59	13771	510.04	142.79	453.55 – 566.52	4.28	4.25 – 4.32
<b>Year 2</b>	25	38.5	44	15258	610.32	100.75	568.73 – 651.91	2.88	2.86 – 2.91
<b>Year 3</b>	13	20.0	22	8285	637.31	25.62	621.82 – 652.00	2.66	2.62 – 2.69
<b>Male</b>	25	38.5	50	14113	564.52	140.50	506.52 – 622.52	3.54	3.51 – 3.57
<b>Female</b>	40	61.5	75	23201	580.03	113.19	543.82 – 616.22	3.23	3.21 – 3.26
<b>Ballet</b>	31	47.7	58	17138	552.83	167.86	491.26 – 614.41	3.38	3.36 – 3.41
<b>Modern</b>	34	52.3	67	20176	593.41	56.43	573.72 – 613.10	3.32	3.29 – 3.35
<b>Time-Loss</b>	43	66.1	74	37314	574.06	123.57	543.44 – 604.68	1.98	1.97 – 1.99
<b>Non Time-Loss</b>	35	53.8	51	37314	574.06	123.57	543.44 – 604.68	1.37	1.35 – 1.38
<b>Total Cohort</b>	65	100.0	125	37314	574.06	123.57	543.44 – 604.68	3.35	3.33 – 3.37

N = number of subjects RI= reported injuries DE = dance exposures CI = confidence interval

#### 4.4.2 Self-reported injury incidence.

The clinical incidence for self-reported injuries was 2.85 injuries per dancer over the 2014 academic year (285%). The injury incidence rate for self-reported injuries was 3.40/1000DEhr and 5.03/1000DE. Injury incidence rates (DEhr and DE) for self-reported injuries are presented in Table 4.6 and 4.7.

Table 4.6 Injury incidence rates for self-reported injuries per hours of dance exposure (DEhr)

Variable	Subjects		Total Injuries	Total DEhr	Mean DEhr	Std Dev	95% CI	SRI Injuries per 1000 DEhr 95%CI	
	N	%	SRI						
Total cohort	61	100	174	51123	838:05	200:42	786:40 – 889:29	3.40	3.39- 3.42

SRI = self-reported injuries DEhr = dance exposure hours

Table 4.7 Table of injury incidence rates for self-reported injuries per number of dance exposures (DE)

Variable	Subjects		Total Injuries	Total DE	Mean DE	Std Dev	95% CI	SRI Injuries per 1000 DE 95%CI	
	N	%	SRI						
Total cohort	61	100	174	34572	557.61	147.33	520.21 – 595.28	5.03	5.01- 5.05

SRI = self-reported injuries DE = dance exposures

## 4.5 Injury Characteristics

### 4.5.1 Characteristics of injured and non-injured dancers.

#### 4.5.1.1 Dancers reporting injuries.

Sixty-five subjects were included in the reported injury data analysis (one student opted out of reported injury data collection). No significant difference was found

between dancers who reported an injury and those who did not for age, height, weight, and BMI ( $p>0.05$ ). Fishers exact test found no significant difference between these groups for: gender, year of study, major, and previous or current injury history. Descriptive characteristics of dancers who reported injuries and those who did not are presented in Table 4.8.

Table 4.8 Descriptive characteristics of dancers reporting injuries

		Injured		No injury reported		p-value
		Mean (SD)		Mean (SD)		
N		56		9		
Age (years)		18.23	(1.47)	17.77	(1.30)	0.388
Height (cm)		170.66	(9.36)	173.33	(9.50)	0.432
Weight (kg)		59.23	(9.43)	62.88	(11.58)	0.299
BMI		20.25	(1.87)	20.31	(2.00)	0.935
Previous history injury		49	(87.5%)	8	(88%)	0.600†
Current injury		10	(17.9%)	1	(12%)	1.000†
Gender	Male	22	(39.3%)	3	(33.3%)	1.000†
	Female	34	(60.7%)	6	(66.6%)	
Major	Ballet	27	(48.2%)	5	(55.6%)	1.000†
	Modern	29	(51.8%)	4	(44.4%)	
Year of study	1	23	(41.1%)	4	(44.4%)	0.902†
	2	21	(37.5%)	4	(44.4%)	
	3	12	(21.4%)	1	(11.1%)	

<sup>†</sup> p-value calculated using fishers exact test N= number of dancers



#### ***4.5.1.2 Dancers self-reporting injuries.***

Forty-six subjects (77.9%) completed all twelve of the self-reported online injury questionnaires via Survey Monkey. Of the total number of surveys sent (n=756), 655 (86.6%) were completed, 101 (13.4%) were either incomplete or non-responders. Five subjects did not complete any online surveys and this included those with poor English/non responders (n=4), and those who opted out of online surveys (n=1). No significant differences were found between dancers who self-reported an injury and those who did not for the variables of: age, height, weight, BMI, gender, major, year of study or previous injury history ( $p>0.05$ ).

#### **4.5.2 Reported injury characteristics**

Of the 125 injuries reported to the in-house physiotherapist, 104 (83%) were new injuries and 21 (16.8%) were recurrent injuries. Of the recurrent injuries 13 (61.9%) were considered an exacerbation, while eight (38.1%) were defined as a re-injury. The majority of reported injuries were classified as overuse (59.2%). The lower limb was the most common site of injury (68%), followed by trunk (20%) and upper limb (8.8%). The ankle was the most common site of lower limb injury, followed by the knee, foot, and hip/thigh respectively. The thoracic spine was the most common site of trunk injury, followed by the lumbar spine then the cervical spine. In the upper limb the majority of injuries were shoulder.

Modern dancers sustained a greater percentage of all trunk injuries than ballet majors, 72% and 28% respectively, while ballet majors sustained a greater percentage of lower limb injuries (57.6%) compared to modern majors (42.2%). All reported upper-limb injuries (n=11) were sustained by modern majors. Year one dancers sustained a greater percentage of injuries across all injury locations compared to other years (two and three). Females sustained a greater percentage of

injuries across all injury locations. The distribution of reported injury characteristics is presented in Table 4.9. Figures 4.4 and 4.5 show the distribution of injury via location and year of study and major.

Table 4.9 Characteristics of reported and self-reported injuries

	<b>Reported Injuries</b>		<b>Self-reported Injuries</b>	
<b>Total injuries (n)</b>	125		174	
<b>% dancers injured</b>	86.2%		91.8%	
<b><u>Injury Type</u></b>				
<b>New</b>	104	(83%)	130	(74.7%)
<b>Recurrent</b>	21	(16.8%)	43	(24.7%)
<b>Re injury</b>	8	(38.1%)	27	(1.6%)
<b>Exacerbation</b>	13	(61.9%)	17	(9.8%)
<b>Acute</b>	51	(40.8%)	77	(44.3%)
<b>Overuse</b>	74	(59.2%)	96	(55%)
<b><u>Injury Location</u></b>				
<b>Head/Neck</b>	4	(3.2%)	5	(2.3%)
<b>Trunk</b>	25	(20%)	60	(27.5%)
<b>Lower Limb</b>	85	(68%)	124	(56.9%)
<b>Upper Limb</b>	11	(8.8%)	28	(12.8%)
<b>Not reported</b>			1	

\* SRI injury – one self reported injury did not complete characteristics

\* SRI injury sites = 218 (some dancers chose more than one body site per injury)

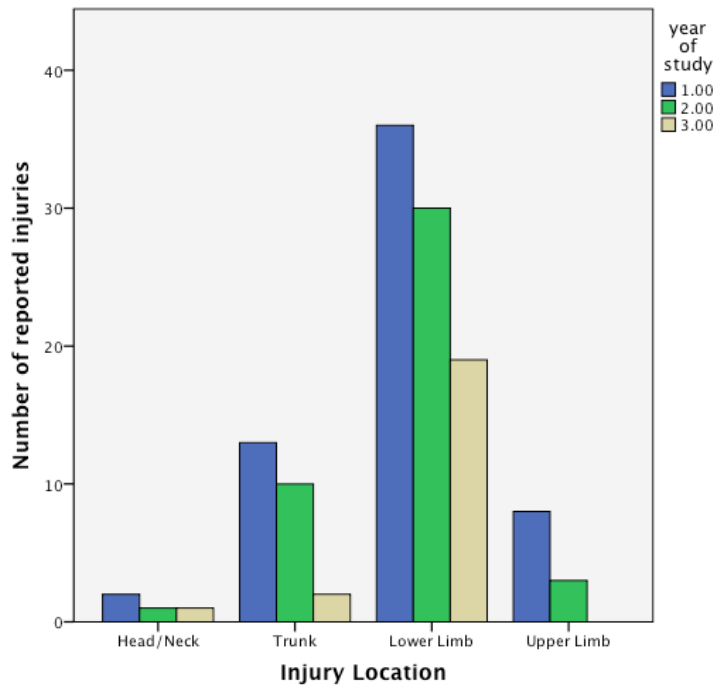


Figure 4.4 Distribution of reported injuries via location and year of study

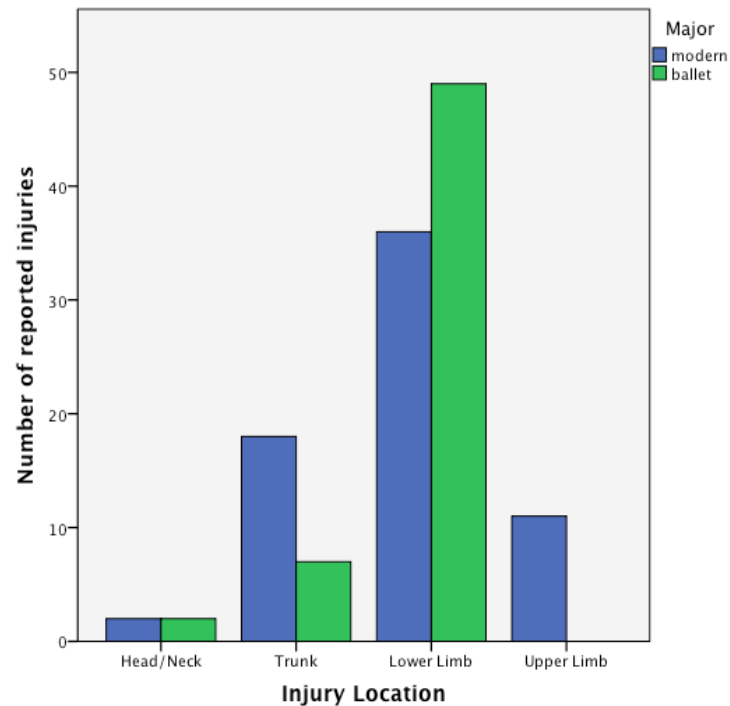


Figure 4.5 Distribution of reported injuries via location and dance major

#### **4.5.3 Self-reported injury characteristics.**

The majority of self-reported injuries were new injuries (74.7%) with 96 injuries being overuse in nature (55%). The majority of self-reported injuries were lower limb (56.9%), followed by trunk (27.5%). The distribution of injury characteristics for self-reported injuries is presented in Table 4.9.

#### **4.6 Relationship between dance exposure, time of year and injury**

A linear regression was undertaken to determine the relationship between dance exposure (hours and events), time of year and injury. For the purposes of this analysis only reported injury data was used.

##### **4.6.1 Relationship between number of dance exposures (DE) and injury.**

Figure 4.6 depicts the relationship between the total number of dance exposures (DE) per month and the total number of injuries per month. The total number of dance exposures (DE) per month was significantly associated with the total number of reported injuries reported per month ( $p=0.016$ ). A significant association was also found between the average number of dance exposures (DE) per dancer per month and the total number of injuries per month ( $p=0.027$ ). See Appendix 11, Table 1 & 2 for a summary of the regression analysis output for these variables.

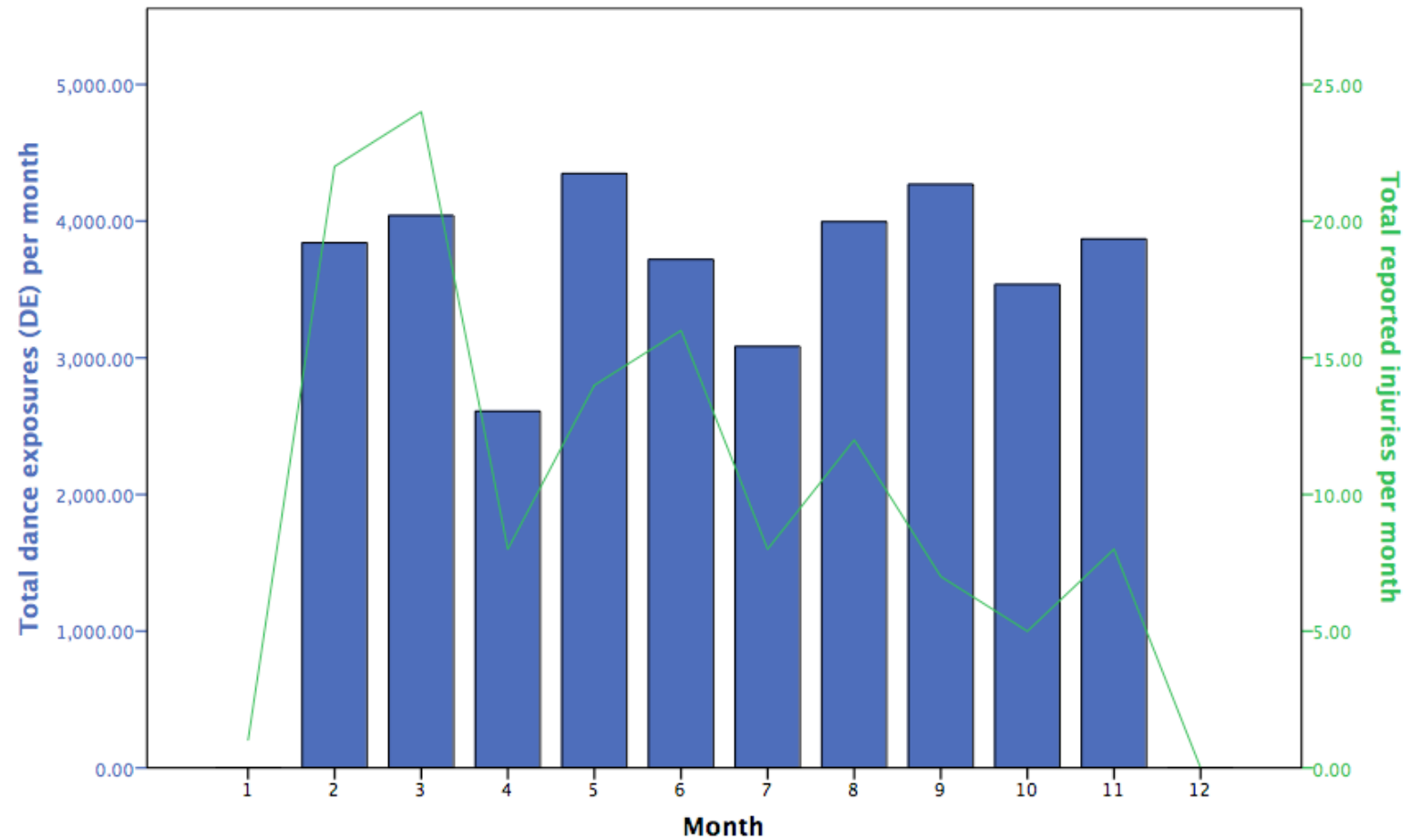


Figure 4.6 The relationship between total number of dance exposures (DE) per month and the number of reported injuries per month over the 2014 academic year

#### **4.6.2 Relationship between hours of dance exposure (DEhr) and injury.**

Total hours of dance exposure (DEhr) was not a significant predictor of injury ( $p=0.964$ ). A borderline statistically significant association was identified showing that increases in average DEhr per month resulted in a nominal increase in the total number of injuries ( $B=2.9E-5$ , 95% CI=  $4.0E-6$  -  $6.2E-5$ ,  $p=0.076$ ), as well as the number of dancers reporting one or more injuries per month ( $B=2.6E-5$ , 95% CI=  $9.01E-7$  -  $5.4E-4$ ,  $p=0.057$ ). The adjusted R square values for these (0.210 and 0.249 respectively) were low, further iterating that only a small percentage of the variation relating to the injury was due to hours of dance exposure. No significant association was found between total DEhr per month and total number of injuries based on injury location. See Appendix 11, Table 3 & 4 for a summary of the regression analysis output for these variables.

#### **4.6.3 Relationship between time of year (term) and injury.**

A significant association was found between the total number of reported injuries, and the term of study ( $p=0.018$ ) whereby the number of injuries per term decreased, on average, by twelve during the year (Table 4.10). On average, across this study it was found that the number of time-loss injuries reduced by six for every increment in term, such that dancers were more likely to sustain a time-loss injury in term one compared to term four ( $p=0.024$ ). Further analysis indicated that the higher number of injuries earlier in the year were more likely to be explained by trunk injuries ( $p=0.063$ ) and lower limb injuries ( $p=0.083$ ) compared to upper limb ( $p=0.265$ ), or head and neck injuries ( $p=0.817$ ). See Appendix 11, Table 5,6,7 & 8 for a summary of the regression analysis output for these variables.

Table 4.10 Association between total number of injuries and term of study

Variable	Adjusted R Square	B	95% CI	p-value
Term of year	0.946	-12.300	-19.538 – -5.062	0.018*

CI = confidence interval \* statistically significant at  $p \leq 0.05$

## 4.7 Relationship between risk factors and injury

### 4.7.1 Subjects Movement Competency Screen (MCS) assessment scores.

All subjects enrolled in the study completed the MCS screening assessment. Significant differences were found between males and females for the individual movement patterns of squat ( $p=0.046$ ), single leg squat on left ( $p=0.025$ ), bend push pull ( $p=0.015$ ), and press-ups ( $p=0.001$ ). No significant differences in total MCS score, total MCS jump scores or other individual scores were found between males and females ( $p > 0.05$ ). No significant difference in total MCS scores was found between ballet and modern majors ( $p=0.091$ ), or year groups ( $p=0.297$ ). Descriptive characteristics of these groups are presented in Tables 4.11 and 4.12

Table 4.11 MCS screening scores for gender and dance major

	Male Mean (SD)	Female Mean (SD)	p-value	Modern Mean (SD)	Ballet Mean (SD)	p-value
N	26	40		32	34	
Total MCS score (/36)	22.16 (3.04)	22.53 (3.32)	0.912	23.21 (3.13)	21.88 (3.16)	0.091
Total jump score (/15)	7.65 (1.79)	8.13 (1.80)	0.301	7.97 (1.68)	7.91 (1.94)	0.886

t-test used to determine significance \*statistically significant at  $p < 0.05$

N = number of dancers

Table 4.12 MCS screening scores for year groups

	<b>Year 1</b>	<b>Year 2</b>	<b>Year 3</b>	<b>p-value</b>
	<b>Mean (SD)</b>	<b>Mean (SD)</b>	<b>Mean (SD)</b>	
<b>N</b>	28	25	13	
<b>Total MCS score (/36)</b>	22.07 (3.38)	23.64 (2.69)	21.53 (3.28)	0.297
<b>Total jump score (/15)</b>	7.84 (1.52)	8.04 (1.46)	7.85 (1.52)	0.161

Chi squared test used to determine significance N = number of dancers

#### 4.7.2 Relationship between reported injuries and risk factors.

To determine the relationship between possible risk factors and sustaining a dance related injury over the 2014 academic year, a linear regression was undertaken utilising the longitudinal data set. Total number of reported injuries was the dependent variable and this was compared to: age, gender, major, year of study, BMI previous injury history, current injury, year started dancing seriously, total MCS and jump scores, and mean MCS score. No significant association was found for these variables apart from the mean MCS score. A significant association was found between the total number of injuries and MCS score  $\geq 23$  ( $p=0.035$ ) such that there were on average seven more injuries amongst those dancers who had a MCS score  $<23$ . Further investigation suggests that the higher number of injuries in those with a MCS score  $<23$  was more likely to be explained by the number of trunk injuries ( $p=0.036$ ). A summary of regression analysis between the total number of reported injuries and risk factors is presented in Table 4.13. See Appendix 11, Table 9 for a summary of the regression analysis output for trunk injuries and risk factors.



Table 4.13 Association between the total number of reported injuries and risk factors

<b>Independent Variables</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Age</b>	-0.016	-0.001	-0.235 – 0.233	0.992
<b>BMI</b>	-0.013	0.039	-0.141 – 0.220	0.667
<b>Gender</b>	-0.014	-0.125	-0.817 – 0.567	0.720
<b>Major</b>	-0.014	-0.100	-0.774 – 0.575	0.769
<b>Year of study</b>	0.008	-0.272	-0.714 – 0.169	0.222
<b>Total MCS score</b>	0.022	-0.081	-0.186 – 0.023	0.125
<b>Mean MCS Score</b>	0.054	-0.702	-1.354 – -0.050	0.035*
<b>Previous Injury</b>	0.016	-0.685	-1.646 – 0.277	0.160

\*statistically significant at  $p \leq 0.050$

#### 4.7.3 Relationship between injury location and risk factors.

The total number of injuries via location (lower limb, upper limb, trunk, head/neck) was compared to: age, gender, BMI, major, year of study, and previous injury risk and MCS scores. A near statistically significant association was identified which indicated that the total number of lower limb injuries tended to increase by 0.87 with each incremental decrease in total MCS score ( $p=0.062$ ). See Appendix 11, Table 10 for a summary of the regression analysis output.

A significant association was found between injury location and major. Modern majors were more likely than ballet majors to sustain trunk injuries ( $p=0.042$ ) and upper limb injuries ( $p=0.001$ ). Refer to Appendix 11, Tables 9 & 11 for a summary of the regression analysis output for these variables. There was only a very marginal association between the total number of lower limb injuries and major. This indicated ballet majors sustained a slightly higher number of lower limb injuries.

However, this was not statistically significant ( $p > 0.05$ ) (see Appendix 11, Table 10 for regression analysis output). Upper limb injuries were more common amongst year one students decreasing for every year of study ( $p=0.025$ )

#### **4.7.4 Relationship between previous history of injury and risk factors.**

A history of previous injury was compared with: age, gender, major, year of study, BMI, total MCS and jump scores, as well as the age they started dancing seriously. A significant association between previous history of injury and gender was found whereby more females had sustained previous injuries compared to males ( $p=0.022$ ). There appeared to be an association between increasing age and previous injury risk (borderline statistical significance,  $p=0.067$ ) (see Appendix 11, Table 12 for a summary of the regression analysis output for these variables). Similarly, a previous history of lower limb injury was compared with possible risk factors. A marginal association between previous history of lower limb injury and age was found; however this was not statistically significant ( $p > 0.05$ ).

#### **4.7.5 Relationship between injury severity and risk factors.**

A review of the distribution of injury data indicated that the number of time-loss injuries more closely followed a categorical classification (no time-loss injury = 0, time-loss = 1+). This used the data more appropriately, given the small dataset ( $n=65$ ) where very few people reported greater than two time-loss injuries ( $n=5$ ) (Figure 4.7).

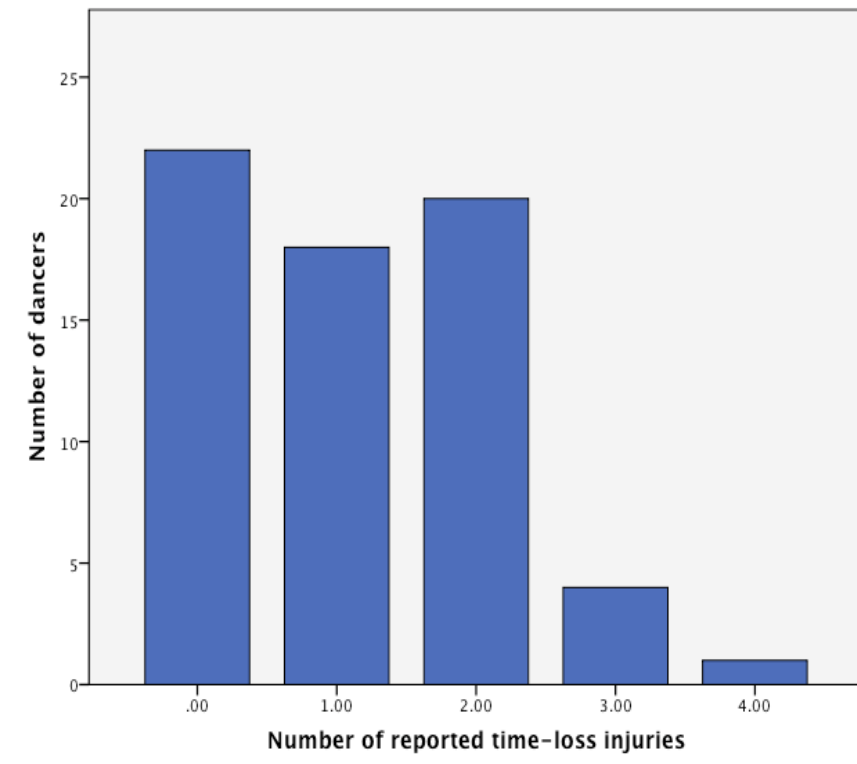


Figure 4.7 Distribution of reported time-loss injuries per dancer

A logistic regression forward selection model was, therefore, used to determine if there was a relationship between injury severity (time-loss) and possible risk factors. The dependant variable was one or more time-loss injuries and this was compared to: age, gender, BMI, major, total and mean MCS scores, total jump score, previous injury history and current injury history. Dancers who sustained a time-loss injury (one or more) had a lower total MCS score than those who did not sustain time-loss injuries, however this only reached a near statistical association ( $p=0.059$ ). Further to this, lower limb injuries were more likely to result in time-loss ( $p<0.001$ ), while this was not the case for other injury locations. No association between reporting a time-loss injury and other risk factors was identified. No association was found

between risk factors and reporting a non time-loss injury. See Appendix 11, Tables 13,14 & 17 for a summary of the regression analysis output for these variables.

A significant association was also found between the total number of days lost to injury and reporting one or more lower limb injuries ( $p=0.002$ ), such that dancers who sustained one or more lower limb injuries during the year had on average 7.339 more days off than those who did not sustain a lower limb injury. No association was found between the number of days lost to injury and other risk factors or injury locations. Refer to Appendix 11, Table 15 & 16 for a summary of the regression analysis output for these variables.

## **Chapter 5**

### **Discussion**

#### **Overview**

The aim of this study was to establish the injury incidence and characteristics of pre-professional modern and ballet dance students over a full academic year, as well as to determine the utility of the Movement Competency Screen (MCS) in predicting injury risk. The risk of musculoskeletal injury was high within this cohort. The injury incidence across the cohort was comparable to that reported by other similar studies, although was at the higher end of the reported range. Injury incidence when defined by time-loss or major (modern or ballet) was similar to those of other comparable studies. The injury characteristics of this cohort including injury type and location were also consistent with that of other studies. Dance exposure (DE) was significantly associated with injury risk and dancers were more likely to sustain injuries in term one. Dancers who scored lower than the mean MCS score sustained significantly more injuries than those who score at or above the mean MCS.

#### **5.1 Subjects**

Dancers included in this study are representative of elite adolescent modern and ballet dance students undertaking elite full-time pre-professional training in New Zealand. Although several other institutes in New Zealand provide tertiary level dance diplomas and degrees, the course structure and hours of exposure mean results from this study may not be reflective of the broader pre-professional dance population. The age of dancers in this study ranged from 16 – 24 years old. Dancers attending other tertiary level institutes in New Zealand would typically be slightly older (17-18+years) beginning training after the completion of high school (The

University of Auckland, 2015). The ages of dancers in this study are, however, comparable to those undertaking elite full-time pre-professional training at similar institutes internationally (Bowerman et al., 2014; Ekegren et al., 2014; Negus et al., 2005). While some studies have reported dancers to begin elite level training at much younger ages, this is often commenced on a part-time basis, with fewer hours of dance exposure compared to their older full-time counterparts (Gamboa, 2008; Leanderson et al., 2011; Steinberg, Aujla, et al., 2013). These factors should be considered when comparing the results of this study to other research involving pre-professional dance students.

Male participation in dance has historically been less than that of females. This was also a common trend within the dance literature reviewed. A greater number of females (n=40) than males (n=26) participated in this study, which is consistent with other research. As expected, males were on average, older, heavier, taller, and had a higher BMI than that of their female counterparts. The average BMI of dancers in this study was similar to those reported in other studies, inclusive of both modern and ballet students (Askling et al., 2002; Wiesler et al., 1996). The average BMI of dancers in this study also increased with age and with each year of study. Although this did not reach statistical significance, this finding is consistent with other research where BMI has been shown to increase with age, reaching a plateau at professional level (Wyon et al., 2014). A lower muscle mass in younger dancers is considered one factor contributing to the lower BMI found in younger age groups (Wyon et al., 2014). History of previous injury was also found to differ between males and females, with significantly more females reporting a previous history of injury ( $p=0.011$ ). This may reflect the lower average age at which females started dancing seriously, hence possibly a greater degree of dance exposure.

Several significant differences were also found between ballet and modern majors. Ballet majors were, on average, slightly younger, weighed less and had a lower average BMI than modern majors in this study. The average BMI of ballet dancers (males and females) in this study was 19.25, which was comparable to other reported studies (Stokic, Srdic, & Barak, 2005; Wyon, Allen, M., Nevill, & Twitchett, 2006). The lower BMI of ballet students may, in part, reflect the differing aesthetic demands of this discipline. The ballet dancers in this study were also on average, slightly younger than the modern majors ( $p=0.04$ ); hence, this may be another factor contributing to a lower BMI.

Further to this, female ballet dancers in this study had the lowest BMI when compared to all other dancers (BMI = 18.35 SD 0.25). This was also lower than the average BMI of females of the same age range (Centres for Disease Control and Prevention, 2015). The average BMI of female ballet dancers in the cohort being investigated was also slightly lower than that reported in a study by Wyon et al. (2014). They found the BMI of female pre-professional ballet dance students aged between 15-17 years, to range from 18.9  $\pm$  1.77 to 20.1  $\pm$  3.07 (Wyon et al., 2014). The BMI of the male ballet dancers in our study (mean BMI 20.62, SD 0.32) was, however, comparable to other research (Wyon et al., 2014). While BMI has recognised limitations when considering an athlete's wellbeing, the relationship between a low BMI and other risk factors such as menstrual dysfunction and reduced energy deficiency syndrome (RED-S) indicates that this potentially warrants further attention, particularly amongst pre-professional ballet students.

## **5.2 Compliance**

Overall, this study achieved a high level of compliance with 77% of dancers at the NZSD participating in the study. Further to this, 86.2% of dancers reported one or more injuries over the 2014 academic year, indicating the in-house physiotherapy service to be accessed by the majority of students. Reported injury data allowed a reliable and consistent means of data collection. Further to this, the high use of the in-house physiotherapy service indicates that the injury data collected is representative of students attending the NZSD. Although self-reported data was not used for statistical analysis, over 86% of all surveys were completed. Self-reported surveys were also completed every three weeks reducing the effect of recall error.

## **5.3 Clinical incidence, injury prevalence and incidence rates**

### **5.3.1 Clinical incidence and injury prevalence.**

A total of 125 injuries were reported to the in-house physiotherapist. The clinical incidence over the 2014 academic year was 1.92 reported injuries per dancer (range 0 – 5, SD 1.35). This was higher when compared to other studies, including pre-professional ballet and/or modern dancers, where clinical incidence rates have ranged from 0.44 – 1.5 injuries per dancer (Baker et al., 2010; Baker-Jenkins et al., 2013; Bowerman, 2013; Ekegren et al., 2014; Gamboa, 2008; Leanderson et al., 2011; Luke et al., 2002). While it appears dancers in this study, on average, sustained more reported injuries per dancer, this may reflect differences in study methodologies such as injury definition, inception periods and exposure. Only one study of mixed genre (modern, Mexican folkloric and Spanish) reported a higher clinical incidence (average: 2.63 injuries per dancer and 4 injuries per modern dancer) (Echegoyen et al., 2010). Possible comparisons between the overall clinical incidence with this current study are limited due to the inclusion of different genres.



The clinical incidence of just the modern dancers was, however, still higher than that in found our study. Studies of professional dancers have also typically reported higher clinical incidence rates compared to the findings in our study (Allen et al., 2013; Byhring & Bo, 2002; Nilsson et al., 2001; Ojofeitimi & Bronner, 2011). The clinical incidence for time-loss injuries in this current study was 1.14 injuries per dancer. This was lower than that reported by Ekegren et al. (2014), who found a clinical incidence of 1.42 injuries per ballet dancer utilising the same injury definition. This may be, in part, due to this being a much larger cohort than this current study. However, it may also reflect that the cohort only included ballet dancers who were, on average, slightly younger (15 -19 years) and who also danced, on average, more hours per week (average: 1030hr/week) compared to the dancers in this current study.

Fifty-six dancers (86.2%) reported one or more new injuries over the 2014 academic year. There was no significant difference in injury prevalence between ballet (84%) and modern dancers (85%). The injury prevalence found in this study is amongst the highest of those reported across similar dance cohorts. However, there is a lack of prospective studies including a similar mixed cohort with which to compare the overall all injury prevalence. A prevalence rate of 76% was reported in a prospective study of pre-professional ballet students from three different schools in London (Ekegren et al., 2014). However, this only included time-loss injuries and would likely, therefore, have reported a higher injury prevalence if non time-loss injuries had been included. Baker et al. (2010) reported a comparable prevalence rate of 89% over a one-year retrospective study of modern dance students. The average age of these students (20-21years) was higher than this study and included both reported and self-reported injury data, which may account for the slightly higher rate found.

Another prospective study of elite ballet students also reported a lower injury prevalence to this study of 77%, although the self-reported injury prevalence in the same study was 90% (Luke et al., 2002). Studies of modern dance students have reported injury prevalence to be similar to or slightly lower rates than those found in the current study (Baker-Jenkins et al., 2013; Coplan, 2002). The high injury prevalence in this study may reflect the mixed cohort of ballet and modern dancers who are required to train in both disciplines. The ready access to on-site healthcare enabling early reporting of injuries may also contribute to the high number of reported injuries compared to other studies where this service may not be so readily accessed or so willingly used by students.

### **5.3.2 Injury incidence.**

This study aimed to quantify the volume of dance (class, rehearsal and performance) that full-time pre-professional dance students are exposed to over a full academic year. The total dance exposure for the entire cohort was 55,162 DEhrs (mean 882.52, SD 84.08) and 37,314 DE (mean 565.36, SD 141.52). This was lower than that reported in one study of pre-professional ballet dancers in London using the same exposure definition, where the average was 1,030 hours (mean 30.3hr per week) (Ekegren et al., 2014). In another comparable study of pre-professional ballet dancers, the weekly exposure was reported to be 20 hours per week; however, this was only an approximate and the total hours of exposure was not provided (Gamboa, 2008). Fewer hours of dance exposure have been reported in studies including university led dance courses (Baker et al., 2010; Weigert & Erickson, 2007), and those where dancers begin training at younger ages (<16 years) (Steinberg et al., 2011). While the available literature indicates that dancers at elite full-time pre-professional dance schools are exposed to the highest number of dance

hours/exposures, there are few studies with which to make meaningful comparisons. The limited use of standardised exposure measures is problematic and should be taken into consideration when comparing injury incidence rates.

Injury incidence rates in this study were calculated using reported injury data, whereby any injury that met the injury definition and required triage, assessment and or management from the in-house physiotherapist was included in analysis. The injury incidence in this study was 2.27 injuries per 1000 dance exposure hours (DEhr) and 3.35 per 1000 dance exposures (DE). Female dancers had a slightly higher injury incidence (2.39/1000DEhr) compared to the male dancers (2.19/1000DEhr). Overall, prospective studies utilising a mixed cohort (ballet and modern dance students) with which to compare the results of this study are lacking. The injury incidence rates for ballet and modern majors individually were comparable to findings of other similar cohorts. However, they are at the higher end of the range reported within the dance literature. The injury incidence rate of the ballet majors in this study was 2.11/1000DEhr. Injury incidence rates reported for ballet students have ranged from 0.9 - 2.9/1000hrs (Gamboa, 2008; Leanderson et al., 2011; Luke et al., 2002). The lowest of these was reported amongst pre-professional dancers of a similar age (15 -21years) at the Royal Swedish Ballet School (females 0.9/1000hrs and males 1.1/1000hrs) (Leanderson et al., 2011). However, the authors of this study utilised retrospective injury data from the medical notes of those dancers who had received orthopaedic care and no injury definition was given. Another study of pre-professional ballet dancers did report a similar injury incidence (2.4/1000DEhr and 3.52/1000DE) (Bowerman, 2013). This study only included overuse injuries of the lumbar spine and lower limb and was over a shorter inception period (six months). It may be that the injury incidence

could have declined as the year progressed, as was the case in the current study. Hence, if it had run for the entire academic year a lower injury incidence may have been reported. Few studies have reported the injury incidence for modern dance students. One study that did, included dancers at the Escuela Nacional de Danza in Mexico (Echegoyen et al., 2010). The researchers reported a significantly higher injury incidence rate of four injuries per 1000 training hours for the modern dance students. These dancers were, on average, older (23.1 years) compared dancers in this study (18.57 years), which, alongside the use of a different injury definition and a lack of clarity as to how exposure was calculated may contribute in part to this finding.

The injury incidence for time-loss injuries was 1.34 injuries per 1000DEhr. One prospective study of 266 pre-professional ballet dancers from three schools in London utilised the same time-loss injury definition (Ekegren et al., 2014). In that study the injury incidence for time-loss injuries was 1.38/1000 DEhr, which was comparable to the findings in this study. However, they reported a lower injury incidence per 1000 dance exposures (1.87/1000DE) compared to this current study where the dancers sustained slightly more time-loss injuries per 1000 exposures (class, rehearsal, performance) (1.98/1000DE). It is difficult to compare the demands and nature of each exposure for factors such as duration, intensity, technical demand, and class structure. However, these may be factors contributing to the differences found. Ekegren et al. (2014) also only included ballet students, while this current study included a mixed cohort, hence this should also be considered when comparing these results.

Injury incidence in this current study was highest amongst first year students, decreasing with each subsequent year. This is in contrast to findings in other studies of pre-professional dancers. In one study of pre-professional ballet dancers at an elite training school in London the second year students had a significantly higher injury incidence than first year students and third year students were higher than first year students (Ekegren et al., 2014). The authors reported that the increase in incidence with year of study reflected increased demands associated with performance and rehearsals. This current study demonstrated a decreased injury risk with each year of study, which may be due to fewer dancers with each increase in year of study. Another factor may be a change in injury reporting culture year to year, with younger dancers more willing to seek help and needing more assistance with injury management compared to older dancers who have more experience and ability to self-manage injury. Year one dancers are also likely to be less accustomed to the training volumes and technical demands of full-time dance training, compared to second and third year dancers. One might also expect dancers in years two and three to be technically better and stronger than those in year one.

In this study, the injury incidence of self-reported injuries was markedly higher than that of reported injuries. This is consistent with findings by Luke et al. (2002) in a cohort of elite pre-professional dancers, where self-reported injury incidence was also considerably higher than reported injury incidence. While there are well-documented limitations with self-reported injury data, such as recall bias and interpretation of injury definitions, delayed or non-reporting of dance injuries may also be a factor contributing to these findings (Baker et al., 2010; Jacobs, 2010). In some cases, the dancer may simply believe medical intervention is not needed. For others, factors such as minimising possible time-loss or activity modification play a

role. This may be to avoid missing out on training and career opportunities, such as being chosen for performances or secondments with professional companies. Providing an anonymous voice for students by collecting self-reported injury data alongside that of reported injuries may be a useful means by which to monitor changes in injury reporting culture over time, or indeed, the impact of injury education initiatives. Future research investigating reasons why injuries are not being reported, and the types/nature of these injuries could also aid in optimising healthcare education and services.

### **5.3.3 Lifetime injury prevalence.**

The lifetime prevalence of dance injuries was established via survey at the beginning of the study. In this study 86.4% (n=57) of dancers reported a previous history of dance-related injury. Interestingly, few studies have reported the lifetime injury prevalence of the cohort prior to undertaking the study. In one study of female dancers at the School of American Ballet, 82% of dancers had a previous history of injury during ballet classes; however, no injury definition was given (L. H. Hamilton et al., 1997). A higher life-time prevalence of 95% was found in a cohort of dancers (14-18years), but this only included ballet dancers (Luke et al., 2002). An earlier study with a mixed cohort of both ballet and modern dancers reported a life-time prevalence of at least one injury to be 94% and 79% respectively (Krasnow et al., 1999). Reliability of lifetime injury prevalence is limited in part due to recall bias. However, current rates do indicate that sustaining dance related injury is more common than not in adolescent dancers and, as such, highlights that this as a significant issue for this population.

## 5.4 Injury Severity

This study aimed to establish the severity of injuries sustained by pre-professional dancers attending the NZSD. This was firstly achieved by defining an injury as a time-loss or non time-loss injury and then by calculating the number of days lost to injury. Fifty-nine per cent of all injuries sustained over the 2014 academic year were time-loss injuries (requiring one or more full days off dance beyond the day of injury). The mean number of full days off dance due to injury was 5.85 days (range 1 - 42, SD 6.37). This was considerably less than the mean number of full days off full participation (full days off + days modified activity) reported in a prospective study of pre-professional ballet dancers (n=28days) (Ekegren et al., 2014). Another study by Weigert and Erickson (2007) found the average number of self-reported (estimate) of days missed or modified per term was 7.27 and 8.73 days. In comparison, this current study only included full days of dance, which most likely contributes to the difference in these findings. Another study of modern dance students and professionals similarly reporting 'full days off dance' found dancers took, on average, less days off dance (2.4 +/-1.3) than this current study (Angioi, Metsios, Koutedakis, et al., 2009). This was, however, limited by a small sample size (n=16). Although it was the intention of this current study to also report the number of days modified for time-loss injuries, the data was not consistently recorded, hence not included in the analysis. While the number of full days off dance provides the most reliable and comparable data, activity modification also plays a large role in injury rehabilitation, and as such helps to better illustrate the impact and severity of these injuries.

Injury severity was further classified based on activity modification and number of days lost (S0-S4). One study identified, that used the same injury severity

classification reported that the majority of injuries were recorded as S1 (modified class) (Bowerman, 2013). This differed to the current study findings where the majority of dancers (51%) were classified as S2 ( $\leq 7$  days off dance). This difference may be attributed to the fact Bowerman (2013) only included overuse injuries of the lumbar spine and lower limb, while our study included all injuries, including traumatic which, at least initially, are often managed with time off. The greater number of S2 injuries in this current study may also reflect the pro-active management of the in-house physiotherapist, whereby injuries are treated more aggressively with rest in the early stages resulting in more dancers taking days off.

Non time-loss injuries accounted for 40.8% of all reported injuries and on average required 7.14 days of modified activity (range 0-28 days, SD 5.49). Further to this, the majority of these required a 'moderate' degree of activity restriction as diagnosed by the in-house physiotherapist. It is apparent from this that a significant number of dancers continue training with an injury. Dancers in this cohort must participate in at least 80% of all classes in order to pass the year. However, it is the dance teacher's discretion as to whether a dancer has participated to an adequate level to be marked as 'attended'. Time-loss injuries requiring even moderate restrictions have the potential to have a significant impact on a dancer's attendance record. Quantifying the degree of activity modification poses a challenge given the large number of potential variables involved. Overall, these findings indicate the injuries sustained had significant impact on dance participation during an academic year. Therefore, future research and injury prevention strategies directed at those injuries resulting in the greatest time-loss and/or degree of activity modification is needed to begin to reduce the impact these injuries have on training and participation.



## 5.5 Injury Characteristics

One aim of this study was to establish the nature and characteristics of dance related injuries sustained by elite full-time pre-professional dance students in New Zealand. Fifty-six dancers (86.2%) reported one or more injuries during the 2014 academic year. No significant differences were found between the injured and un-injured groups for any of the variables including: age, height, weight, BMI, previous injury history, current injury history, gender, major or year of study. Overuse injuries were the most common type of reported injury (59.2%). This was consistent with that of previous research which has reported overuse injuries to account for the majority of all dance injuries (49.3 - 93.1%) (Bronner et al., 2003; Ekegren et al., 2014; Leanderson et al., 2011; Luke et al., 2002; Negus et al., 2005). Only one study reviewed reported a much lower rate of overuse injuries (29%) (Echegoyen et al., 2010). However, this only included four specific overuse injury diagnoses, which likely accounts for this finding.

The distribution of injury via location in this study was also comparable to that of previous research. The lower limb is consistently reported as the most commonly injured body site amongst pre-professional dancers (refer to Table 2.2). In this study 68% of all injuries were lower limb followed by trunk injuries (20%). This finding was similar to a study of pre-professional ballet dancers, where 77% of injuries occurred in the lower limb and 16% were in the trunk (Ekegren et al., 2014). The mixed cohort in our study may account for the slight differences noted. Modern majors sustained all of the upper limb injuries in this study, accounting for 16% of all injuries within this subgroup. This finding is similar to that reported by other studies of modern dancers where upper limb injuries have accounted for 13 - 17.7% of all injuries (Baker et al., 2010; Sides, Ambegaonkar, & Caswell, 2009).

Comparable studies of pre-professional ballet dancers have reported lower rates of upper limb injury compared to modern dancers, albeit higher than was found in this study where no upper limb injuries were sustained by ballet students over the study period (Ekegren et al., 2014; Leanderson et al., 2011).

Of all reported injuries 74.4% occurred during regular class. This would be expected given that dancers in this study are attending a full time-training school where classes make up the majority of their dance exposure. Compared to professional dancers, the opportunity for injury during performance is less, due to fewer hours of performance exposure.

## **5.6 Relationship between dance exposure and injury**

### **5.6.1 Dance exposure and injury risk.**

The results of this study demonstrated a significant association between the total number of reported injuries and total number of dance exposures (DE) per month. In comparison, only borderline statistical association was found between the average dance exposure hours (DEhr) per month and injury risk. This indicates that the number of individual classes/rehearsals/performances a dancer is exposed to was more predictive of injury risk than the total number of hours of dance exposure. Interestingly, this finding coincides with an increase in the duration of some classes, hence resulting in a small reduction in the overall number of DE's during the year.

There is very limited research involving pre-professional dancers with which to compare these findings, with few studies reporting the yearly exposure (hours or event) or the relationship to injury risk. The hours of dance exposure in this study were less than that reported in a comparable study of full time pre-professional dancers, however the relationship to injury risk was not examined (Ekegren et al.,

2014). Steinberg, Aujla, et al. (2013) investigated the association between injury risk and dance exposure in non-elite dancers. They found injured dancers aged 11-12 years danced significantly more hours per week doing 'other' dance styles than non-injured dancers of the same age, albeit this was not found for the other age groups, nor were the 'other' dance styles defined. Another study found no significant association between total hours of dance practice per week and injury risk amongst non-elite dancers aged between 8-16 years, although time spent en pointe (>60 minutes per week) was associated with an increased risk of injury (Steinberg et al., 2012a). Both of these studies included younger, non-elite dancers who are in part-time training, therefore limiting possible comparisons with this study.

The results from this study also showed that the number of injuries increased with exposure to a greater number of classes/rehearsals or performances. Unlike traditional sport, there is significant potential for variation at each exposure. A dance student's typical day is made up of individual classes, often taught by different teachers and/or involving different dance genres and repertoire. Each class may have varying levels of intensity, technical difficulty, and even time spent actually dancing. Content of a class may involve learning new work or involve rehearsing/performing familiar work. When dancers are exposed to a greater number of classes, rehearsals or performances they may, therefore, also be exposed to significant fluctuations in demand over a day, week and term. It could be hypothesised that this may be a contributing factor to injury risk in this population and hence, possibly also contributes to this finding. Managing students' dance load with regard to these factors poses a challenge. Thus far, there has been very little

reported within the dance research specifically exploring methods to optimise training load and, hence, this warrants further focused research.

When interpreting these results consideration must also be given to the fact that conditioning (pilates and gym) was not included in the total number of training hours/events. Dancers in this study had time allocated for attending both the pilates studio and gym. However, ascertaining who attended and duration of these sessions was not possible. It may be that the dance exposure (hours and events) in this study is, therefore, under reported in comparison to studies which have included cross training (Gamboa, 2008).

#### **5.6.2 Term of year and injury risk.**

Another finding in this study was the significant association between term of the year and injury risk, whereby dancers were at greater risk of sustaining an injury in term one, decreasing with each subsequent term. Further to this, dancers sustained significantly more time-loss injuries in term one, again decreasing with each subsequent term. These findings are consistent with that of Baker et al. (2010) who reported increased injury rates after students returned from holidays. Rapid changes in training volume have been highlighted in recent literature as contributing to injury risk (Drew, 2015). The increase in injuries, particularly at the start of the year, may reflect the rapid change in training volume after a break over the summer holidays (Baker et al., 2010; Drew, 2015). While the majority of dancers in this study reported having undertaken some form of conditioning or dance class during the holiday period, it is likely this was substantially lesser hours/exposures than they are exposed to during term time.

Timing of dance injuries has also been reported to be associated with changes in intensity such as can occur during times of assessment, rehearsal and performance (Gamboa, 2008). In this study the number of injuries decreased each term despite a relatively consistent volume of exposure. Further to this, the increased demands associated with greater time spent preparing for assessments in term two, and rehearsing and performing in term four, for example, did not result in a corresponding increase in injuries compared to other terms. It may be that during these times dancers are less able or willing to take time out to report injuries or simply self-manage until end of graduation season prior to seeking care. Dancers may also be better conditioned to meet their demands later in the year, thereby resulting in fewer injuries to report. Another possible factor contributing to this finding is that the lowest injury rate also occurs at a time when there is a change in both the nature and volume of standard class hours, with a greater number of hours focusing on rehearsals and performances later in the year. Dancers will also be embedding learnt technique, and repertoire will be more familiar as the year progresses. Less variability to cope with may also contribute to fewer injuries seen later in the year.

## **5.7 Relationship between injury and risk factors**

### **5.7.1 Relationship between the Movement competency Screen (MCS) and injury risk**

A primary aim of this study was to establish the relationship between movement competency, as determined utilising the Movement Competency Screen (MCS), and injury risk. MCS scores were analysed both as a continuous (total MCS score) and categorical (mean MCS score) variables. The mean (and median) MCS score of 23 was used to define the categorical variables (1= < 23, 2= ≥23). In this study dancers

who scored less than 23 were more likely to sustain an injury than those who scored at or above 23 ( $p=0.035$ ). This suggests that those dancers who demonstrated reduced or altered movement control during functional movement patterns, beyond that which was typically seen within the cohort, may be more susceptible to future injury. This provides some support for the use of functional movement screening as a tool for guiding injury prevention, whereby those dancers who score lower than average may be identified and referred for further screening, directed conditioning or load modification. While the use of functional movement screening tools in relation to injury risk has not been reported in the dance literature, a recent three year prospective study utilised the functional movement screen (FMS) to guide the development of individualised conditioning programmes for a group of professional ballet dancers (Allen et al., 2012). This resulted in a significant reduction in all injuries as well as recurrent injury over the three years.

No other studies utilising the MCS (inclusive of dynamic jump tasks) were identified in the literature to enable comparison of these results. A recent prospective study of elite rowers in New Zealand did, however, investigate the relationship between the total MCS score (five fundamental movements only) and risk of lower back injury (Newlands, 2013). The authors of that study found rowers who scored at, or higher, than the mean MCS (16) had a greater relative risk of sustaining a lower back injury compared to those who scored lower, albeit this finding was not significant. It may be that those rowers with high MCS scores are also exposed to other contributory risk factors such as greater training exposures or competition demands. Interestingly, the current study also found that the higher number of injuries in those who scored  $< 23$  was likely to be explained by the number of trunk injuries ( $p=0.036$ ). It may be that the broader definition of 'trunk'

injuries used in our study captured a larger number of possible injuries, hence the difference in findings compared to Newlands (2013).

Further to this, the results showed that the number of lower limb injuries increased with decreasing MCS scores, although this only demonstrated borderline significance ( $p=0.062$ ). Given that lower limb injuries are the most common injury location amongst dancers, this finding suggests functional movement screening tools such as the MCS, may be useful in identifying dancers who would benefit from further intervention. This study was, however, limited by a small sample size; therefore, further focused research across a larger population is necessary to support these findings. Future directed research utilising functional movement screening to help guide injury prevention interventions is also indicated either at an individual or group level, with specific focus on the lower limb and trunk.

The findings in this study support those of other studies that have also reported a positive relationship between functional movement screening outcome scores and injury risk. The most reported tool to do so is the Functional Movement Screen (FMS). A positive relationship between a FMS score of  $\leq 14$  (established via ROC curve analysis) has been associated with increased injury risk in professional football players, marine corps, college basketball players and female collegiate athletes of mixed sports (Chorba et al., 2010; Kiesel et al., 2014; Kiesel et al., 2007; O'Connor et al., 2011; Wieczorkowski, 2010). While these findings are positive they should, however, be considered in the context of other reported studies where no association and bimodal associations with injury risk have been found (Hall, 2014; M. Warren et al., 2014; Wiese et al., 2014). The variations in results seen within the literature may also reflect differing study methodologies, in particular injury

definitions and inception periods. Overall, while functional movement screening is, no doubt, a valuable screening tool, the variability within the research indicates that outcome scores should not be viewed in isolation when determining those at risk of injury.

In the current study, no significant difference in total MCS scores was found for gender, major or year of study. However, significant differences were found between males and females for individual scores for squat, single leg squat on the left, bend push and pull and press-ups. Males scored slightly lower than females for squat, single leg squat on the left and bend push and pull. The smaller sample of males compared to females within this study cohort may have contributed to this result. Females scored lower than males for press-ups which would be an expected result given that males are typically stronger in the upper body and have a greater lifting demand than females.

### **5.7.2 Relationship between injury location and risk factors.**

Injury location was found to be significantly associated with dance major, whereby modern dancers were more likely to sustain trunk injuries and upper limb injuries than ballet majors. This is consistent with the reviewed literature in Table 2.2, where modern majors typically reported higher numbers of upper limb injuries. Modern dance choreography involves significantly more upper body demand for both male and female dancers. Comparatively, male ballet dancers do most of the lifting or supporting body weight of other dancers, and this is considered a factor contributing to higher rates of upper body injury amongst male ballet dancers compared to females. However, in this study no upper body injuries were reported amongst the ballet dancers. Interestingly, the number of upper limb injuries reduced with each



year of study; however, this demonstrated only borderline significance ( $p=0.056$ ). Overall, these findings suggest that modern dancers, specifically first year modern dancers, may benefit from focused upper body training or load modification in an attempt to reduce the risk of upper limb injury.

### **5.7.3 Relationship between previous injury and risk factors.**

This study found a significant association with previous history of injury and gender, whereby females were more likely to have a history of previous injury compared to males. One reason for this finding may be that females typically started dancing at younger age and, hence, have had greater period of dance exposure. A second reason may be that the smaller sample size of males compared to females in this study biased this result. The dance literature has reported that a previous history of injury is associated with an increase risk of future injury amongst dancers, specifically ankle and lower back (Gamboa, 2008; Hiller et al., 2008; Laws, 2010; Wiesler et al., 1996). This study found no association between the total number of new injuries or the total number of dancers reporting one or more injuries and previous injury risk. Furthermore, no association was found between previous history of lower limb injuries and sustaining a new lower limb injury. This cohort was relatively homogenous whereby the majority of dancers (86.4%) reported a previous injury and also sustained a new injury (86.2%). A larger population is, therefore, necessary to better detect if there would be a significant association between these factors.

This study found only a borderline association between increasing age and previous history of injury. Current literature indicates chronological age of pre-professional dancers is not a consistently reliable indicator of injury risk (Bowerman, 2013).

However, it may be that a larger sample size is necessary to detect any significant difference across this relatively narrow age band.

#### **5.7.4 Relationship between injury severity and risk factors.**

Sustaining time-loss injuries was found to be independent of age, gender, BMI, major, year of study or previous injury history. The results of this study did indicate a borderline association between dancers who had lower total MCS scores and increased risk of sustaining time-loss injuries; however, this only reached near statistical significance ( $p=0.059$ ). While no comparative studies were identified utilising the MCS, a positive association between injury severity and FMS score was reported in a cohort of 874 marine officers (O'Connor et al., 2011). The findings of this study found marines who scored  $\leq 14$  were two times as likely to sustain a serious injury (any injury that required time off training), although no relationship to injury type (acute or overuse) and FMS score was found.

The results of this study did not find any relationship between the total number of days lost to injury and any variables including: age, gender, BMI, major, previous injury history, total MCS or mean MCS scores. This indicates the MCS was not sensitive enough to detect those dancers at risk of the most severe injuries.

Further analysis indicated that dancers reporting lower limb injuries were more likely to require time off, and also required significantly more days off dance compared to other injury locations (trunk, upper limb or head/neck). Lower limb injuries were the most commonly reported in this study and, hence, might contribute to this finding given the small sample size. This finding does concur with another study of pre-professional ballet dancers where lower limb injuries, specifically knee, ankle and foot required, on average, a greater number of days to return to full

participation compared to the average across all injuries (Ekegren et al., 2014). Overall, this provides further support for the need for focused injury prevention strategies for the lower limb in pre-professional dancers.

### **5.8 Limitations of the study**

Interpretation of these results should be considered alongside the following methodological limitations.

This study was inherently limited by the small sample size. While a larger number of dancers were initially recruited (n=75), nine dancers were not able to participate due to injury or being away on secondments. In order to detect small to moderate associations between risk factors and injury risk a larger population is necessary (Portney & Watkin, 2009). This limitation may be addressed by continuing to collect injury data over consecutive years and/or the inclusion of university led dance courses within New Zealand, to achieve a larger population.

This study did not collect the ‘number of days of modified activity’ for time-loss injuries. Such injuries would potentially require substantial periods of activity modification prior to returning to full dance activity. Hence, this must be considered when interpreting the impact and severity of time-loss injuries on dance participation.

This study did not include analysis of the repertoire, technical demand, or intensity of dance exposure. Such factors may impact on the potential injury risk of individual dancers. The time spent actually dancing during a class, rehearsal, or performance also varies between exposure and dancer. Dance exposure was calculated each week from the timetables, for each year group (major and gender), but not individually. Hence, the dance exposure hours recorded may not truly reflect the actual hours of

each individual dancer, where some will dance more or less than others. Therefore, this should be considered when interpreting these results.

Exposure data for this study included class, rehearsal, and performances. Although time was allocated in the weekly timetable for dancers to attend the pilates studio and the gym, establishing who attended and for how long was not achieved. Therefore, exposure totals both via hours and event may be under reported resulting in a slightly over estimated injury incidence in comparison to studies which potentially did include these hours.

Dancers undertook the MCS screening at the start of the study. As the dancers progressed through the year their movement competency may have changed. Future research would be well placed to establish if MCS scores taken at regular intervals during the year are a more reliable means of assessing injury risk or, indeed, if changes in MCS scores over time are associated with injury risk.

Statistical analysis highlighted associations between some risk factors and injury. However, there are still a lot of unknown factors for these injuries. This was highlighted by the very low adjusted R-squared values shown in some of the statistical models (see Appendix 11). This indicated that in some cases only a small percentage of the variation relating to the injury outcome was being explained by the variable in the dataset. Further research is, therefore, still required to identify other possible risk factors for these injuries.

## **5.9 Future Research**

Dance exposure has been poorly reported within the dance literature and there is little written with regard to optimal training volumes, intensities, or technical demands for pre-professional dancers. Future research investigating both exposure

(hours and units) and the nature of exposure (intensity, frequency, class and timetable structure, technique, repertoire) is needed so as to begin to better optimise training outcomes and minimise injury risk.

Future research utilising multiple raters of different disciplines and years of experience, and across repeated testing sessions, is necessary to establish the inter-rater reliability of the MCS as a screening tool for use within the dance population.

Future intervention studies are indicated, whereby functional movement screening may be used as a tool to help identify those dancers who would benefit from further assessment, specific conditioning, and/or load modifications, or to guide injury prevention programmes aimed to optimise lower limb and trunk control. The MCS may also be a useful teaching tool for this purpose, particularly within dance where the understanding of movement control is essential to the art.

### **5.10 Practical Implications**

Consistent and ongoing injury surveillance is needed at both a national and international level to provide a more robust body of injury data, and to enable the development and efficacy of injury prevention strategies to be established.

First year dancers require targeted injury prevention initiatives to reduce the high incidence found in this specific group compared to those of other years.

Training volumes (number of dance exposures) and the nature of training exposures over a day/week/term should be carefully monitored by those co-ordinating dance timetables. This will require careful planning and consideration with regard to the number, intensity, genre, and technical difficulty of exposures. Considering changes

to optimise the volumes and nature of dance exposure may have an immediate impact on current injury rates.

The MCS is a screening tool that can be used by teaching staff, trainers, and physiotherapists to identify dancers with movement deficits, as well as to optimise communication and injury management. The MCS may also be a useful teaching tool, with which to educate dancers on movement control and alignment as part of an injury prevention strategy.

### **5.11 Conclusion**

This study provides prospective injury prevalence, incidence, and severity data utilising standardised injury reporting measures, and as such, will contribute to a more comparable body of dance research. This study is one of few to have also examined the relationship between injury risk and dance exposure. Another objective of this study was to investigate the relationship between injury risk and possible risk factors, in particular functional movement competency.

The findings of this study indicate the risk of musculoskeletal injury was high within in this cohort, and the clinical incidence to be among the highest reported within the pre-professional dance population. While the overall injury incidence rate found in this study was, comparable to, although at times higher than other studies, the injury incidence for time-loss injuries was, similar to that of other studies. However, although these findings indicate pre-professional dancers have a high risk of sustaining musculoskeletal injury, the injury incidence was comparable, if not lower, than rates reported amongst other adolescent sports. Overall, these findings highlight the need for ongoing injury surveillance within this specific population, to monitor trends as well as establish the efficacy of much needed injury prevention

initiatives. In particular, the high injury incidence found amongst first year students within this specific cohort indicates injury prevention may also need to specifically target this subgroup.

The distribution of injuries (nature and location) in this study was comparable to previous research, supporting the need for future research focusing on strategies to reduce lower limb and overuse injuries amongst pre-professional dancers. However, the differences in injury distribution (location) found in this study, between ballet and modern majors, and year of study, indicate that injury prevention initiatives may be more effective if specifically targeted towards each genre and or year of study.

Overall, the injuries sustained in this cohort resulted in considerable amount of time-loss, with lower limb injuries requiring significantly more days off dance. Identifying risk factors for injury, and specifically lower limb injury, is essential so dancers can avoid the negative consequences associated with time-loss from training and participation.

This study found that the number of dance exposures (class/rehearsal/performance) was more predictive of injury risk than the hours of dance exposure. Further to this, dancers had a greater risk of sustaining injury in term one, reducing with each term of the year. There is currently a need for further prospective longitudinal studies within the dance literature examining dance exposure (volume and nature) and the relationship to injury, to better optimise training and performance outcomes as well as reduce injury risk.

This research showed a significant association between increased risk of any injury and trunk injuries and a MCS score < 23. The findings of this study, therefore,

support the use of the MCS to help identify individuals with reduced or altered functional movement control that may contribute to an increased risk of injury. As such, including the MCS as part of an overall injury screening strategy may be an efficient and effective strategy to help best identify those dancers who could benefit from more directed input.

Overall there is a need for ongoing and consistent injury surveillance to monitor trends and, in particular, the effect of targeted injury prevention strategies. This will also help to establish with more certainty the influence of other risk factors, which were not significantly associated with injury risk within this study. This will also enable the efficacy of screening strategies to be monitored, and further developed specific to the needs of dancers.

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## Glossary

Term	Definition
<b>Ballet dance</b>	An artistic form of dance performed to music, involving precise and highly formalised steps and gestures.
<b>Contemporary/modern dance</b>	A style of free and expressive theatrical dancing not bound by the classical rules of ballet and often inclusive of many different dance styles.
<b>Demi pointe</b>	The position of the foot when the heel is raised from the floor and the dancer is poised on the ball of one or both feet.
<b>Développé</b>	A movement in which the leg is first lifted into retire, to the level of the knee of the supporting leg, then fully extended outward into an open position.
<b>First position</b>	Turned out legs with the feet pointing in opposite directions, heels touching.
<b>Fifth position</b>	One foot is placed in front of, and in contact with the other, with the heel of one foot aligned with the toe of the other foot.
<b>Fondu</b>	A lowering of the body made by bending the knee of the supporting leg.
<b>Grande plié</b>	In first, third, crossed fourth and fifth positions, the heels come off the ground past demi-plié with the feet ending in high demi-pointe at the bottom of the bend. In second and open fourth position the heels stay on the ground.
<b>Pointe, en</b>	Supporting one's body weight on the tips of the toes, usually while wearing structurally reinforced pointe shoes.
<b>Pre pointe</b>	Dancer who has not yet begun dancing en pointe.
<b>Pre-professional dancer</b>	A dancer undertaking concentrated study or practice of the dance profession.
<b>Plié</b>	A smooth continuous bending of the knees outward with the upper body held upright.
<b>Relevé</b>	The action when a dance rises up to demi-pointe or en pointe
<b>Temp levé</b>	Hop on one foot while the other is raised in any position.
<b>Turnout</b>	Rotation of the legs at the hips resulting in knees and feet facing away from each other.
<b>Sissone fermé</b>	A jump done from two feet finishing with closing both feet into fifth position.

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Adapted from: Clippenger (2007), G. Warren (1989), and Ballethub (2015)

# Appendices

## Appendix 1 Ethics Approval



A U T E C  
S E C R E T A R I A T

23 September 2013

Duncan Reid  
Faculty of Health and Environmental Sciences

Dear Duncan

Re Ethics Application: **13/245 Injury incidence and the use of the movement competency screening tool to predict injury risk in full time dance students at the New Zealand School of Dance (NZSD): A prospective cohort study.**

Thank you for providing evidence as requested, which satisfies the points raised by the AUT University Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 23 September 2016.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/researchethics>. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 23 September 2016;
- A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/researchethics>. This report is to be submitted either when the approval expires on 23 September 2016 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at [ethics@aut.ac.nz](mailto:ethics@aut.ac.nz).

All the very best with your research,

Kate O'Connor  
Executive Secretary

**Auckland University of Technology Ethics Committee**

Cc: Linda Lee [linda@westmerepilates.co.nz](mailto:linda@westmerepilates.co.nz)

## Appendix 2 Participant Information Sheet



### Participant Information Sheet

#### Date Information Sheet Produced:

31 July 2013

#### Project Title

Injury incidence and the use of the Movement Competency Screening (MCS) tool to predict injury risk in full time dance students at the New Zealand School of Dance

#### An invitation

My name is Linda Lee. I am a Physiotherapist currently undertaking a Masters in Health Science under the supervision of Associate Professor, Dr Duncan Reid and Jill Caldwell at AUT University.

I am inviting all dancers enrolled in full time vocational training at the New Zealand School of Dance to participate in this study, which will be investigating injury incidence and the use of the Movement Competency Screen to predict injuries.

To take part in the study you should be:

1. Enrolled as a full-time student at the NZSD (Years 1-3)
2. Able to fully participate in the initial stages of this study
3. Have **NO** known health problems including injuries that would limit your participation in this study.

#### If you agree to take part in this research:

1. Any injury data and screening data and videos will be confidential.
2. You will in no way be personally identified in the study
3. Participation in this research is voluntary and you shall in no way be disadvantaged/advantaged if you choose to participate or not.
4. You may withdraw yourself or any information at any time prior to the completion of the study without being disadvantaged in any way.

#### What is the purpose of this research?

Dancers are elite athletes and artists. The demands of modern choreography, and intense training demands place dancers at risk of injury. Research reports high injury rates amongst dancers. There are however no current studies determining injury incidence and risk factors in New Zealand dancers. The aim of this study is to investigate injury incidence and associated risk factors in full time vocational dancers in New Zealand. Functional movement tests which simultaneously assess balance, strength and range of motion are now commonly used in sports medicine as part of pre season screening to help identify those athletes at risk of injury and

thereby better prepare those athletes for the demands of their sport. The Movement Competency Screen (MCS) is one such screening tool currently being utilized by High Performance Sport New Zealand (HPSNZ). This study also aims to determine if the Movement Competency Screen can predict those dancers who may be at risk of injury by assessing functional movement patterns. This research study will be my Thesis and will contribute to the Completion of my Masters in Health Science qualification at AUT University. As part of this research I may be required to provide a summary of my findings for publication in research journals or conference paper. Participants in this research can in no way be personally identified.

### **How was I identified and why am I being invited to participate in this research?**

Dancers between the ages of 16 -20 are reported to have some of the highest injury rates. In New Zealand we do not have any current research on injury rates amongst dancers undertaking vocational training. This research will begin to look at this by investigating injury rates and related risk factors amongst dancers undertaking full time vocational training in New Zealand. All dancers enrolled full time at the New Zealand School of Dance (NZSD) are invited to participate in this study. You may not be able to participate in the study if:

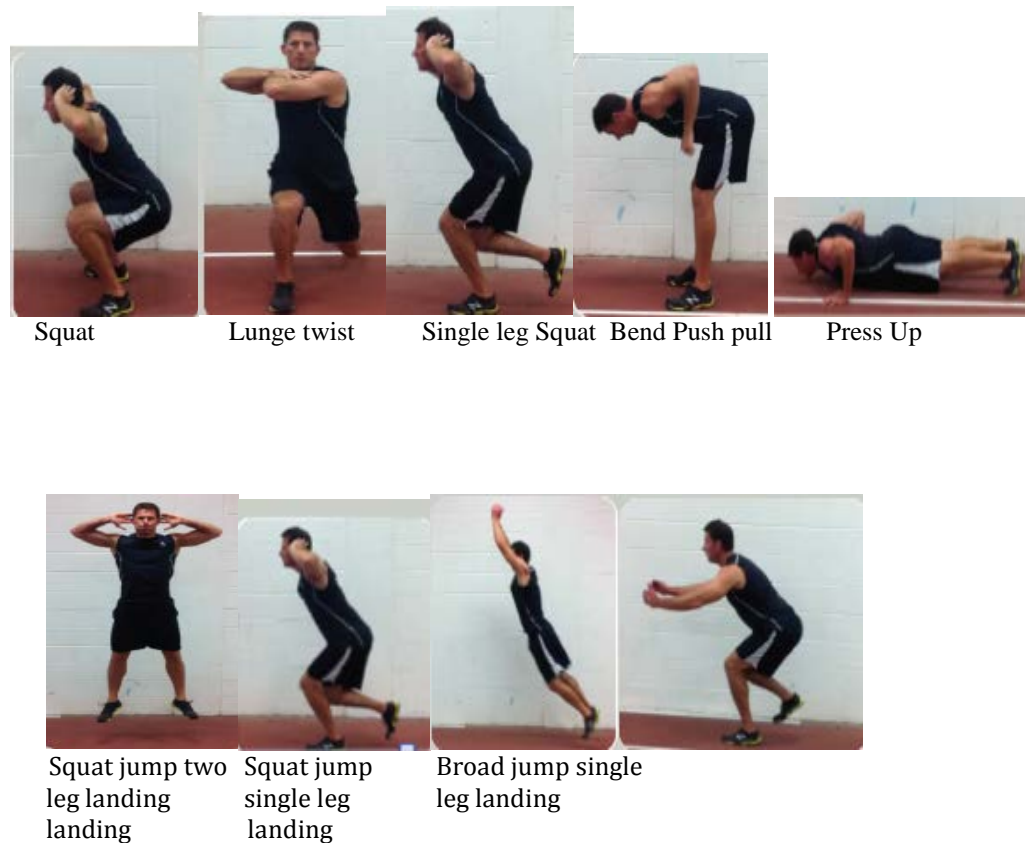
1. You are not able to fully participate in training and performance demands at the time of screening.
2. You have been deemed medically unfit for study participation by a doctor (i.e. have known health problems or injuries which would affect your participation in the study)
3. If you do not complete and return the Consent form and Dancers Questionnaire

### **What will happen in this research?**

If you choose to participate in this study you will be asked to:

1. Complete the ***Dancers Questionnaire***, which will provide us with background information i.e. gender, age, year at the NZSD and dance major. This will also ask for information on previous and or current injuries.
2. Undertake a **Movement Competency Screen (MCS)**. This involves completing 5 basic functional movement patterns and 3 simple jump sequences (figure 1). You will be asked to complete each movement 3 times. These are designed to measure whole body functional movement competency. Each movement pattern will be filmed to allow further analysis. This will be undertaken by the researcher/s at the NZSD.

Figure 1: The Movement Competency Screen© Developed by Dr. Matthew Kritz



- Completion of **3 Injury Questionnaires** per term over the full academic year. These will be sent to you via Survey Monkey and will take approximately 5 minutes to complete. (Nb: There will be no questionnaires over holiday periods). By completing the regular online surveys each term you will receive a café voucher. The first student in each year to complete the surveys each term will also win iTunes gift vouchers.
- If you attend physiotherapy for treatment and assessment of an injury, you will fill out an **IPAIRS** (International Performing Arts Injury Reporting System) questionnaire with your physio. This was developed at the Harkness Center for Dance Injuries in New York.
- All the information we collect will be given a unique code. This means your data is linked to this code rather than your name and hence you will not be identified personally to this information.

## **Who else will be involved in this research?**

In order to do this research several other people will help with data collection and screening. They include:

- Susan Simpson –NZSD Physiotherapist  
Susan will be recording details of all reported injuries utilizing the IPAIRS.
- Research Assistants: Richard Gallen (Physiotherapist)  
Richard will be helping with filming of the Movement Competency Screen.
- Sue Tuck (Pastoral Care Manager – NZSD)  
Sue will be collecting all the consent forms.

## **What are the discomforts and risks?**

While the risks to participation in this study appear to be minimal, there is a possible risk that during testing procedures you sustain a musculoskeletal injury (e.g. muscle strain). Further to this, you may experience delayed onset muscle soreness following the testing procedures. Given you are an elite athlete I would not anticipate any significant adverse effects from undertaking the movement screening exam.

However should you feel any discomfort during testing you should stop immediately and inform the researcher. Should we find that your movement patterns are outside the normal limits we expect you will be referred to Susan Simpson the NZSD physiotherapist for advice on how to manage this going forward as is normal practice within the school. Should we also find a musculoskeletal condition or disorder that is outside of what is expected to be found, we will inform you at the conclusion of the screening. This will allow you to take this information and discuss this with your preferred health professional. If the condition is such that it may impact on your ability to complete the screen we will stop the screen and withdraw from the study as per the exclusion criteria.

## **How will these discomforts and risks be alleviated?**

All reasonable effort will be made to prevent and avoid discomfort and risk during the Movement Competency Screen. This will take place at the NZSD itself so the environment will be familiar to you. Participants will only be asked to perform each movement 3 times, which will minimise risk of delayed muscle onset soreness.

In the unlikely event that you injure yourself during the screening process ice and a first aid kit will be available. The researcher is also a fully qualified physiotherapist who will be able to administer the appropriate care.

## **What are the benefits?**

While there are no immediate benefits to you personally, you will however be contributing (via your participation) to the dance community by increasing our understanding of injury incidence and risk factors. We will also be able to establish if the Movement Competency Screen can potentially predict injury risk. This information can then be utilized to focus on injury prevention strategies with the goal of reducing time off dance due to injury. Injury data collected utilizing the IPAIRS will also contribute towards a larger body of research. This data may be used for comparative studies by the Harkness Center for Dance Injuries. By participating you will be contributing internationally to Dance Medicine Research.

This research Thesis contributes to the requirements for the completion of my Masters in Health Science at AUT University

### **What compensation is available for injury or negligence?**

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the corporation's regulations.

### **How will my privacy be protected?**

Data collected from you will only be used for the study to determine injury incidence and related risk factors, and the use of the MCS in predicting injuries in dancers.

Only the investigators and administrators of the study will have access to your personal information and this will be kept secure and strictly confidential.

Online survey and injury surveillance systems employ multiple layers of security to make sure that data collected remains private and secure

You will be allocated a unique code and therefore you will not in any way be personally identifiable.

All raw data on which the results of this study depend will be retained in secure storage for 10 years after which it will be destroyed.

No information that could identify you as an individual participant will be used in any of the research reports or given to the New Zealand School of Dance.

### **What are the costs of participating in this research?**

Participation in this research will require you to:

1. Undertake a MCS assessment the first week of Term 1. This will take approximately 15-30 minutes per student.
2. Completion of a Dancers Questionnaire – 6 minutes
3. Completion of 3 Dancers Injury Questionnaire's per term – 5 minutes (i.e. 15 minutes total per term)

### **What opportunity do I have to consider this invitation?**

You will be invited to attend an information session at the start of 2014. Data collection for this study will commence on the first week of Term One.

### **How do I agree to participate in this research?**

If you agree to participate in this research you will be asked to complete the Consent Form attached to this information sheet and place this in the collection box provided. The completed forms will then be sent to my Supervisor Dr Duncan Reid at AUT University.

### **Will I receive feedback on the results of this research?**

You can choose if you wish to receive feedback on the results of this research please indicate this in the box provided on the consent form.

Those participants who wish to receive feedback will be emailed a summary of the research findings at the conclusion of the study.

**Who is funding this research?**

This research is funded by the New Zealand Manipulative Physiotherapy Association (NZMPA), and the Physiotherapy New Zealand Scholarship Trust Fund. Some funding is also provided by AUT University as part of the normal funding for postgraduate students.

**What do I do if I have concerns about this research?**

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Duncan Reid, dreid@aut.ac.nz, 09 9219999 ext 7806

Concerns regarding the conduct of the research should be notified to the Executive Secretary of ATEC, Kate O'Connor, ethics@aut.ac.nz, 921 9999 ext 6038.

**Whom do I contact for further information about this research?**

Researcher Contact Details:

Linda Lee

Westmere Pilates, 152 Garnet Road, Westmere, Auckland, 1022

linda@westmepilates.co.nz

09 3781612 or 0210324574

Project Supervisor Contact Details:

Duncan Reid

AUT University

dreid@aut.ac.nz

09 9219999 ext 7806

*Approved by the Auckland University of Technology Ethics Committee on 23 September 2012 ATEC Reference number 13/245*



## Appendix 3 Consent Form

### **Consent Form** **Injury Data Collection and Movement Competency** **Screen**



***Project title:***

Injury incidence and the use of the movement competency screening (MCS) tool to predict injury risk in full time dance students at the New Zealand School of Dance: A prospective cohort study.

***Project Supervisor:*** Duncan Reid

***Researcher:*** Linda Lee

- ☐ I have read and understood the information provided about this research project in the Information Sheet dated 31 July 2013.
- ☐ I have had an opportunity to ask questions and to have them answered.
- ☐ I understand that if I receive treatment from the Physiotherapist at the NZSD details of my injury will be recorded utilizing the International Performing Arts Injury Surveillance System (IPAIRS).
- ☐ I understand that I will be asked to complete an injury questionnaire 3 times per term over the full academic year (excluding the holiday period) which I will receive via email.
- ☐ I understand that the Movement Competency Screen will be video recorded by the researcher for analysis at a later date.
- ☐ All my personal details, injury data and MCS scores are confidential and I will in no way be personally identified.
- ☐ I understand that the results of this study may be published/reported at conferences however that I will not be identified individually.
- ☐ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection that would impact on my ability to safely participate in this research.
- ☐ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ☐ If I withdraw, I understand that all relevant information collected or parts thereof, will be destroyed.
- ☐ I agree to take part in this research.
- ☐ I wish to receive a copy of the report from the research (please tick one): Yes ☐ No ☐

Participants signature: .....

Participants Name:.....

Participants Contact Details

Address :.....

Phone :..... Email : .....

***Approved by the Auckland University of Technology Ethics Committee on 23<sup>rd</sup> September 2013 AUTEK Reference number: 13/245***

***Note: The Participant should retain a copy of this form***

## Appendix 4 Dancers' Initial Questionnaire



### Dancers' Initial Questionnaire

*All information provided in this questionnaire will be used for the study only and will be treated as confidential*

**Name:** \_\_\_\_\_ (Note: you will NOT be personally identified in this research)

**Date of birth:** \_\_\_\_\_

**Gender:** ☐ male ☐ female

**Year at NZSD:** ☐ 1 ☐ 2 ☐ 3 ☐ other \_\_\_\_\_ (Please specify if repeating/transferring)

**Major:** ☐ Contemporary ☐ Classical

#### Injury History:

An injury is defined as "Any physical complaint sustained by a dancer resulting from performance, rehearsal or class, irrespective of the need for medical attention or time-loss from dance activities"

#### **1. Previous Injuries**

Have you have had any previous injuries (as defined above) to the following body part/s ? (if so please tick those that apply)

<input type="checkbox"/> Head	<input type="checkbox"/> Shoulder	<input type="checkbox"/> Wrist	<input type="checkbox"/> Breast bone	<input type="checkbox"/> Hip
<input type="checkbox"/> Face	<input type="checkbox"/> Collar bone	<input type="checkbox"/> Hand	<input type="checkbox"/> Ribs	<input type="checkbox"/> Groin
<input type="checkbox"/> Neck	<input type="checkbox"/> Shoulder blade	<input type="checkbox"/> Fingers	<input type="checkbox"/> Mid back	<input type="checkbox"/> Thigh
	<input type="checkbox"/> Upper arm	<input type="checkbox"/> Thumb	<input type="checkbox"/> Abdomen	<input type="checkbox"/> Knee
	<input type="checkbox"/> Elbow		<input type="checkbox"/> Low back	<input type="checkbox"/> Lower leg
	<input type="checkbox"/> Forearm		<input type="checkbox"/> Pelvis	<input type="checkbox"/> Achilles
			<input type="checkbox"/> Sacrum	<input type="checkbox"/> Ankle
				<input type="checkbox"/> Foot
				<input type="checkbox"/> Toes

Please list details of any **previous injuries** below:

Injury Date (month/year is fine)	Location	Diagnosis (If known)	Did you have to stop dancing for 1 or more days due to this injury: yes/no	Cause (i.e. trauma, overuse)

## 2. Current Injuries

Do you have any **current injuries** that are limiting you from **fully** participating in dance training and performance? (if so please tick those that apply)

<input type="checkbox"/> Head	<input type="checkbox"/> Shoulder	<input type="checkbox"/> Wrist	<input type="checkbox"/> Breast bone	<input type="checkbox"/> Hip
<input type="checkbox"/> Face	<input type="checkbox"/> Collar bone	<input type="checkbox"/> Hand	<input type="checkbox"/> Ribs	<input type="checkbox"/> Groin
<input type="checkbox"/> Neck	<input type="checkbox"/> Shoulder blade	<input type="checkbox"/> Fingers	<input type="checkbox"/> Mid back	<input type="checkbox"/> Thigh
	<input type="checkbox"/> Upper arm	<input type="checkbox"/> Thumb	<input type="checkbox"/> Abdomen	<input type="checkbox"/> Knee
	<input type="checkbox"/> Elbow		<input type="checkbox"/> Low back	<input type="checkbox"/> Lower leg
	<input type="checkbox"/> Forearm		<input type="checkbox"/> Pelvis	<input type="checkbox"/> Achilles
			<input type="checkbox"/> Sacrum	<input type="checkbox"/> Ankle
				<input type="checkbox"/> Foot
				<input type="checkbox"/> Toe/s

Please list the details of any **current injuries** below:

Injury Date (month/year is fine)	Location	Diagnosis (if known)	Did you have to stop dancing for 1 or more days Yes/No	Cause (trauma or overuse)

**Medical History:**

1. Do you have any of the following medical conditions? *(tick those that apply)*

- ☐ Epilepsy
 ☐ Diabetes
 ☐ Hepatitis A
 ☐ Hepatitis C
- ☐ Hernia Problems
 ☐ Glandular Fever
 ☐ Eating disorder
 ☐ Heart
- ☐ Asthma
 ☐ Easy bleeding
 ☐ Anaemia
 ☐ Depression
- ☐ High/Low blood pressure
 ☐ Osteopenia/osteoporosis
 ☐ Concussion
 ☐ Rheumatologic disease
- ☐ Other (Please specify) \_\_\_\_\_

2. Do you take any regular medication? *(tick those that apply)*

- ☐ Prescription Medication
 ☐ Herbal supplements
 ☐ Over the counter medications
- ☐ Calcium supplements
 ☐ Daily vitamins
- ☐ Other (please specify) \_\_\_\_\_

3. Do you have any visual concerns/problems? *(please state if you wear glasses/contacts)*

- ☐ No
 ☐ Yes (please specify) \_\_\_\_\_

4. Do you have any hearing concerns?

- ☐ No
 ☐ Yes (please specify) \_\_\_\_\_

5. Are you on a special diet or avoid eating certain types of food?

- ☐ No
 ☐ Vegetarian
 ☐ Vegan
 ☐ Weight reducing
 ☐ Weight gaining
- ☐ Other \_\_\_\_\_

**6. Do you smoke?**

☐ No ☐ Yes (if yes how many cigarettes per day) \_\_\_\_\_

**7. Do you drink alcohol?**

☐ No ☐ Yes (Average number of drinks per week) \_\_\_\_\_

**8. How tall are you (cm)?** \_\_\_\_\_

**9. How much do you weigh (kg)?** \_\_\_\_\_

**10. Do you ever worry about your weight?**

☐ No ☐ Yes ☐ What is your ideal weight? (kg) \_\_\_\_\_

**11. Is your weight stable or does it tend to fluctuate?**

☐ Stable ☐ Fluctuates

**12. (FEMALE PARTICIPANTS ONLY)**

At what age did your periods start? \_\_\_\_\_

Do you take medications to regulate your period's e.g contraceptive pill?

☐ No ☐ Yes

(specify) \_\_\_\_\_

Do you currently have regular periods (i.e. every 28-35 days)? i.e. when not on the pill

☐ Yes ☐ No - if so how long have your periods been irregular? \_\_\_\_\_

Have your periods ever stopped for greater than 3 months?

☐ No ☐ Yes (If yes how often?) \_\_\_\_\_

What is the longest gap between your periods? \_\_\_\_\_

**13. Dance history**

At what age did you start dancing seriously? (age) \_\_\_\_\_

At what age did you begin pointe work (Females) \_\_\_\_\_

Do you typically **warm up**? i.e. at least 10 minutes of pulse raising activity, joint mobilization and short stretches. Tick those that apply

Before class ☐ No ☐ Seldom ☐ About ½ the time ☐ Usually ☐ Always

Before rehearsal ☐ No ☐ Seldom ☐ About ½ the time ☐ Usually ☐ Always

Before performance ☐ No ☐ Seldom ☐ About ½ the time ☐ Usually ☐ Always

Do you typically **warm down**? i.e. at least 10 minutes of pulse lowering activity, re-mobilization and stretches. Tick those that apply

After class ☐ No ☐ Seldom ☐ About ½ the time ☐ Usually ☐ Always

After rehearsal ☐ No ☐ Seldom ☐ About ½ the time ☐ Usually ☐ Always

After performance ☐ No ☐ Seldom ☐ About ½ the time ☐ Usually ☐ Always

**14. Over the summer holidays did you participate in regular dance classes or conditioning sessions.**

☐ No

☐ Yes - If yes how many sessions *per week* of each (on average) – mark below

☐ Gym

☐ Pilates

☐ Yoga

☐ Dance class

☐ Running/walking

☐ Other (specify) \_\_\_\_\_

**15. Will you undertake any other regular conditioning exercise outside of school during the year?**

☐ No

☐ Yes - If yes which of the following will you do?

☐ Gym

☐ Pilates

☐ Yoga

☐ Running

☐ Cycling

☐ Other (please specify) \_\_\_\_\_

**17. Where will you live while you are studying at the New Zealand School of Dance?**

☐ Home with your family

☐ Home Stay

☐ Hostel

☐ Flatting

☐ Other (please specify) \_\_\_\_\_

**18. Employment**

While you are studying at the New Zealand School of Dance will you also be working in *paid* employment?

☐ No

☐ Yes -What is your job title \_\_\_\_\_ (Job Title)

How many hours do you/intend to work per week \_\_\_\_\_ (hours/week) *if known*

***All information provided in this questionnaire will be used for the study only and will be treated as confidential***

## Appendix 5 Reported Injuries Summary Sheet



### Injury Summary Sheet

Dancers Name: \_\_\_\_\_

DOI: \_\_\_\_\_

#### 1. Injury Type

☐ New ☐ Recurrent (re-injury/exacerbation) (circle which applies)

#### 2. Injury Cause

☐ Trauma ☐ Overuse

Occurred During: (circle) ballet, contemporary, other \_\_\_\_\_

#### 3. Is this a time-loss injury?

☐ Yes (Go to question 4, 7-9)

☐ No The dancer is still able to participate (*Go to questions 5-9*)

#### 4. If the dancer has sustained a time-loss injury and is/was not able to dance please state the date the dancer stopped dancing and when they returned to dance.

☐ \_\_\_\_\_ (date stopped dance) or ☐ Estimated number of full days off dance

☐ \_\_\_\_\_ (date resumed dance)

#### 5. If the dancer did NOT take time off due to their injury to what extent did they have to reduce/modify training load during this injury?

☐ Not at all ☐ Minor ☐ Moderate ☐ Major

#### 6. How many days did the dancer have to modify their dance training load due to this injury?

☐ \_\_\_\_\_ (total number of days of modified training)

OR

☐ \_\_\_\_\_ (estimated number of modified training)

#### 7. Injury location

☐ \_\_\_\_\_

#### 8. Injury diagnosis (Preliminary/Final)

☐ \_\_\_\_\_

#### 9. Treatment Provider/s

☐ Physio ☐ Sports Physician ☐ Investigation (x-ray/MRI/US)

☐ Other (Specify)

Approved by the Auckland University of Technology Ethics Committee on 23 September 2013  
AUTEK Reference number 13/245

## **Appendix 6 International Performing Arts Injury Reporting System (IPAIRS©) Survey**

The IPAIRS© Survey form has been removed from this thesis for publication due to copyright laws. If the reader wishes to access further information regarding the IPAIRS© or it's content therein, please contact the author directly at the address provided below:

Marijeanne Liederbach, PhD, PT, ATC, CSCS  
Director of Research and Education; Department Head  
Harkness Center for Dance Injuries  
NYU Hospital for Joint Diseases  
NYU Langone Medical Center  
301 East 17th Street, New York, NY 10003  
p. 212-598-6022 f. 212-598-7613

<http://www.med.nyu.edu/hjd/harkness>

<http://www.danceinjury.org>



## Appendix 7 Self Reported Injuries Online Questionnaire

**Dancers Injury Questionnaire 2**

**Dancers Injury Questionnaire 2**

Please report all injuries (traumatic or overuse) newly incurred since the last survey.

An injury is defined as:

\*Any physical complaint sustained by a dancer resulting from performance, rehearsal or class irrespective of the need for medical attention or time-loss from dance activities\*

**1. Please complete your full name**  
(Remember you will NOT be personally identified in this research)

Full Name

Email Address

Phone Number

**2. Have you had an injury or injuries (traumatic, recurrent or overuse) since the last survey?**

☐ No (Answer questions 19 - 21 only)

☐ Yes (Go to question 3)

**Dancers Injury Questionnaire 2**

**INJURY 1**

The following questions relate to an injury you sustained since the last survey.

NOTE: If you have had more than one injury you will be asked to complete another set of questions for a second injury

**3. What was the date of your injury?**

DO MM YYYY  
Date (if known)  /  /

**4. What type of injury do you have?**

☐ New

☐ Recurrent (This is any injury of the same type/diagnosis and at the same site as a previous injury, which has occurred again within 2 months of returning to full participation after the initial injury)

**5. \*\*\*Only answer this if your injury was recurrent\*\*\***

**Had you recovered fully from your previous injury episode?**

☐ Yes (Re-injury: an injury of the same type and same site as the first episode occurring within two months after returning to full dance participation)

☐ No (Exacerbation: worsening state of a non recovered injury)

**6. What was the cause of your injury?**

☐ Trauma (Any injury occurring as a direct result of a single episode e.g. fall, trip, stumble)

☐ Overuse (Any injury occurring as the consequence of repetitive micro-trauma)

**7. Did you have to take 1 or more full days off dancing due to your injury? i.e. where you were unable to participate in any dance activity.**

☐ Yes

☐ No - I am still dancing but have modified my activity due to my injury.

☐ No - I am still able to participate fully in all dance without having to modify my activity.

**8. To what extent did you modify/reduce your training load due to your injury?**

☐ Not at all

☐ To a minor extent (i.e attending all classes with minor limitations)

☐ To a moderate extent (i.e attending all classes with moderate limitations)

☐ To a major extent (i.e unable to participate in significant components of a class or missing some but not all classes over a normal school day)

**9. Rate the average pain level of your injury on a scale of 0 - 10 (where 0 = no pain and 10 = worst possible pain).**

0 1 2 3 4 5 6 7 8 9 10

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

## Dancers Injury Questionnaire 2

### 10. How did your injury happen? (Tick those that apply)

- ☐ body twist
- ☐ overuse
- ☐ collision
- ☐ lift
- ☐ catching person or object
- ☐ landing
- ☐ slip
- ☐ jump landing
- ☐ jump take off
- ☐ fall
- ☐ twisting
- ☐ partnering
- ☐ stretching
- ☐ turning
- ☐ alignment
- ☐ Other (please specify)

### 11. What were you doing when your injury happened?

- ☐ class
- ☐ rehearsal
- ☐ performance
- ☐ warm-up
- ☐ cool-down
- ☐ conditioning
- ☐ Other (please specify)

## Dancers Injury Questionnaire 2

### 12. What do you think was the cause of your injury? (Tick those that apply)

- ☐ fatigue
- ☐ class timetable
- ☐ floor
- ☐ environment (hot/cold)
- ☐ insufficient warm up
- ☐ new/difficult choreography
- ☐ different repertory
- ☐ repetitive movements
- ☐ partnering work
- ☐ incorrect technique/training
- ☐ inadequate diet
- ☐ inadequate hydration
- ☐ set/props
- ☐ costume
- ☐ footwear
- ☐ schedule of classes/performance or rehearsals
- ☐ unsure
- ☐ Other (please specify)

### 13. What genre of dance were you doing at the time of your injury?

- ☐ contemporary
- ☐ ballet
- ☐ Other (please specify)

### 14. Where were you dancing when your injury happened?

- ☐ dance studio
- ☐ theatre/stage
- ☐ Other (please specify)

### Dancers Injury Questionnaire 2

#### 15. What part/s of your body were injured?

- ☐ head
- ☐ face
- ☐ neck
- ☐ shoulder clavicle
- ☐ shoulder blade
- ☐ upper arm
- ☐ elbow
- ☐ forearm
- ☐ wrist
- ☐ hand
- ☐ fingers
- ☐ thumb
- ☐ breast bone
- ☐ ribs
- ☐ upper back
- ☐ abdomen
- ☐ low back
- ☐ sacrum
- ☐ hip
- ☐ groin
- ☐ thigh
- ☐ knee
- ☐ lower leg
- ☐ achilles
- ☐ foot
- ☐ toes
- ☐ Other (please specify) \_\_\_\_\_

#### 16. Did you have an assessment or treatment for your injury?

- ☐ Yes
- ☐ No

### Dancers Injury Questionnaire 2

#### 17. Who did you see for assessment and treatment of your injury? (tick all those that apply)

- ☐ GP
- ☐ Sports Physician
- ☐ Physiotherapist
- ☐ Osteopath
- ☐ Massage therapist
- ☐ Chiropractor
- ☐ Acupuncturist
- ☐ Other (please specify) \_\_\_\_\_

#### 18. What was your injury diagnosis?

Injury diagnosis (If Known) \_\_\_\_\_

## Dancers Injury Questionnaire 2

### Dance Exposure

**19. How many full days of dance have you missed or been unable to attend since the last survey? (enter number)**

As a result of injury (Total number of full days missed)

Due to other factors e.g. flu, tummy bug (Total number of full days missed)

**20. Since the last survey have you taken part in any of the following activities over and above your time-table?**

- ☐ dance classes
- ☐ performance/s
- ☐ rehearsal/s
- ☐ pilates
- ☐ yoga
- ☐ cardio session (biking, swimming, running, treadmill etc)
- ☐ gym program
- ☐ home exercises (self prescribed)
- ☐ none
- ☐ Other (please specify)

**21. \*\* If you ticked any of the above activities answer this question \*\***

**How many hours on average per week have you participated in the above activities?**

Hours

## Dancers Injury Questionnaire 2

### INJURY 2

ONLY ANSWER THESE QUESTIONS IF YOU HAVE A SECOND INJURY TO REPORT

The following questions relate to a second injury you have sustained since the last survey.

**22. What was the date of your 2nd injury?**

DD MM YYYY  
Date (if known) / /

**23. What type of injury do you have?**

- ☐ New
- ☐ Recurrent (This is any injury of the same type/diagnosis and at the same site as a previous injury, which has occurred again within 2 months of returning to full participation after the initial injury)

**24. \*\*Only answer this question if your injury was recurrent\*\***

**Had you recovered fully from your previous injury episode?**

- ☐ Yes (Re-injury: an injury of the same type and same site as the first episode occurring within two months after returning to full dance participation)
- ☐ No (Exacerbation: worsening state of a non recovered injury)

**25. What was the cause of your 2nd injury?**

- ☐ Trauma (Any injury occurring as a direct result of a single episode e.g. fall, trip, stumble)
- ☐ Overuse (Any injury occurring as the consequence of repetitive micro-trauma)

**26. Did you have to take 1 or more full days off dancing due to your injury?**

- ☐ Yes
- ☐ No - I am still dancing but have modified my activity due to my injury
- ☐ No - I am still able to participate fully in all dance without having to modify my activity

**27. To what extent did you modify/reduce your training load due to your injury?**

- ☐ Not at all
- ☐ To a minor extent (i.e. attending all classes with minor limitations)
- ☐ To a moderate extent (i.e. attending all classes with moderate limitations)
- ☐ To a major extent (i.e. unable to participate in significant components of a class or missing some but not all classes over a normal school day)

**28. Rate the average pain level of your injury on a scale of 0 - 10 (where 0 = no pain and 10 = worst possible pain).**

0 1 2 3 4 5 6 7 8 9 10

### Dancers Injury Questionnaire 2

#### 29. How did your injury happen? (Tick all those that apply)

- ☐ body twist
- ☐ overuse
- ☐ collision
- ☐ lift
- ☐ catching person or object
- ☐ landing
- ☐ slip
- ☐ jump landing
- ☐ jump take off
- ☐ fall
- ☐ twisting
- ☐ partnering
- ☐ stretching
- ☐ turning
- ☐ alignment
- ☐ Other (please specify)

#### 30. What were you doing when your injury happened?

- ☐ class
- ☐ rehearsal
- ☐ performance
- ☐ warm-up
- ☐ cool-down
- ☐ conditioning

Other (please specify)

### Dancers Injury Questionnaire 2

#### 31. What do you think was the cause of your injury? (Tick all those that apply)

- ☐ fatigue
- ☐ class timetable
- ☐ floor
- ☐ environment (hot/cold)
- ☐ insufficient warm up
- ☐ new/difficult choreography
- ☐ different repertory
- ☐ repetitive movements
- ☐ partnering work
- ☐ incorrect technique/training
- ☐ inadequate diet
- ☐ inadequate hydration
- ☐ set/props
- ☐ costume
- ☐ footwear
- ☐ schedule of classes/performance or rehearsals
- ☐ unsure
- ☐ Other (please specify)

#### 32. What genre of dance were you doing at the time of your injury?

- ☐ contemporary
- ☐ ballet
- ☐ Other (please specify)

#### 33. Where were you dancing when your injury happened?

- ☐ dance studio
- ☐ theatre/stage
- ☐ Other (please specify)

### Dancers Injury Questionnaire 2

#### 34. What part/s of your body were injured?

- ☐ head
- ☐ face
- ☐ neck
- ☐ shoulder/clavicle
- ☐ shoulder blade
- ☐ upper arm
- ☐ elbow
- ☐ forearm
- ☐ wrist
- ☐ hand
- ☐ fingers
- ☐ thumb
- ☐ breast bone
- ☐ ribs
- ☐ upper back
- ☐ abdomen
- ☐ low back
- ☐ sacrum
- ☐ hip
- ☐ groin
- ☐ thigh
- ☐ knee
- ☐ lower leg
- ☐ achilles
- ☐ foot
- ☐ toes
- ☐ Other (please specify)

#### 35. Did you have an assessment or treatment for your injury?

- ☐ Yes
- ☐ No

### Dancers Injury Questionnaire 2

#### 36. Who did you see for assessment and treatment of your injury? (tick all those that apply)

- ☐ GP
- ☐ Sports Physician
- ☐ Physiotherapist
- ☐ Osteopath
- ☐ Massage therapist
- ☐ Chiropractor
- ☐ Acupuncturist
- ☐ Other (please specify)

#### 37. What was your injury diagnosis?

Injury diagnosis (If Known)

## Appendix 8 Movement Competency Screen Scoring Form

HPNZ Rehab Centre MSK Screening 2013 <small>(part 1 of 3)</small>				
Movement Competency Tests				
Athlete: _____		Sport / Discipline: _____		
Physio: _____		Date: _____		
<p>The key difference with these movement tests is "there are no instructions" - see attached picture guide for the athlete which displays the start &amp; finish positions for the 12 (3 repetitions of each) movement tests</p> <p>Film via smart phone, ipad, video etc &amp; upload to a private youtube account &amp; put the "private" link on the MSK Screen Form (you basically need to have access to or create your own Youtube account &amp; upload the MCS videos to this account. You then need to make this "unlisted" which means people can only view it if you share the link to that particular video - specific instructions can be found here <a href="http://support.google.com/youtube/bin/answer.py?hl=en-G&amp;answer=181547&amp;topic=16647&amp;ctx=topic">http://support.google.com/youtube/bin/answer.py?hl=en-G&amp;answer=181547&amp;topic=16647&amp;ctx=topic</a>)</p>				
<b>Scoring</b>				
1 = 2 or more primary's or 4 secondary; 2 = 1 primary & / or 0-3 or secondary's; 3 = 0 primary or 0-2 secondary's				
Test	Primary	Secondary	Load Level	Comment
Squat	<input type="checkbox"/> Shoulders	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Knees	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Depth	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Lunge & Twist - Left	<input type="checkbox"/> Balance	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Knees	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Depth	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Lunge & Twist - Right	<input type="checkbox"/> Balance	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Knees	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Depth	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Bend & Pull	<input type="checkbox"/> Shoulders	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Knees	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Ankles / Feet	2	
	<input type="checkbox"/> Depth	<input type="checkbox"/> Balance	3	
Push Up	<input type="checkbox"/> Shoulders	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Knees	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Ankles / Feet	2	
	<input type="checkbox"/> Depth	<input type="checkbox"/> Balance	3	
Single Leg Squat - Left	<input type="checkbox"/> Depth	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Shoulders	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Knees	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Single Leg Squat - Right	<input type="checkbox"/> Depth	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Shoulders	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Knees	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Jump & Land (both feet)	<input type="checkbox"/> Shoulders	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Knees	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Depth	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Vertical Jump & Land - jump off two land on left	<input type="checkbox"/> Depth	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Shoulders	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Knees	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Vertical Jump & Land - jump off two land on right	<input type="checkbox"/> Depth	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Shoulders	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Knees	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Broad Jump & Land - jump off two land on left	<input type="checkbox"/> Depth	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Shoulders	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Knees	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Broad Jump & Land - jump off two land on right	<input type="checkbox"/> Depth	<input type="checkbox"/> Head	0	
	<input type="checkbox"/> Lumbar	<input type="checkbox"/> Shoulders	1	
	<input type="checkbox"/> Hips	<input type="checkbox"/> Knees	2	
	<input type="checkbox"/> Ankles / Feet	<input type="checkbox"/> Balance	3	
Movement Competency Score (out of 36)				
			< 20 = Poor; 21-30 = Moderate; > 30 Good	

## Appendix 9 Movement Competency Screen Protocol

### Movement Competency Screen



HOW AN INDIVIDUAL PRODUCES POWER  
IS MORE IMPORTANT THAN THE POWER  
THEY PRODUCE

Developed by Dr. Matt Kritz

The movement strategy a person uses to accomplish a movement task can be described as that person's movement competency. Good movement competency is considered movement strategies that are mechanically sound free of dysfunction and/or pain. Poor movement competency is considered movement strategies that are considered dysfunctional and/or painful that may contribute more to injury than performance. Poor movement competency can increase injury risk. An individual's movement competency may be influenced by several variables, but what is important is that the training prescribed does not exceed the person's movement and/or strength capability and strategies are undertaken to mitigate the injury risk. The objective of the movement competency screen (MCS) is to identify which fundamental movement patterns can be aggressively loaded, which require developmental attention and which indicate injury risk.

The fundamental movement patterns that exist in activities of daily living, sport and sport related training are; the squat pattern, lunge pattern, upper body push pattern, upper body pull pattern, trunk flexion or bend pattern, trunk rotation or twist pattern, and unilateral lower limb or single leg squat pattern.

The MCS is made up of 10 movement tasks that challenge each of the aforementioned fundamental movement patterns and provide an individual with the opportunity to demonstrate their movement competency.

The MCS movement tasks are the squat, bilateral counter movement jump, lunge-and-twist, bilateral broad jump to a unilateral land, single leg squat, bilateral counter movement jump to a unilateral land, push up, explosive push up, band-and-pull, and band-and-pull at speed. A video demonstration of the MCS can be accessed by clicking this link <http://www.youtube.com/watch?v=albiOZKfkhg>.

Visually watch or video-record an individual performing 2-4 repetitions of each of the MCS movement task from the front and to the side. Make sure the individual load leg during side view trials is closest to the screener or video recorder. The link above illustrates exactly how the MCS should be performed for reliability. Below are the verbal instructions that may be given before each movement task is performed.

After watching the athlete perform the MCS movement tasks simply choose which level accurately depicts the quality of the movement you observe. For example if the athlete performs the Squat + CMJ and has good movement competency during the bodyweight squat but moderate control of their lower limb alignment upon landing and / or their trunk flexes slightly through the lumbar and / or they only moderately load their hips upon landing then their Squat pattern may be rated "Good" or level 4. You will need to detail WHY you have selected level 4 for the squat pattern. In other words, what did you see that you believe validates the level you have selected? If necessary you can use the criteria rationale sheet to help define WHY you have scored that athlete the way you have.

The load level is the recommended load the individual should use all exercises associated with the fundamental pattern until their movement competency is enhanced. The load levels are based on the notion that an individual's movement strategies are influenced by the load that is required to overcome. If a load is too great then an athlete will move in a manner that embraces their anatomical strengths, which may not be biomechanically correct or safe. The amount of time an individual should train at their movement competency load level would be determined by progression within the MCS movement task.

THE MOVEMENT COMPETENCY SCREEN®, Developed by Dr. Matt Kritz



**Order of MCS and verbal instructions for each of the MCS movement tasks**  
**Make sure to get a video from the front and side views for each MCS task**



1. Bodyweight Squat
2. Counter movement Jump (CMJ)

**Bodyweight Squat:** Perform a body weight squat with your fingertips on the side of your head and your elbows held inline with your ears. Squat as low and as fast as you comfortably can. **CMJ:** With your fingertips on the side of your head and your elbows held inline with your ears, jump as high as you can.



3. Lunge and Twist at self selected speed (Right)
4. Lunge and Twist at self selected speed (Left)
5. Lunge and Twist as fast as possible (Right)
6. Lunge and Twist as fast as possible (Left)
7. Bilateral broad jump with unilateral land (Right)
8. Bilateral broad jump with unilateral land (Left)

**Lunge and Twist:** Cross your arms and place your hands on your shoulders with your elbows pointing straight ahead. Perform a forward lunge then rotate toward the forward knee. Return to center and then push back to return to the starting position. Alternate legs with each repetition

**Broad Jump with unilateral land:** Perform a broad jump with a two-foot take off and a one-foot land.



9. Bodyweight single leg squat (Right)
10. Bodyweight single leg squat (Left)
11. CMJ off two legs with a single leg land on the right
12. CMJ off two legs with a single leg land on the left

**Single Leg Squat:** Perform a single leg body weight squat with your fingertips on the side of your head your elbows in line with your ears. Position the non-stance leg behind your body as you squat. Squat as low and as fast as you comfortable can. **CMJ with unilateral land:** Perform a jump squat with a two-foot take off. Jump as high as you can. Land on only one foot.



13. Bend and Pull at self selected speed
14. Bend and Pull as fast as possible

**Bend & Pull:** Start with your arms stretched overhead. Bend forward allowing your arms to drop under your trunk. Pull your hands into your body as if you were holding onto a bar and performing a barbell rowing exercise. Return to the start position with your arms stretched overhead. **Bend & Pull at speed:** Perform the bend and pull as fast as you possibly can.



15. Push Up
16. Explosive Push UP

**Push Up:** Perform a standard push up. **Explosive Push UP:** Perform a fast pushup and try to lift your upper body off the ground.

## Appendix 10 Movement Competency Screen (MCS) Scoring Criteria

Body Region/Capacity	MCS Task 1 Body Weight Squat	MCS Task 2 Counter Movement Jump	MCS Task 3 Lunge and Twist	MCS Task 4 Bilateral broad jump with unilateral land	MCS Task 5 Body weight single leg squat	MCS Task 6 Counter movement jump off two landing on one
<b>Head</b>	Held stable in a neutral position and centrally aligned					
<b>Shoulders</b>	Held down and away from ears. Elbows appear in line with ears. Thoracic extension is evident	Held down away from ears. Elbows in line with ears.	Held down and away from ears. Rotation appears to occur through thoracic spine. Elbows are at least inline with the lead knee at end range of rotation	Held down away from ears.	Held down away from ears. Elbows in line with ears. Thoracic extension is clear	Shoulders held down away from ears. Elbows in line with ears.
<b>Lumbar</b>	Neutral curve	Maintains lumbar curve, no hyperextension, rotation or flexion	Held stable, neutral spine is maintained throughout rotation. Rotation and/or lateral flexion does not occur about the lumbar region during trunk rotation	Maintains lumbar curve, no hyperextension, rotation or flexion	Held stable in a neutral spine position throughout lower limb flexion and extension	Maintains lumbar curve, no hyperextension, rotation or flexion
<b>Hips</b>	Movement is initiated with hip flexion. Remain horizontally aligned during flexion and extension. Obviously moving back and down during flexion		Horizontally aligned, mobile and stable to prohibit elevation and depression during rotation	Horizontally aligned and stable to minimize elevation and depression during landing	Movement is initiated with hip flexion. Remain horizontally aligned during flexion and extension. Clearly moving back and down during flexion, minimal weight shift over stand leg.	
<b>Knees</b>	Aligned with hips and feet during flexion		Aligned with hips and feet during flexion and do not move laterally with rotation	Aligned with hips and feet	Aligned with the hip and foot during flexion and extension	Aligned with hips and feet
<b>Ankles</b>	Mobility allow adequate dorsiflexion during knee and hip flexion					
<b>Feet</b>	Stable with heels grounded during lower limb flexion		Heel of lead leg in contact with the floor, trail foot flexed and balanced on forefoot	Stable	Stable with heels grounded during lower limb flexion	
<b>Balance</b>	Evenly distributed		Maintained on each leg	Able to control and stick landing	Maintained on each leg	Able to control stick landing
<b>Depth</b>	90 degrees or greater of hip flexion	70 degrees or greater of hip flexion	Lead thigh parallel to the floor	70 degrees of hip flexion	70 degrees of hip flexion	70 degrees of hip flexion

Body Region/Capacity	MCS Task 7 Bend and Pull	MSC Task 8 Press up
<b>Head</b>	Held stable in a neutral position	
<b>Shoulders</b>	Held down away from ears during arm flexion and extension. Scapulae move balanced and rhythmic and are not excessively abducted at arm extension	Held down and away from ears during arm flexion and extension. Scapulae move balanced and rhythmic and are not excessively abducted at arm extension
<b>Lumbar</b>	Held stable in neutral spine position throughout trunk flexion and extension	Held in stable neutral spine position
<b>Hips</b>	Movement is initiated with hip flexion. Extension is obvious and controlled	Held in line with the body during arm flexion and extension
<b>Knees</b>	Neutral position and held stable	Extended and held stable
<b>Ankles</b>	NA	NA
<b>Feet</b>	Pointing straight	Feet straight, heels not falling in or out
<b>Balance</b>	Maintained	NA
<b>Depth</b>	75 - 90 degrees or greater of trunk flexion	Chest touches floor

Adapted from Kritz (2012); (2013) and Vanweerd (2013)

## Appendix 11 Summary of regression analysis output

### Dance exposures (DE) and injury

Table 1. *Dependant variable = total number of reported injuries per month*

Independent Variable	Adjusted R Square	B	95% CI	p-value
Total DE/per month	0.399	0.003	0.001 – 0.006	0.016*
Average DE/per month	0.341	0.192	0.027 – 0.358	0.027*

\* statistically significant at  $p \leq 0.050$  DE = dance exposures

Table 2. *Dependant variable = total number of dancers reporting injuries per month*

Independent Variable	Adjusted R Square	B	95% CI	p-value
Total DE/per month	0.432	0.003	0.001 – 0.005	0.012*
Average DE/per month	0.380	0.172	0.034 – 0.310	0.019*

\* statistically significant at  $p \leq 0.050$  DE = dance exposures

### Dance Exposure hours (DEhr) and injury

Table 3. *Dependant Variable = total number of reported injuries per month*

Independent Variable	Adjusted R Square	B	95% CI	p-value
Total DEhr/per month	-0.125	2.916E-8	-1.0E-6 – 1.0E-6	0.964
Average DEhr/per month	0.210	2.906E-5	-4.0E-6 – 6.2E-5	0.076

DEhr = dance exposure hours

Table 4. *Dependant variable = total number of dancers reporting 1 or more injuries per month*

Independent Variable	Adjusted R Square	B	95% CI	p-value
Total DEhr/per month	-0.124	4.342E-8	-1.0E-6 – 1.0E-6	0.084
Average DEhr/per month	0.249	2.651E-5	-9.01E-7 – 5.4E-4	0.057

DEhr = dance exposure hours

**Time of year and injury**

Table 5. *Dependant variable = total number of injuries*

<b>Independent Variable</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Term of year</b>	0.946	-12.300	-19.538 – -5.062	0.018*

\* statistically significant at  $p \leq 0.050$

Table 6. *Dependant variable = total number of time-loss injuries*

<b>Independent Variable</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Term of year</b>	0.929	-6.000	-10.082 – -1.980	0.024*

\* statistically significant at  $p \leq 0.050$

Table 7. *Dependant variable = total number of trunk injuries*

<b>Independent Variable</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Term of year</b>	0.816	-3.100	-6.622 – 0.422	0.063

\* statistically significant at  $p \leq 0.050$

Table 8. *Dependant variable = total number of lower limb injuries*

<b>Independent Variable</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Term of year</b>	0.762	-7.300	-16.950 – 2.350	0.083

\* statistically significant at  $p \leq 0.050$

**Risk factors for injury**

Table 9. *Dependant variable = total number of trunk injuries*

<b>Independent Variables</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Age</b>	-0.003	-0.46	-0.150 – 0.058	0.379
<b>BMI</b>	-0.006	0.032	-0.048 – 0.113	0.423
<b>Gender</b>	0.002	-0.155	-0.463 – 0.153	0.318
<b>Major</b>	0.049	-0.304	-0.596 – -0.011	0.042*
<b>Year of study</b>	0.021	-0.152	-0.348 – 0.045	0.128
<b>Total MCS</b>	0.001	-0.016	-0.047 – 0.049	0.969
<b>Mean MCS</b>	0.053	-0.313	-0.605 – -0.021	0.036*
<b>Previous injury</b>	-0.015	-0.060	-0.496 – 0.377	0.786

\* statistically significant at  $p \leq 0.050$

Table 10. *Dependant variable = total number of lower limb injuries*

<b>Independent Variables</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Age</b>	-0.013	0.043	-0.164 – 0.250	0.681
<b>BMI</b>	-0.010	-0.049	-0.208 – 0.111	0.546
<b>Gender</b>	-0.015	-0.085	-0.528 – 0.698	0.783
<b>Major</b>	0.027	0.490	-0.095 – 1.075	0.099
<b>Year of study</b>	-0.016	0.002	-0.393 – 0.398	0.990
<b>Total MCS</b>	0.039	-0.087	-0.179 – 0.005	0.062
<b>Mean MCS</b>	0.008	-0.366	-0.957 – 0.225	0.220
<b>Previous injury</b>	-0.006	-0.339	-1.200 – 0.521	0.434

Table 11. *Dependant variable =total number of upper limb injuries*

<b>Independent Variables</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Age</b>	-0.015	-0.006	-0.079 – 0.066	0.861
<b>BMI</b>	0.036	0.050	-0.005 – 0.104	0.072
<b>Gender</b>	-0.012	-0.050	-0.624 – 0.164	0.642
<b>Major</b>	0.139	-0.324	-0.516 – -0.131	0.001**
<b>Year of study</b>	0.062	-0.152	-0.285 – -0.020	0.025*
<b>Total MCS</b>	-0.015	0.003	-0.030 – 0.036	0.836
<b>Mean MCS</b>	-0.016	0.015	-0.193 – 0.224	0.885
<b>Previous injury</b>	0.011	-0.196	-0.494 – 0.101	0.192

\* statistically significant at  $p \leq 0.050$     \*\* statistically significant at  $p \leq 0.010$

### Previous history of injury and risk factors

Table 12. Logistic Regression: *Dependant variable = reported a previous history of injury*

Independent Variables	Odds Ratio (OR)	Standard Error (SE)	95% CI	p-value
Age	0.524	0.353	0.262 – 1.047	0.067
BMI	0.959	0.194	0.656 – 1.403	0.830
Gender	0.143	0.850	0.027 – 0.755	0.022*
Major	4.480	0.845	0.855 – 23.474	0.076
Year of study	1.010	0.475	0.398 – 2.562	0.983
Total MCS score	0.987	0.112	0.792 – 1.230	0.906
Mean MCS score	1.207	0.721	0.294 – 4.961	0.794
Age started dancing seriously	1.042	0.108	0.843 – 1.287	0.705

\* statistically significant at  $p \leq 0.050$

### Injury severity and risk factors

Table 13. Logistic regression: *Dependant variable = reported a time-loss injury*

Independent Variables	Odds Ratio (OR)	Standard Error (SE)	95% CI	p-value
Age	0.718	0.213	0.473 – 1.090	0.120
BMI	0.836	0.145	0.629 – 1.111	0.218
Gender	0.718	0.213	0.692 – 6.436	0.189
Major	0.873	0.526	0.312 – 2.446	0.796
Year of study	0.857	0.351	0.431 – 1.706	0.661
Total MCS	1.198	0.096	0.993 – 1.446	0.059*
Mean MCS	2.707	0.551	0.919 – 7.973	0.071*
Previous injury	1.689	0.729	0.404 – 7.053	0.472

\*statistically significant at  $p \leq 0.050$

Table 14. Logistic regression: *Dependant variable = reported a non time-loss injury*

<b>Independent Variables</b>	<b>Odds Ratio (OR)</b>	<b>Standard Error (SE)</b>	<b>95% CI</b>	<b>p-value</b>
<b>Age</b>	0.998	0.173	0.711 – 1.399	0.989
<b>BMI</b>	1.031	0.134	0.794 – 1.340	0.816
<b>Gender</b>	0.682	0.512	0.250 – 1.863	0.456
<b>Major</b>	1.524	0.501	0.571 – 4.065	0.400
<b>Year of study</b>	1.172	0.330	0.614 – 2.240	0.630
<b>Total MCS</b>	1.055	0.080	0.902 – 1.234	0.503
<b>Mean MCS</b>	1.781	0.504	0.663 – 4.783	0.252
<b>Previous injury</b>	1.550	0.723	0.376 – 6.390	0.544

Table 15. *Dependant variable = total number of days off dance due to injury*

<b>Independent Variable</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Age</b>	-0.008	0.557	-0.999 – 2.113	0.477
<b>BMI</b>	-0.014	0.203	-1.004 – 1.410	0.738
<b>Gender</b>	-0.010	-1.445	-6.060 – 3.170	0.534
<b>Major</b>	-0.010	1.335	-3.162 – 5.832	0.555
<b>Year of study</b>	-0.010	-0.864	-3.842 – 2.114	0.564
<b>Total MCS</b>	0.026	-0.576	-1.274 – 0.121	0.104
<b>Mean MCS</b>	0.023	-3.493	-7.916 – 0.929	0.119
<b>Previous injury</b>	-0.010	1.950	-4.552 – 8.453	0.551

Table 16. Dependant Variable = total number of days off dance due to injury  
Independent variable = injury location

<b>Independent Variable</b>	<b>Adjusted R Square</b>	<b>B</b>	<b>95% CI</b>	<b>p-value</b>
<b>Lower limb injury</b>	0.130	-7.339	-11.856 – -2.822	0.002*
<b>Trunk injury</b>	-0.014	0.857	-3.898 – 5.612	0.720
<b>Upper limb injury</b>	-0.009	-1.973	-8.195 – 4.250	0.529

\*statistically significant at  $p \leq 0.010$



Table 17. Logistic Regression: *Dependant variable = reported a time-loss injury*  
*Independent variable = injury location*

<b>Independent Variables</b>	<b>Odds Ratio (OR)</b>	<b>Standard Error (SE)</b>	<b>95% CI</b>	<b>p-value</b>
<b>Lower limb injury</b>	10.792	0.625	3.173 – 36.707	0.001*
<b>Upper limb injury</b>	5.559	1.090	0.656 – 47.077	0.116
<b>Trunk injury</b>	2.223	0.597	0.690 – 7.160	0.181
<b>Head and Neck injury</b>	0.952	1.254	0.082 – 11.124	0.969

\*statistically significant at  $p \leq 0.01$