Risk factors for lower extremity injuries among contemporary dance students

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Abstract

This prospective cohort study was conducted to assess if student characteristics, lower extremity kinematics and strength are risk factors for sustaining lower extremity injuries in pre-professional contemporary dancers. At the start of the academic year (2015/2016) a total of 45 first year students of Bachelor Dance and Bachelor Dance Teacher received a questionnaire containing items on injury history (only lower extremity) and student characteristics (age, gender, educational program); height and weight measurements (BMI); and functional tests (single-leg squat (SLS) and countermovement jump). During the academic year injuries were recorded using a monthly questionnaire. Substantial lower extremity injuries during the academic year (main outcome) were defined as any problems leading to moderate or severe reductions in training volume or in performance, or complete inability to participate in dance at least once during follow-up as measured with the Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems. Analyses on leg level were performed using Generalized Estimating Equations to test the associations between substantial lower extremity injuries and potential risk factors. The one-year prevalence of lower extremity injuries was 82.2%. Of these 51.4% was a substantial lower extremity injury. Multivariate analyses identified that ankle dorsiflexion during the SLS (OR 1.25; 95%CI 1.03–1.52) was a risk factors for a substantial lower extremity injury. The findings indicate that contemporary dance students are at high risk for lower extremity injuries. Therefore, the identified risk factor should be considered for prevention purposes.

Keywords: dance, pre-professional, injury, lower extremity, risk factors, prospective cohort study

Introduction

Contemporary dance students participate in long hours of class, rehearsal and performance.(1) Training consists of repetitive movements (2,3) exceeding anatomical limitations (4) and demanding versatility(5). These demands make a dance student at high risk for injuries.(6) The yearly overall risk of injuries in pre-professional contemporary dancers is more than 60% (6–8), with dancers returning to full dancing after a mean of 57 ± 91 days (males) and 41 ± 55 days (females) as a consequence of an injury.(9) Most predominant musculoskeletal injuries seen in dancers are lower extremity injuries.(1,7,8,10,11) The highest injury rates are found for the ankle/foot (20.5% - 28.0%), the knee (16.0% - 21.4%) and the lower back (13.4% - 17.0%).(7–9) The three most common diagnoses reported in professional contemporary dancers were muscle strains (28%), ligament sprains (23%), and chronic processes such as tendonitis and bursitis (21%).(9)

In athletes the dynamic position of the knee is considered to be a risk factor for injuries of the lower extremity.(12) For instance, external rotation and abduction of the knee during landing or squatting tasks are known risk factors for Anterior Cruciate Ligament (ACL) lesions and Patellofemoral Pain (PFP) in the general athletic population.(13–15) Additionally, cross-sectional studies have shown that patients with PFP have more hip adduction, knee flexion, knee medio-lateral displacement and peak ipsilateral trunk lean during these tasks than healthy people. (16,17) In two cross-sectional studies with (pre-) professional contemporary- and ballet dancers, a difference in lower extremity strength was found between injured and non-injured dancers, with a lower strength among injured dancers.(18,19) These findings suggest that the dynamic position of the knee and lower extremity strength may be risk factors for lower extremity injuries in dancers.

Considering the high frequency of lower extremity injuries in dancers and the corresponding high absenteeism (i.e. classes, rehearsals and performances) as a result of injuries, insight in factors predicting substantial injuries would enables us to enhance the prevention of dance related injuries. Therefore, the aim of the present study is to test if the lower extremity kinematics and strength, using the single-leg squat (SLS) and the countermovement jump (CMJ), are potential risk factors for lower extremity injuries in pre-professional contemporary dancers.

Methods

Study design

A prospective cohort was set up among first year students of Codarts University of The Arts, Rotterdam, The Netherlands. The participants were full-time students in a Bachelor degree in Dance and Bachelor degree in Dance Teacher. Inclusion in the study was regardless of a previous lower extremity injury. Only students who were injured at baseline and not able to perform the physical tests were excluded from the study. Ethical approval was given by the Medical Ethics Review Committee of the Academic Medical Centre Amsterdam, The Netherlands (W15_200). Written informed consent was obtained from all participating students.

Procedures and measurements

Baseline measurements were conducted at the start of the academic year (2015/2016) and consisted of an intake questionnaire, physical examination and physical performance tests. The intake questionnaire included items on age (years), gender and injury history (only lower extremity in the prior year). During the physical examination height and weight were measured with which Body Mass Index (BMI) was calculated. The physical performance tests consisted of the single leg squat (SLS) and the countermovement jump (CMJ) to measure lower extremity kinematics and strength.(20–22) During the following academic year (September 2015 to June 2016) injuries were recorded by means of a monthly questionnaire which included the Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems.(23) A reminder was sent to all students who did not respond on the questionnaire after one week

Physical performance tests

The SLS was used to evaluate the dynamic position of the knee, and shows a good inter-rater, intra-rater and test-retest reliability.(12,21,22) The SLS was performed following the guidelines of Stensrud et al. (2011).(24) All students practiced the test 3 times with each leg with the researcher controlling the 90 degrees knee flexion with a goniometer. Markers were placed on the pre-acromion, manubrium sterni, Spina Iliaca Anterior Superior (SIAS), trochanter major, lateral and medial epicondyle of the knees and lateral and medial malleoli of ankles. As starting position, students stood straight up and placed their arms across the chest. Movement was recorded on video in the frontal and sagittal plane using IPads. Students were instructed to squat until a knee flexion of 90 degrees was reached. The trial was not valid if the non-weight bearing leg touched the ground or if the student fell.(24) The SLS was performed three times on each leg.

The frontal and sagittal videos of SLS were analyzed using Kinovea (Kinovea, version 0.08.15) by measuring the following angles on the first frame of peak knee flexion: hip flexion (HF) , knee flexion (KF), ankle dorsiflexion (DAF), knee valgus (KV), lateral trunk motion (LTM) and pelvic tilt (PT). HF was defined as the angle between the line formed by pre-acromion and trochanter major and the line between the lateral knee epicondyle and trochanter major. KF was defined as the angle between the line formed by trochanter major and lateral epicondyle and the line between lateral knee epicondyle and lateral malleolus. DAF was the angle between the line formed by lateral epicondyle and calcaneus through lateral malleolus and the line between the fifth toe and calcaneus, with a larger dorsiflexion indicating limited ankle dorsiflexion. PT was the angle between the line formed by ipsilateral and contralateral SIAS and the horizontal line starting in the ipsilateral SIAS. The KV and LTM were measured accordingly to Dingenen et al. (2014).(25) The average angle of three trials was calculated for both legs separately.

The CMJ test was used as a measure for strength of the lower extremity, and shows a good inter-rater, intra-rater and test-retest reliability.(20,26) Students were instructed to stand on the electronic timing plate(Fusion Sport) with their hands on the hips. The plate detects flight time and converts this in jump height (cm). Students were instructed to squat as deep as preferred and consequently jump as high as possible without flexion of the knees during the jump or removing the hands from the hips. The trial was rejected if an arm swing or knee bending occurred or if the student fell or lost balance while performing the CMJ. Students were instructed to land on the plate at exactly the same place as the starting point. The CMJ test was performed three times for jumping with both legs, and three times on the left and right leg separately.(27) Consequently, the average jump height of these three trails from the different jumping tasks was computed.

Prior to the physical performance tests the students performed a standardized warming-up consisting of bipodal squats (2x8 repetitions), bipodal jumps (2x5 repetitions) and stretching of the calf muscle with straight and bended knees.(24)

Injury registration

The monthly questionnaire consisted of four key questions on the consequences of health problems on participation, training volume, and performance as well as the degree to which the student perceived symptoms (OSTRC Questionnaire on Health Problems). Each question of the OSTRC was scored with a four or five point scale, ranging from 0 (respectively: no problem, no reduction, no effect and no symptoms) to 25 (cannot participate at all or severe symptoms). The severity of a health problem was calculated on a scale of 0 (no health problem) – 100 (cannot participate at all due to sever health problems) by summing the score of the four questions, according to the method proposed by Clarsen et al..(28,29) If the severity score was 0, the questionnaire was finished for that month. However, if a symptom was reported, the students were asked whether they referred to a physical injury, mental problem or an illness. For physical injuries, the student was automatically directed to an injury registration form based on an international consensus statement on injury surveillance methodology for football to collect further details (e.g. location, history and acute or overuse onset).(30–33)

Lower extremity injuries are defined as injuries at the lower back, pelvis, leg, knee and foot. Students were defined to be substantial injured at their lower extremity if they reported problems leading to moderate or severe reductions (value ≥13 on question 2 or 3 of the OSTRC) in training volume, or moderate or severe reductions in performance or complete inability to participate in dance at least once during follow-up.(23)

Statistical methods

Statistical analyses were conducted using SPSS (SPSS, V21.0) and statistical significance level was set at an alpha level >0.05. Descriptive statistics were used to describe baseline characteristics of all participants using means and standard deviation (SD) or number and percentages (%). The one year prevalence of all lower extremity injuries and substantial lower extremity injuries was calculated by dividing the number of students that reported at least 1 lower extremity injury during the academic year by the number of respondents

To examine potential risk factors for lower extremity injuries, univariate and multivariate regression models were applied on leg level using Generalized Estimating Equations (GEE), taking into account the association between two legs within one person. Potential risk factors included age (years), gender (male), BMI (kg/m2), educational program (Bachelor Dance Teacher versus Bachelor Dance), injury history in the prior year (only lower extremity injuries), all measured angles from the SLS (°) and jump height from the CMJ (cm) for jumping with both legs and single leg. First, univariate associations between the potential risk factors and the dichotomized outcome: substantially injured at the lower extremity during follow-up (yes/no) were assessed. Secondly, multivariate regression modeling using GEE was performed including all potential risk factors and the outcome of interest. The results of the regression analyses were expressed in odds ratio’s (OR) with corresponding 95% confidence interval (95% CI).

Results

Participants

All approached students (n=45) agreed to participate and were consequently included in the present study. Four of these did not perform the CMJ and one student was not able to execute the SLS on the right leg. The cohort comprised 28 females (62.2%), the mean age was 18.6 years (SD 1.1), mean BMI was 20.7 kg/m^2 (SD 1.6) and 17 students had a lower extremity injury history (37.8%). Twenty eight (62%) were students enrolled in the Bachelor degree Dance and 17 (38 %) in the Bachelor Dance Teacher (Table 1). The monthly response rate of the follow-up questionnaires ranged from 88.9% up to 100%.

Injuries

During the academic year a total of 37 (82.2%) students reported a lower extremity injury of which 19 (51.4%) were categorized as substantial. The monthly prevalence of all lower extremity injuries ranged from 14.5% to 28.0% and from 4.4% to 12.2% for substantial lower extremity injuries (Figure 1).

Risk factors for lower extremity injuries

The univariate analyses showed a significant association between a limited dorsiflexion of the ankle (OR 1.11; 95% CI 1.02 – 1.20) and substantial lower extremity injuries during follow-up (Table 2). None of the other tested variables were univariately associated with the outcome of interest.
The multivariate analysis also showed a significant association between limited dorsiflexion of the ankle (OR 1.25; 95% CI 1.03 – 1.52) and the occurrence of substantial injuries. None of the other potential risk factors were associated with the outcome in the multivariate analysis.

Discussion

This is the first prospective cohort study investigating risk factors for lower extremity injuries among contemporary dance students. We found a one year prevalence of lower extremity injuries of 82.2%. Of these, 51.4% were substantial injuries meaning that the students were not able to participate at all or had a moderate or severe reduction in training volume or performance due to a lower extremity injury. Results of the multivariate analysis showed that students with a limited ankle dorsiflexion (OR 1.25; 95% CI 1.03 – 1.52) had a higher risk of sustaining a substantial lower extremity injury during the academic year.

The monthly prevalence of all lower extremity injuries ranged from 14.5% to 28.0% and from 4.4% to 12.2% for substantial lower extremity injuries. In contrast to our findings, a retrospective cohort study of contemporary dance students found a one year prevalence of lower extremity injuries of 64%.(8) Besides, injury prevalence in professional contemporary dancers ranged from 24% to 74% in literature.(7,9,34) Differences in reported injury prevalence may be due to differences in injury registration and associated injury definitions. Therefore, there is a need for one universal injury case definition in dance medicine.(6,35) Liederbach et al. (2012) made a first attempt for standardized testing and reporting methodology in dance medicine and science research.(36) Their recommendation is to define an injury as an anatomic tissue-level impairment diagnosed by a health care practitioner that results in full time loss of activity for one or more days beyond the day of onset. However, this time-loss definition would be inadequate if the focus is on early detection. Therefore, the OSTC Overuse Injury Questionnaire as used in the current study seems to be a good instrument for this population, in addition to the recommendation of Liederbach et al. (2012), as it registries all health problems (injuries, illness and mental health problems) with standardized questions resulting in a summary severity score providing a measure of the impact of health problems. Using this questionnaire, we found injury rates higher previously described in literature.

To our knowledge, up to now no prospective studies have been performed to determine if lower extremity kinematics (SLS) and strength (CMJ) can predict lower extremity injuries in contemporary dance students. The current study showed that limited ankle dorsiflexion was associated with a higher risk on lower extremity injuries during 9 months follow-up. None of the other potential risk factors measured with the SLS were associated with lower extremity injuries. In other sport disciplines prospective studies were performed to determine risk factors for injuries using functional tests. Bayne et al (2016) conducted a prospective injury study in cricket fast bowlers and found that an increased knee valgus angle during the single leg decline squat was associated with a higher low back injury risk during the season.(37) In elite Olympic class sailors left-sided single-leg-decline squat performance was associated with overall injury status, with better performing athletes recording fewer injuries.(38) Furthermore some cross-sectional studies have found significant associations between injury rates and SLS performances.(17,39) However, due to the cross-sectional design of these studies, conclusions on causation cannot be drawn.

The contribution of limited ankle dorsiflexion to accumulation of lower extremity injuries remains unclear from the current study. From different studies it is known, for example, that in individuals with a history of ankle sprains and/or functional ankle instability a limited ankle dorsiflexion is associated with impaired balance.(40,41) This indicates that changes in ankle motion may negatively influence dynamic postural control and may contribute to the occurrence of lower extremity injuries . To unravel the influence of limited ankle dorsiflexion on sustaining lower extremity injuries it is necessary to assess the association of ankle dorsiflexion with injuries of specific lower extremity regions (e.g. ankle, knee or hip) or with specific lower extremity injuries (e.g. ankle sprain, patellofemoral pain syndrome). More large-scale prospective studies are needed to gain insight into the association between limited ankle dorsiflexion and specific lower extremity regions/injuries.

The outcomes of the CMJ in the present study were not associated with a higher risk on lower extremity injuries. In contrast to our findings, Henry et al. (2016) found that poorer lower limb power output measured with the vertical jump was associated with an increased risk of noncontact ankle injuries among amateur soccer players.(42) Likewise, a retrospective study among police recruits found a significant correlation between vertical jump height and reported injuries.(43) The difference in outcomes between our study and these latter studies could be due a different study population (dance students vs. police recruits and soccer players) or a different outcome of interest (lower extremity injuries vs. ankle injuries and upper- and lower extremity injuries).

It is notable that students enrolled in the Bachelor Dance Teacher showed generally higher ORs, although not significant, for sustaining a lower extremity injury during the academic year compared to students enrolled in the Bachelor Dance. The fact that Dance Teacher students are possibly more susceptible for lower extremity injuries may be due to differences in the structure of the educational program and/or their physical fitness. Due to the differences in the educational program Dance Teacher students might be exposed to higher physical strain and have less time to recover from their training, rehearsals and performances. Combined with a lower physical fitness makes a Dance Teacher student at higher risk for injuries. However, in the present study the balance between exposure and recovery, and physical fitness have not been measured. To understand why these students might be at higher risk for sustaining a lower extremity injury more research is needed to get insight in the relation between exposure, recovery and physical fitness.

Strengths and limits

The major strength of the current study is the prospective study design with a monthly follow-up, resulting in low interference of recall bias. Additionally, the response rate to the monthly questionnaires was high (89% to 100%). Although it is recommended to register injuries on a weekly basis with the OSTC Overuse Injury Questionnaire, the frequency of injury registration once a month does not influence the average prevalence and severity scores.(23)

However, there are some limitations. First, because of the small sample size (N=45, 90 legs) it was not possible to adhere to the 'rule of 10' (14 potential risk factors, 31 events), resulting in overfitting of the final model.(44) This causes us to be cautious to draw firm conclusions. Second, all injuries were self-reported, which lead to a lack of detailed diagnostic information on each case. This limits us to distinguish between diagnoses of different lower extremity injuries. Third, the knee flexion of the dance students while performing the SLS was on average 120.5° to 125.2° for the non-injured and injured leg respectively. From the literature is known that a knee flexion of 75°-90° is needed to differentiate between genders.(12,45,46) Therefore, it can be expected that the relatively small knee flexion was not sufficient to show relevant discrepancies in all measured angles in order to predict lower extremity injuries. This might have influenced our study outcomes. Finally, Stensrud et al. (2011) found that 50% of the participants with poor knee control were not detected when only one test, like the SLS, would be used.(24) Poor knee control was defined as having lateral tilt of the pelvis and/or moving the knee in valgus position and/or clear medial/lateral side-to-side movements of the knee.(24) Since we may not have identified all students with poor knee control, it may have limited us in recording an association between the SLS and lower extremity injuries in this population. Combining information from several tests may improve sensitivity identifying participants with poor knee control. However, in a recent critical review of Bahr (2016) it becomes clear that there is no screening test with adequate test properties to predict sports injuries, and that evidence in support for screening injury risk is lacking.(47) Therefore, screening tests to predict and prevent dance related injuries should be developed according to the three steps proposed by Bahr (2016).(47)

Implications for future research

Although this is the first prospective cohort study investigating risk factors for lower extremity injuries among contemporary dance students, more prospective research with larger sample sizes is needed. These studies will allow us to draw stronger conclusions about risk factors for lower extremity injuries and compare different dance populations. Besides, it will enables us to identify risk factors for specific injuries. Insight in factors predicting substantial injuries enables us to enhance the prevention of dance related injuries in the future by developing preventive strategies.

Conclusion

The present study aimed to identify risk factors, i.e. lower extremity kinematics and strength for lower extremity injuries in contemporary dance students during the academic year. The results show that students with a limited ankle dorsiflexion during the SLS are at higher risk for lower extremity injuries during the academic year. Since the results of the present study are based on a small population the conclusions should be interpreted with some caution. Therefore, further research is needed in order to gain more insight in risk factors for this high risk population in order to develop preventive strategies.

Perspectives

Thus far, research to identify risk factors for lower extremity injuries by using functional tests was mainly done in other disciplines than dance.(37,38) This is the first prospective cohort study investigating risk factors for lower extremity injuries among contemporary dance students. The findings that the risk of sustaining a lower extremity injury increases if you have a limited ankle dorsiflexion provides us essential information to enhance the prevention of dance related injuries.

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Table 1: Participants characteristics. Data are presented as mean (SD) or n (%).

			Total population (N=45)
Gender (female)			28 (62.2%)
Age (years)			18.6 (1.1)
BMI (kg/m2)			20.7 (1.6)
Educational program			
		Bachelor Dance	28 (62.2%)
		Bachelor Dance Teacher	17 (37.8%)
Injury history (yes)			17 (37.8%)
Single Leg Squat			
	Knee Flexion (°)	Right leg	124.7 (9.9)
		Left leg	119.1 (8.4)
	Pelvic Tilt (°)	Right leg	2.0 (3.9)
		Left leg	0.5 (3.7)
	Lateral trunk motion (°)	Right leg	14.7 (2.3)
		Left leg	12.6 (2.2)
	Knee Valgus (°)	Right leg	176.8 (6.3)
		Left leg	178.3 (6.1)
	Dorsiflexion ankle (°)	Right leg	59.1 (4.6)
		Left leg	61.2 (5.2)
	Hip flexion (°)	Right leg	151.3 (10.7)
		Left leg	150.2 (10.6)
Countermovement jump			
		DL (cm)†	31.4 (6.8)
		Right, SL (cm)†	14.5 (3.8)
		Left, SL (cm)†	13.9 (3.8)

†missing data from three persons. DL = double leg, SL= single leg, cm= centimeters, ° = degrees.

Table 2: Univariate and multivariate models of potential risk factors for lower extremity injuries

	Non-injured (n=59 legs)	Injured (n=31 legs)	Univariate analyses OR (95% CI)	Multivariate analysis OR (95% CI)
Participant characteristics				
Age (years)	18.5 (0.97)	18.7 (1.30)	1.18 (0.67 – 2.09)	0.78 (0.44 – 1.41)
Gender (male)	18 (30.5%)	16 (51.6%)	2.43 (0.76 – 7.73)	0.56 (0.03 – 10.88)
Educational program (BA dance teacher)	17 (28.8%)	17 (54.8%)	3.00 (0.94 – 9.53)	4.96 (0.82 – 29.98)
Injury history	19 (32.2%)	15 (48.4%)	1.97 (0.63 – 6.19)	1.98 (0.36 – 11.02)
BMI (kg/m^2)	20.4 (1.65)	21.2 (1.38)	1.41 (0.95 – 2.09)	1.02 (0.68 – 1.53)
Physical tests				
Single Leg Squat				
knee flexion (°)	120.7 (9.9)	124.3 (8.6)	1.05 (0.99 – 1.10)	1.02 (0.91 – 1.14)
pelvic tilt (°)	1.1 (3.7)	1.6 (4.3)	1.03 (0.93 – 1.15)	0.99 (0.86 – 1.15)
lateral trunk motion (°)	13.6 (2.5)	13.6 (2.5)	1.02 (0.94 – 1.09)	1.07 (0.93 – 1.23)
knee valgus (°)	178.0 (6.2)	176.7 (6.3)	0.98 (0.93 – 1.03)	0.97 (0.88 – 1.06)
dorsiflexion ankle (°)	59.1 (4.6)	62.3 (5.2)	**1.11 (1.02 – 1.20)**	**1.25 (1.03 – 1.52)**
hip flexion (°)	151.7 (10.1)	148.9 (11.5)	0.99 (0.94 – 1.04)	0.99 (0.91 – 1.06)
Countermovement jump				
double leg (cm)	30.9 (6.4))¥	32.5 (7.4)‡	1.03 (0.95 – 1.13)	1.29 (0.99 – 1.68)
single leg (cm)	14.5 (3.9)¥	13.7 (3.5)‡	0.94 (0.78 – 1.12)	0.72 (0.44 – 1.16)

cm= centimeters, ° = degrees. ‡missing data from two persons (four legs) ¥ missing data from one person (two legs). In bold significant associations

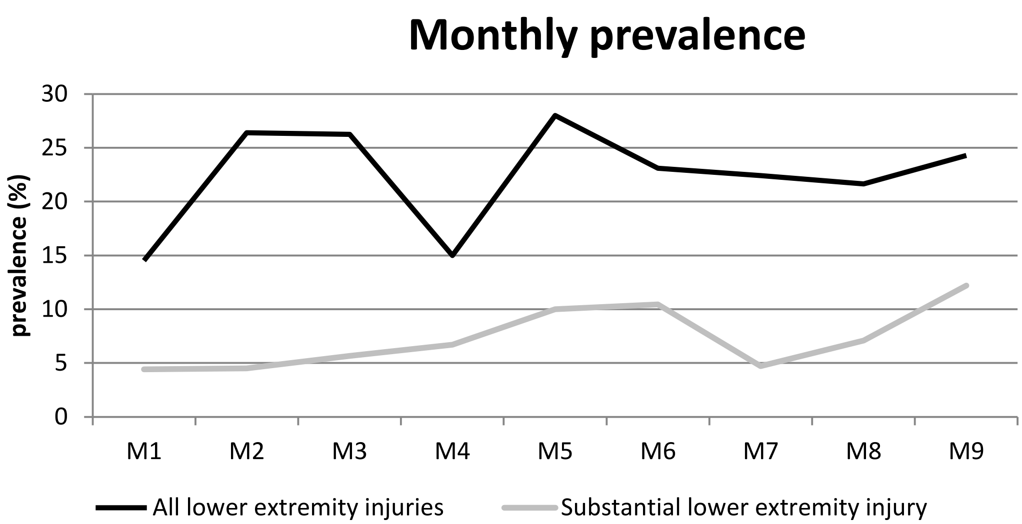

Figure 1: Monthly prevalence of all- and substantial lower extremity injuries during 9 months follow-up