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ORIGINAL RESEARCH

INJURY INCIDENCE, DANCE EXPOSURE AND THE USE OF THE MOVEMENT COMPETENCY SCREEN (MCS) TO IDENTIFY VARIABLES ASSOCIATED WITH INJURY IN FULL-TIME PRE-PROFESSIONAL DANCERS

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ABSTRACT

Background/Purposes: Prospective studies utilizing standardized injury and exposure measures are needed to consolidate our knowledge of injury incidence and associated risk factors for musculoskeletal injury amongst pre-professional dancers. The purpose of this study was to investigate the injury incidence amongst pre-professional dancers attending a fulltime training school in New Zealand. The secondary purposes of this study were to investigate the relationship between dance exposure and injury risk, and the relationship between risk factors (specifically the MCS outcome scores) and injury risk.

Methods: A prospective cohort study of 66 full-time pre-professional dancers was undertaken over one full academic year (38 weeks), included 40 females (mean age 17.78 yrs, SD 1.18) and 26 males (mean age 18.57yrs, SD 1.72). Injury surveillance included both reported and self reported injury data. Dancers were screened using the MCS in the first week of term one.

Results: Eighty-six per cent of dancers sustained one or more injuries. Fifty-nine per cent of all injuries were time-loss. The injury incidence rate was 2.27 per 1000 hours of dance exposure (DEhr) and 3.35 per 1000 dance exposures (DE). There was a significant association between the total number of injuries and total DE per month (B = 0.003, 95% CI 0.001 - 0.006, p = 0.016). Dancers who had a MCS score < 23 were more likely to be injured than those who scored ≥23 (B = -0.702, 95% CI = -1.354 – -0.050, p = 0.035).

Conclusion: Injury prevalence and incidence was comparable with other international cohorts. The number of dance exposures was more highly associated with injury risk than the hours of dance exposure. The MCS may be a useful tool to help identify dancers at risk of injury.

Level of Evidence: Level 3b, Prospective Longitudinal Cohort Study

Keywords: Dance, exposure, functional movement screening, injury, pre-professional

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INTRODUCTION

Pre-professional dance training is demanding, and requires significant physical and artistic ability.[1,2] Long training hours coupled with highly repetitive movement patterns during a time of maturation and development places the pre-professional dancer in a vulnerable position with regard to injury risk.[3,4] Several authors have highlighted musculoskeletal injuries as a significant ongoing health issue for pre-professional dancers.[1-3,5-20] However, consistent reporting of injury incidence is still necessary to enable the development and monitoring of injury prevention strategies.[1,21-23]

Risk factors for dance related injury are still not well understood.[1,5,6,24] The negative effects of changes in training load and/or training loads beyond an athlete's capacity have been cited as potential risk factors for injury.[25-31] To date there is a paucity of prospective studies examining the relationship between dance exposure and injury risk amongst pre-professional dancers. [1,12,16,32,33]

Pre-participation or pre-season screening within dance schools and professional companies has become more widely adopted as the need to optimize dancers' health is recognized as a critical factor in both developing and maintaining talent. [34-42] Functional movement screening tools designed to identify deficits in neuromuscular control, have gained popularity within the sporting arena as an effective and efficient screening strategy. [43-50] The utility of functional movement screening tools, and more specifically the MCS, to detect dancers at risk of injury requires further investigation. [45,47,51,52] The purpose of this study was to investigate the injury incidence amongst pre-professional dancers attending a fulltime training school in New Zealand. The secondary purposes of this study were to investigate the relationship between dance exposure and injury risk, and the relationship between risk factors (specifically the MCS outcome scores) and injury risk.

METHODS

Study design

A prospective cohort study was conducted over one full academic year (38 weeks). Approval for was gained from the Auckland University of Technology (AUT) Ethics Committee. All participants received both verbal and written study information and gave written informed consent.

Participants

Students attending an elite full-time pre-professional dance school in New Zealand were invited to participate (n = 86). A total of 66 dancers completed the necessary documentation and movement screening session at the beginning of the study.

Injury Surveillance

Participating dancers completed an initial questionnaire that collected information on potential risk factors including: age, height, weight, BMI, gender, previous and current injury history, year of pre-professional dance training, dance major, and age started dancing. Prospective injury surveillance was undertaken over one full academic year. The dance school physiotherapist completed a standardized Injury Summary Sheet (Appendix 1) and International Performing Arts Injury Reporting Survey (IPAIRS©) for all reported injuries. Self-reported injury data was collected via an online survey tool (http://surveymonkey.com) and sent to participating students every three weeks. Injury was defined as, "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".[53] Injury was then also sub-classified based on current recommendations; including time-loss or non time-loss, nature of injury i.e. acute or overuse, and if an injury was new or recurrent.[54-56] Recurrent injuries were further classified as exacerbations or re-injuries.[55] (Appendix 2) Injury severity was coded, S0 (no days off or modified), S1 (activity modification), S2 (≤ 7 days off), S3 (> 7 days off) or S4 (year ending).[3,57]

Dance 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".[58] Total dance exposure (hours and events), was calculated from the weekly timetables for each year of study (major and gender).

MCS screening and scoring

All participants were screened using the Movement Competency Screen (MCS©) in the first week of term one. 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) (Appendix 3, Appendix 4).[47,59] The subjects were filmed using Casio EX-ZR100 digital cameras (Shibuya-ku, Tokyo). Video analysis of each movement pattern was performed by the primary researcher, and scored using standardized criteria directly adapted from the original MCS 100 criteria described by Kritz,[45] and that were used by Vanweerd[47] for the Netball Movement Competency Screen.[45,47,59] (Appendix 5) Whole body movement is assessed for each movement pattern and scored from 0 – 3, based on identification of primary or secondary areas of concern as described by Kritz.[45] Primary areas of concern are those that are most likely to impact on the athlete's movement competency during the selected movement task.[45] 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. The scores of all individual movements were totalled to provide a composite outcome score (out of a possible 36). The reliability of the MCS has been shown to be good to excellent in adolescent female netballers[52] and in military populations.[60] Prior to the current study a pilot study assessed the intra-rater reliability of the primary researcher using the MCS. 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).

Statistical Analysis

Descriptive analysis of the data established the injury prevalence and incidence of reported injuries. Injury prevalence was defined as the total number of reported injuries in one full academic year. Injury incidence over the academic year (Jan-Dec) was expressed as the number of reported injuries per 1000 hours of dance exposure (DEhr). Injury rates were also calculated using the number of reported injuries per 1000 dance exposures (DE), as it is considered to achieve a higher level of reliability as well as comparability betweeen cohorts, and is also consistent with reporting methods utilized by other international sporting bodies.[58,61] Pearson's correlations were used to determine the relationship between dance exposure and injury. A univariate linear regression model was used to investigate the relationship between injury status and individual potential risk factors. A multivariate linear regression model was used to examine the influence of a combination of risk factors for becoming injured. Covariates 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 of clinical significance. A logistic regression was used to investigate the relationship between injury severity 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).

RESULTS

Participants

Sixty-six dancers (females = 40, males = 26) aged between 16-24 years old (mean 18.15yrs, SD 1.45) gave consent to participate. There were 28 dancers in year one, 25 in year two and 13 in year three. Thirty-two were ballet majors and 34 were modern majors. Seventy-seven per cent of dancers attending the dance school participated in the study. During the course of the study one dancer opted out of reported injury data collection and four dancers left the school. Demographic characteristics of participants are presented in Table 1.

Injury Prevalence

Fifty-seven (86.4%) dancers reported a history of previous dance related injury at the start of the study. A total of 125 reported injuries, involving 56 dancers (86.2%), were recorded over the academic year. Injury prevalence across the year ranged from 1.5% to 36.9% per month. No significant demographic differences were found between dancers who reported any injury or time-loss injuries and those who did not (Table 2).

Injury Characteristics

Reported injury characteristics are shown in Table 3. 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

Table 1. *Demographic data, reported as mean (SD)*

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

BMI= Body mass index
*Statistically significant at p<0.05

Table 2. *Descriptive characteristics of injured and non-injured groups*

		Injury reported Mean	(SD)	No injury reported Mean	(SD)	p-value
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
		Injury reported N	**(%)**	**No injury reported N**	**(%)**	**p-value**
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 training	**1st**	23	(41.1%)	4	(44.4%)	0.902†
	2nd	21	(37.5%)	4	(44.4%)	
	3rd	12	(21.4%)	1	(11.1%)	

N= number of dancers; SD = standard deviation; BMI= Body mass index
† p-value calculated using fishers exact test

common site of trunk injury, followed by the lumbar spine. The shoulder was the most common upper limb injury.

Injury Severity

Of all reported injuries, 59.2% (n = 74) were time-loss resulting in a total of 433 full days off dance. Eighty-six per cent (n = 64) of all time-loss injuries required the dancer to take ≤ 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 tendon injuries of the foot and ankle. The distribution of injury severity via injury location is presented in Figure 1.

Injury Incidence

The total injury incidence rate over the 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)

Table 3. *Characteristics and severity of reported and self-reported injuries*

Characteristics	Reported Injuries n	%
Total injuries	125	
% dancers injured		86.2
New	104	83
Recurrent	21	16.8
- Re injury	*8*	*38.1*
- Exacerbation	*13*	*61.9*
Acute	51	40.8
Overuse	74	59.2
Head/Neck	4	3.2
Trunk	25	20
Lower Limb	85	68
Upper Limb	11	8.8
Injury Severity	Reported as mean (SD) or n	%
Mean numerical pain score	5.29 (1.91)	
Time-loss injuries:	n=74	59.2
Full days off dance	5.85 (6.37) (range: 1 - 42 days)	
Non time-loss injuries:	n= 51	40.8
Days of modified activity	7.14 (5.49) (range: 0 - 28 days)	
Activity modification:		
none	n=1	2
mild	n=7	14
moderate	n=43	84
severe	n=0	0

SD = standard deviation n = number

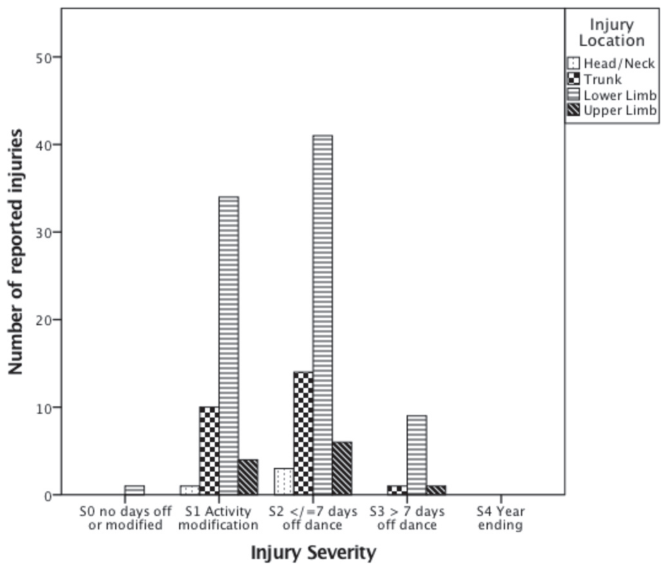
per 1000 dance exposures (DE). The total injury incidence for time-loss injuries was 1.34/1000DEhr and 1.98/1000DE's. The injury incidence rates, for reported injuries were similar for males and females (2.39 and 2.19/1000DEhr), and ballet and modern dancers (2.11 and 2.17/1000DEhr). First year students 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). Injury incidence (DEhr and DE) for reported injuries is presented in Tables 4 and 5.

Relationship between dance exposure and injury

The total number of dance exposures (DE) per month was significantly associated with the total number of reported injuries reported per month ($p = 0.016$) (Figure 2). 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 ($p = 0.027$). The total hours of dance exposure (DEhr) was found not to be a significant predictor of injury ($p = 0.964$).

Relationship between reported injuries and risk factors

The association between potential risk factors and injury is presented in Table 6. A MCS score < 23 was significantly associated with increased risk of injury ($p = 0.035$). Furthermore, the higher number of injuries in those with a MCS score < 23 was more likely to be explained by a greater number of trunk injuries ($p = 0.036$). No significant difference in total MCS scores was found for age, gender, major, or year group ($p > 0.05$).



Injury severity was coded based on definitions from previous research by Dick, Agel, Marshall 57 and Bowerman 64
S0 = No days off or modified
S1 = Activity modification only
S2 = ≤ 7 days off dance
S3 = > 7 days off dance
S4 = Year ending - if a dancer was unable to return to training due to injury

Figure 1. *Location severity of reported injuries.*

A history of previous injury was found not to be associated with increased injury risk. However, a significant association between previous history of injury and gender was noted, whereby more females had sustained previous injuries compared to males (p = 0.022). A significant association was found between injury location and major, whereby modern majors were more likely than ballet majors to sustain trunk injuries (B = -0.304, p = 0.042) and upper limb injuries (B = 0.324, p = 0.001). Upper limb injuries were more common amongst first year students, decreasing for every year of study (B = -0.152, p = 0.025).

DISCUSSION

Participants

The key strengths of this prospective study included: (1) seventy-seven per cent of eligible dancers participated in the study, (2) the use of reported injury and exposure data collected over a full academic year and, (3) this is the first prospective longitudinal study of elite pre-professional dancers in New Zealand.

Prevalence, incidence and severity

Prevalence

At the start of the study 86% (n = 57) of dancers reported a previous history of dance-related injury. This was comparable with previous studies (82-95%).[17,18,62,63] The injury prevalence over the academic year was (86.2%), which was within the upper range reported in current literature (30-94%).[2,7,8,10-12,16,18,63] Further to this, 21% of injuries sustained were considered 'recurrent', 8% of which were re-injuries. This was fewer than that reported by Ekegren, Quested, Brodrick[7] where 14% of time-loss injuries were considered a re-injury. Future research utilizing the Subsequent Injury Categorization (SIC) model as proposed by Finch and Marshall[64] may enable a better understanding between injury and each subsequent injury; which can have a considerable impact on a dancer's training and career.[19,65]

Table 4. *Injury incidence rates for reported injuries per dance exposure hours (DEhr)*

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

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

Table 5. *Injury incidence rates for reported injuries per number of dance exposures (DE)*

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

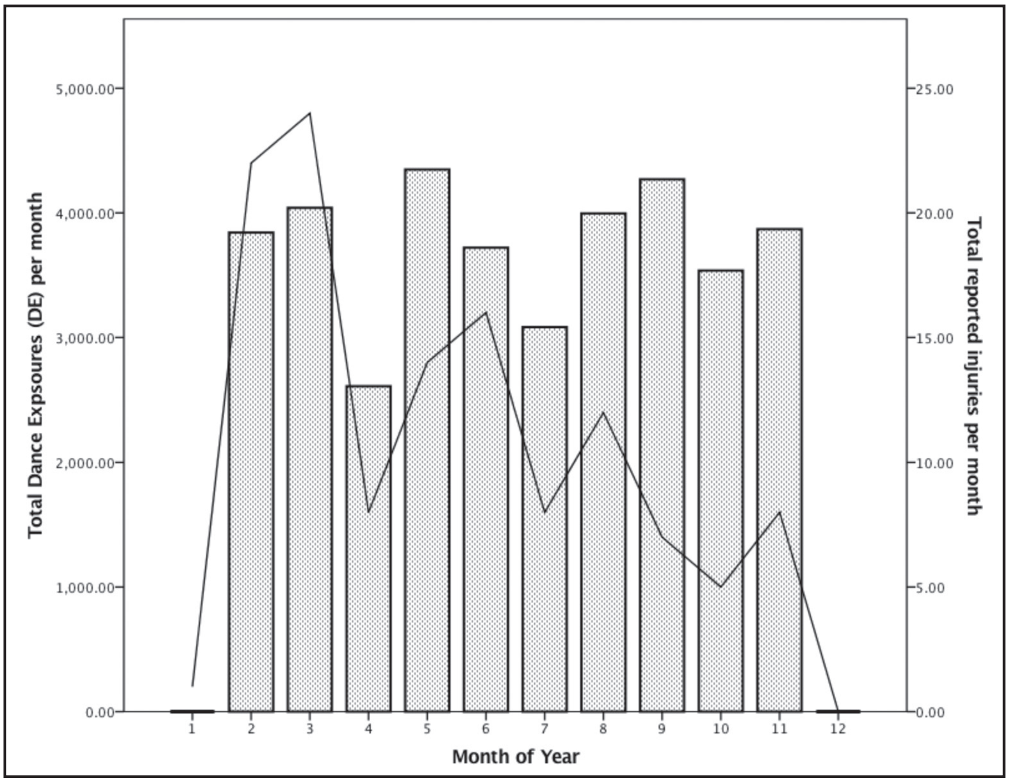


Figure 2. *Dance exposure and injury.*

Incidence

Prospective studies utilizing reported injury data and a mixed cohort with which to compare the overall results of this study are lacking. The incidence of reported injuries for ballet majors alone was 2.11/1000DEhr, which although comparable with previous studies, is at the upper end of the range (range: 0.9-2.9/1000hrs).[11,16,18] Fewer studies have reported the injury incidence for modern dance students. In this study the injury incidence (2.17/1000) was somewhat lower than the 4/1000hours of dance reported amongst modern dancers at the Escuela Nacional de Danza in Mexico.[13] Comparisons between dance schools should, however, be made with caution as differences in demands, nature of exposures, and age of dancers may also impact on injury rates.

Table 6. *Association between the total number of reported injuries and risk factors*

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

*Statistically significant at $p \leq 0.050$

The findings of this study support current evidence that overuse injuries are a significant issue for dancers.[2,7,11,16,17,66,67] The incidence of overuse injuries was found to be lower than that reported in a recent study of pre-professional ballet dancers (2.4/10000DEhr and 3.52/1000DE).[3] The shorter inception period of the compared study (6 months) and single genre cohort may contribute to these differences. Comparatively, Ekegren, Quested, Brodrick[7] reported a higher prevalence of overuse injuries (72%) compared to this current study (59.2%). The higher average dance exposure per year (1030hr) may be a contributing factor, whereby longer training hours, with less relative time for recovery is considered a significant extrinsic risk factor for sustaining overuse injuries.[25,68]

Severity

Severity of injuries amongst pre-professional dancers has, thus far, been infrequently reported and the different measures utilized to define injury severity have also limited comparisons. The injury incidence for time-loss injuries in this study was comparable with findings from a recent prospective study of 266 pre-professional ballet dancers in London that utilised the same time-loss injury definition (1.38/1000DEhr, 1.87/1000DE).[7] The current study found the majority of injuries to be classified as S2 (≤7 days off dance). Although a recent study of pre-professional ballet dancers classified the majority of injuries as S1 (activity modification), this only included overuse injuries of the lumbar spine and lower limb which is likely to contribute to this difference.[3]

Relationship between dance exposure and injury risk

A significant finding in this study was that the total number of dance exposures was found to be more highly associated with injury risk than the total hours of dance exposure. There is considerable potential for variation in volume, intensity, technical demand and nature of exposures during a dancers day/week/term and year.[69] It may be hypothesized that this can result in significant fluctuations in demand, over training or indeed under training the dancer and, hence, contribute to injury risk. Optimizing dance schedules using periodization have been reported to be an effective strategy in reducing injury risk and drop out rates in a pre-professional dance school,[70] and to improve mood states prior to performance in professional dancers.[31] The findings of this research support further investigation into strategies to optimize training outcomes and minimizing injury risk for pre-professional dancers.[30,34,69]

Current evidence indicates that rapid changes in training load precede the onset of injury.[29,71] This is consistent with findings in this study, whereby a greater number of reported injuries were sustained in term one (after the holiday period), peaking again after returning from each semester break. Current literature suggests that high acute:chronic workload ratios may contribute to increased risk of injury.[71,72] Although further research is necessary, this may be a factor contributing to the findings in this study. This study found the number of reported injuries decreased as the year progressed despite a relatively consistent volume of exposure each term.

Unlike previous research, assessments periods and increased exposure to rehearsal and performance (at the end of the year) did not result in a higher number of reported injuries.[16,30] It may be that as the year progressed dancers were better conditioned to meet their demands and therefore more resilient and accustomed to the workload, or simply reported fewer injuries to avoid missing vital assessment and performance opportunities.[73] In contrast to previous research, the year of pre-professional training was not associated with increased injury risk, despite increasing dance exposure.[7] It is possible that emerging adolescent dancers have a lower threshold for injury, as has been reported for other sports.[74] The small cohort and, specifically, the limited number of third year dancers in this study may have contributed to this finding. Further research investigating the dose-response relationship between training and injury and workload ratios across differing age groups and genres is needed.

Relationship between injury and risk factors

A primary aim of this study was to establish the relationship between the Movement Competency Screen (MCS), and injury risk. MCS scores were analyzed both as a continuous (total MCS score) and categorical (mean MCS score) variables. The mean (and median) MCS score for this cohort was 23, and this was used to define the categorical variables group assignment (1 = $<$ 23, 2 = $\geq$23). Those dancers who scored below the mean ($<$23) were considered to demonstrate reduced or altered movement control during functional movement patterns, beyond that which was typically seen within the cohort. Utilizing the mean MCS score as a cut off score enabled comparisons with previous research of movement screening tools, which have also utilized dichotomized pass/fail scores. In this study dancers who scored less than 23 were more likely to sustain an injury than those who scored at or above 23 ($p = 0.035$). This suggests that those dancers who demonstrated reduced or altered movement control during functional movement patterns, beyond what was typically seen within the cohort, may be more susceptible to future injury. This provides some support for the inclusion of the MCS as part of an overall injury screening strategy, whereby those dancers who may benefit from further assessment, conditioning or load modification can be identified in a timely manner. No other studies utilizing the MCS, inclusive of dynamic jump tasks, were identified in the literature, although a recent prospective study of elite rowers in New Zealand did investigate the relationship between the total MCS score (five fundamental movements only) and risk of lower back injury.[51,75] The authors of that study found rowers who scored at or higher than the mean MCS score were more likely to develop low back pain compared to those who scored lower, however, this finding was not statistically significant ($OR = 2.57$, $p = 0.07$). Studies evaluating the efficacy of other functional movement screening tools to identify those at risk of injury have also reported positive associations. The most reported tool to do so is the Functional Movement Screen (FMS™).[76-80] In spite of this, the efficacy of the FMS™ to predict injury risk should be considered in the context of those studies where no association and bimodal associations have been found.[81-83] The variability presented within the research highlights the difficulty of utilizing cut-off scores for predicting injury risk, where the sensitivity of the cut-off score is inversely related to the specificity.[84] While a single screening tool alone is unlikely to identify all those at risk of injury, identifying the most effective and efficient tools which detect factors that contribute to the injury risk profile of dancers is essential. The MCS has the potential to be utilized more widely by dance teachers, strength and conditioning coaches, and healthcare providers, and to educate dancers as part of an injury prevention strategy.

The findings of this study support the development of injury prevention programs targeting neuromuscular control in those with identified deficits. A recent three-year prospective study utilized the functional movement screen (FMS™) to guide the development of individualized conditioning programmes for a group of professional ballet dancers. [85] This resulted in a significant reduction in all injuries as well as recurrent injury over the three years. As injury prevalence has been shown to be high amongst adolescent dancers, specifically lower limb injuries, injury prevention programes involving neuromuscular control aimed at the broader adolescent dance population may have the biggest impact in reducing injury risk.

Limitations of the study

Interpretation of these results should be considered alongside the following methodological limitations. The sample size in this study was small due to the limited number of dancers attending the dance school, and as a result the relationship between some risk factors and injury is unclear.[86] The loss of five dancers during the course of the study may have also affected observed associations. Furthermore, although statistical analysis demonstrated an association between the mean MCS score and injury, there are still a lot of unknown factors that contribute to these injuries. This was highlighted by the very low adjusted R-squared value ($R^2 = 0.054$) (see Table 6). Further research is therefore still required to identify other possible risk factors for these injuries. The number of days of modified activity for time-loss injuries was not included and should be taken into consideration when interpreting the impact and severity of time-loss injuries on dance participation. The intensity and nature of dance exposures, and workload ratios was not included in exposure analysis. These factors may impact on the potential injury risk of individual dancers. Dance exposure was calculated each week from the timetables, for each year group (major and gender), but not individually, hence may not truly reflect the actual hours of training or engagement by each individual dancer. Non-scheduled dance practice or additional workouts such as attending the gym, were also not included in the total hours of dance. As the dancers progressed through the year their movement competency may have changed, and also their injury risk in relation to MCS scores. Research undertaking screening at more regular intervals over the year may better establish the relationship between outcomes scores and injury risk.

Functional movement screening has the capacity to identify dancers at risk of injury. As such, future intervention studies targeting those at risk individuals/groups with focused prevention/conditioning programmes are indicated. Multicentre studies examining training loads (acute and chronic) and nature of exposures in relation to injury risk are necessary to optimise training and performance outcomes across differing age groups and genres. Future research is needed to examine if MCS scores taken at regular intervals during the year may be more useful in establishing injury risk. Research establishing the inter-rater reliability of the MCS is necessary for this tool to be useful between providers and across the broader population.

CONCLUSION

This is the first prospective longitudinal study of pre-professional dancers in New Zealand. Injury prevalence and incidence rates were high, although comparable to those reported internationally. The results of this study indicate, that the number of dance exposures was more highly associated with injury risk than the hours of dance exposure. Furthermore, dancers had a greater risk of sustaining injury in term one, reducing with each term of the year. There is a need for further prospective longitudinal studies examining dance exposure and the relationship to injury. An MCS score < 23 was associated with an increased risk of future injury. Therefore, including the MCS as part of an overall injury screening strategy may be an efficient and effective strategy to help identify those dancers who could benefit from focused injury prevention strategies.

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APPENDIX 1

Reported 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 AUTEC Reference number 13/245

APPENDIX 2

Injury and severity definitions

Definitions utilised for injury recording and associated variables include:

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[53].

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"[58].

Non Time-Loss Injury: An injury that does not rise to the level of a reported time-loss injury[58].

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"[84].

Overuse Injury: "An injury caused by repeated micro-trauma without a single identifiable event responsible for the injury"[84].

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[55,82]. 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"[82].
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"[82].

Injury severity was measured by time-loss (days) 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[57].

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 also coded based on definitions adapted from previous research by Dick, Agel, Marshall[57] and Bowerman[64]

S0 No days off or modified

S1 Activity modification only

S2 ≤ 7 days off dance

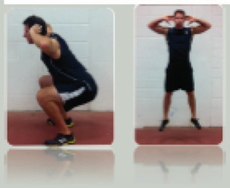
S3 > 7 days off dance

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

APPENDIX 3

Movement Competency Screen Testing Sequence

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.

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

* Each movement was performed a total of six times (three time facing the front and three times facing the side)
** The explosive tasks (Exercises 14 and 16) were not included in the screening assessment

APPENDIX 4

HPNZ Rehab Centre MSK Screening 2013 *(part 1 of 3)*

Movement Competency Tests

Athlete: ____________________ Sport / Discipline: ____________________

Physio: ____________________ Date: ____________________

The key difference with these movement tests is <u>**"there are no instructions"**</u> - see attached picture guide for the athlete which displays the start & finish positions for the 12 (3 repititons of each) movement tests

Film via smart phone, ipad, video etc & upload to a private youtube account & put the "private" link on the MSK Screen Form (you basically need to have access to or create your own Youtube account & 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 http://support.google.com/youtube/bin/answer.py?hl=en-GB&answer=181547&topic=16647&ctx=topic)

Scoring

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	☐ Shoulders	☐ Head	0	
	☐ Lumbar	☐ Knees	1	
	☐ Hips	☐ Depth	2	
	☐ Ankles / Feet	☐ Balance	3	
Lunge & Twist - Left	☐ Balance	☐ Head	0	
	☐ Lumbar	☐ Knees	1	
	☐ Hips	☐ Depth	2	
	☐ Ankles / Feet	☐ Balance	3	
Lunge & Twist - Right	☐ Balacne	☐ Head	0	
	☐ Lumbar	☐ Knees	1	
	☐ Hips	☐ Depth	2	
	☐ Ankles / Feet	☐ Balance	3	
Bend & Pull	☐ Shoulders	☐ Head	0	
	☐ Lumbar	☐ Knees	1	
	☐ Hips	☐ Ankles / Feet	2	
	☐ Depth	☐ Balance	3	
Push Up	☐ Shoulders	☐ Head	0	
	☐ Lumbar	☐ Knees	1	
	☐ Hips	☐ Ankles / Feet	2	
	☐ Depth	☐ Balance	3	
Single Leg Squat - Left	☐ Depth	☐ Head	0	
	☐ Lumbar	☐ Shoulders	1	
	☐ Hips	☐ Knees	2	
	☐ Ankles / Feet	☐ Balance	3	
Single Leg Squat - Right	☐ Depth	☐ Head	0	
	☐ Lumbar	☐ Shoulders	1	
	☐ Hips	☐ Knees	2	
	☐ Ankles / Feet	☐ Balance	3	
Jump & Land (both feet)	☐ Shoulders	☐ Head	0	
	☐ Lumbar	☐ Knees	1	
	☐ Hips	☐ Depth	2	
	☐ Ankles / Feet	☐ Balance	3	
Vertical Jump & Land - jump off two land on left	☐ Depth	☐ Head	0	
	☐ Lumbar	☐ Shoulders	1	
	☐ Hips	☐ Knees	2	
	☐ Ankles / Feet	☐ Balance	3	
Vertical Jump & Land - jump off two land on right	☐ Depth	☐ Head	0	
	☐ Lumbar	☐ Shoulders	1	
	☐ Hips	☐ Knees	2	
	☐ Ankles / Feet	☐ Balance	3	
Broad Jump & Land - jump off two land on left	☐ Depth	☐ Head	0	
	☐ Lumbar	☐ Shoulders	1	
	☐ Hips	☐ Knees	2	
	☐ Ankles / Feet	☐ Balance	3	
Broad Jump & Land - jump off two land on right	☐ Depth	☐ Head	0	
	☐ Lumbar	☐ Shoulders	1	
	☐ Hips	☐ Knees	2	
	☐ Ankles / Feet	☐ Balance	3	

Movement Competency Score (out of 36)		< 20 = Poor; 21-30 = Moderate; > 30 Good

APPENDIX 5

Movement Competency Screen Scoring Criteria

Body Region/Capacity	MCS Task 1 Body Weight Squat	MSC Task 2 Counter Movement Jump	MSC 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
Head	Held stable in a neutral position and centrally aligned					
Shoulders	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 is 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.
Lumbar	Neutral curve	Maintains lumbar curve, no hyperextension, rotation or flexion	Held stable, neutral spine is maintained through out 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
Hips	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.	
Knees	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
Ankles	Mobility allow adequate dorsiflexion during knee and hip flexion					
Feet	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	
Balance	Evenly distributed		Maintained on each leg	Able to control and stick landing	Maintained on each leg	Able to control stick landing
Depth	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

APPENDIX 5 (continued)

Movement Competency Screen Scoring Criteria		
Body Region/Capacity	**MCS Task 7** **Bend and Pull**	**MSC Task 8** **Press up**
Head	Held stable in a neutral position	
Shoulders	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
Lumbar	Held stable in neutral spine position throughout trunk flexion and extension	Held in stable neutral spine position
Hips	Movement is initiated with hip flexion. Extension is obvious and controlled	Held in line with the body during arm flexion and extension
Knees	Neutral position and held stable	Extended and held stable
Ankles	NA	NA
Feet	Pointing straight	Feet straight, heels not falling in or out
Balance	Maintained	NA
Depth	75 - 90 degrees or greater of trunk flexion	Chest touches floor
Adapted from Kritz (34), Kritz [45,59] and Vanweerd [47]		