Potential Predictors of Injury Among Pre-Professional Ballet and Contemporary Dancers

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Abstract

Injuries occur frequently among ballet and contemporary dancers. However, limited literature exists on injuries to pre-professional dancers in the USA. The goals of this study were to 1. provide a descriptive epidemiology of the incidence of musculoskeletal injuries in an adolescent and young adult dance population and 2. identify parsimonious regression models that could be potentially used to predict injury incidence. The study was based at the University of North Carolina School of the Arts (UNCSA) from Fall 2009 to Spring 2015. An injury was defined as any event that caused a dancer to be seen at the UNCSA Student Health Services and caused the dancer to modify or curtail dance activity for at least 1 day. Injury rate ratios (IRRs) were calculated using negative binomial generalized estimating equations. Models predicting injury rates were built using forward selection, stratified by sex. Among 480 dancers, 1,014 injuries were sustained. Most injuries were to the lower extremity and the result of overuse. There were differences in upper extremity, lower extremity, and traumatic injury rates by demographic subgroups. Among females, the most parsimonious predictive model for injury rates included a self-reported history of depression, age at time of injury, and number of injuries sustained at UNCSA prior to the semester of current injury. Among males, the most parsimonious model was a univariate model with family history of alcohol or drug problems. Strategies for traumatic injury prevention among dancers should be both sex- and style-specific. No differences were observed in overuse injury rates by sex or style, suggesting that generic overuse prevention strategies may not need to be guided by these factors. It is concluded that strategies can be implemented to reduce and mitigate the consequences of injuries if not the injuries themselves.

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Injuries from specialized athletic activities (e.g., sports and dancing) are a burden on society. Whereas injuries occur with relative frequency in the general population,[1,2] they are far more prevalent in athletes.[3-7] Over one-quarter of all emergency department visits in the USA are due to injuries.[8] Among children 18 years old or younger in the USA, lifetime costs (both medical costs and work loss costs) associated with being treated at an emergency department for an injury in 2010 were $49.9 billion.[9] Furthermore, among this same age group, 20% of all injury-related emergency department visits were sport-related.[10] In any given year, sport-related injuries account for the highest proportion of injury-related emergency department visits among those 5 to 14 and 15 to 24 years of age.[11] In addition to economic costs, the effects of injuries at a young age are both physical and mental[12] and can persist for years or appear decades later.[5,13,14]

One form of specialized and creative athletic activity is dancing, and injuries occur frequently in ballet and contemporary dancers.[15,16] Among children 3 to 19 years old, it is estimated that over 22,000 injuries related to dance (not limited to ballet and contemporary dance) are seen annually in emergency departments.[17] Previous studies focusing exclusively on ballet or contemporary dancers have found an injury incidence ranging from 0.62 to 4.7 per 1,000 hours of dance.[16,18-22]

Among pre-professional ballet dancers, this injury incidence ranges from 0.8 to 2.9 per 1,000 hours of dance.[23] By way of comparison, in elite adolescent athletes, one review article found that injury incidence ranged from 1.6 (female gymnasts) to 6.4 (female soccer players) per 1,000 hours of activity.[24] Much of the movement in dance involves the legs, and a majority of injuries to dancers are in the lower extremity.[15,19-22,25,26] Although this is true for both females and males, the distribution of anatomic injury location differs by sex.[18-22] Excelling in dance requires intensive practice, and overuse injuries, which can be defined as injuries due to repetitive microtrauma to the musculoskeletal system over time,[27] are the predominant type of injury (comprising 57% to 78% of injuries sustained).[16,18,20,22,25,28]

While many of the studies of injuries in dance already referenced here have involved ballet dancers, to date few have investigated contemporary dancers. Two such studies had populations comprised of both ballet and contemporary dancers,[29,30] and two other studies of contemporary dancers focused on either professional dancers[16] or female collegiate dance majors and minors.[31] None of these prior studies involved pre-professional male dancers studying either ballet or contemporary dance. Indeed, only three studies focused exclusively on pre-professional dancers.[19,21,25] Two of these previous studies were based in the USA: one was limited by small sample size (N = 39),[21] and the other dealt exclusively with ballet dancers.[19] The remaining study was conducted in the UK.[25] Additionally, a recent review article found that the quality of studies and consistency of evidence regarding risk factors for injury among pre-professional dancers is minimal.[32] Therefore, a better understanding of the injury incidence and predictors of injury in pre-professional dancers is clearly needed.[33]

The goals of this study were 1. to provide a descriptive epidemiology of the incidence of musculoskeletal injuries in an adolescent and young adult dance population and 2. to identify parsimonious regression models that could be potentially used to predict injury incidence. In particular, we were interested in comparing ballet to contemporary dancers, female to male dancers, and high school dancers to collegiate dancers. Based on prior literature,[20,29,34] we hypothesize that: 1. contemporary dancers would have a decreased incidence of lower extremity and increased incidence of upper extremity injuries compared to ballet dancers; 2. male dancers would have more upper extremity injuries than female dancers; 3. there would be no difference in lower extremity injury incidence by sex; and 4. there would be no difference in injury distribution when comparing high school dancers to college dancers. We also hypothesize that predictors for dance injury differ by sex and, therefore, built parsimonious predictive models separately for males and females.

Methods

We selected the School of Dance at the University of North Carolina School of the Arts (UNCSA) as our study population because it provides instruction to a diverse group of dance students that includes all the key demographics listed above. Additionally, UNCSA provides on-site health care services to its dancer students and records all health care encounters using a centralized electronic health record (EHR) system. The closed nature and near complete follow-up of this population facilitate the historical reconstruction of a cohort study with clinically verified incident injuries as the endpoint of interest.

Study Design and Subjects

We retrospectively reviewed EHRs of dancers to create a historical cohort with the study outcome of interest as incident injury. The study population was composed of dancers who began enrollment at the UNCSA School of Dance during or after Fall 2009; dancers' EHRs were reviewed through the end of their studies at UNCSA or Spring 2015, whichever came first. The UNCSA dance program trains both high school and college students in either ballet or contemporary dance. Most high school and college students (at least three-quarters) live on campus at UNCSA. On average, the weekly amount of dance students engaged in was 15 to 20 hours, including classes (e.g., technique, composition, and repertory), rehearsals, and performances. Approximately three-quarters of the students of this program move on to become professional dancers.

Outcome Identification

The outcome of interest, incident injury, was ascertained through detailed review of UNCSA EHRs. An incident injury was defined as any event that required care from UNCSA clinicians and limited dance activity for at least 1 day. We only included injuries resulting from dance-related activities (e.g., injuries due to motor vehicle crashes were excluded, even if an involved dancer had to limit dance activity for at least 1 day). Data on potential predictors of injury were obtained from anthropometric assessments and a self-administered health history form that included mental health history, risk-taking behavior, and injury history. Both anthropometric assessments and health history form data were obtained at time of entry to UNCSA.

Incident injuries were identified through a detailed review of the UNCSA Student Health Services (SHS) EHR system. UNCSA SHS is the location on-campus where all students receive clinical care. Clinical records from off-campus locations were not available for this study. Clinicians with services available to the dance students at UNCSA SHS include certified athletic trainers, a nutritionist, a physical therapist, a nurse practitioner, a physician assistant, a certified medical assistant, and a physician. The EHR is the SHS's primary clinical record and provides the unified documentation of all care provided to UNCSA students by SHS clinicians.

Injuries were characterized in a number of ways: by body part (e.g., ankle, back, and knee), diagnosis (e.g., strain, sprain, and tendinitis), and type (traumatic versus overuse). A traumatic injury was defined as one resulting from a specific event, and an overuse injury was defined as described above. The classification of traumatic or overuse was determined by one investigator (RKY) and based on event information available in the EHR. A second investigator (YMG) also coded whether an injury was overuse or traumatic for a 5% sample of the overall injuries recorded. An intraclass correlation coefficient (ICC), assuming that the two investigators represented a random sample of a potential population of raters, was calculated.[35] Overall, there was agreement on the classification of overuse for 49 out of 51 (96%) of the injuries. The ICC was 0.93, meaning that 93% of the variance in the classification of overuse was due to within-rater variation (as opposed to between-rater variation). The start date of an injury was defined as the first day a dancer was seen at the UNCSA SHS for initial care of that injury. The end date of an injury was defined as either 1. the first day that one of the medical providers noted in the EHR that the dancer could either perform dance activity to tolerance or was cleared for dance activity, or 2. the last day a dancer was seen by UNCSA SHS clinical staff for care of the injury, whichever came first.

Person-Time

Injury rates were calculated using person-days as the denominator. Person-days of enrollment at UNCSA were calculated based on the length of academic terms at UNCSA. A person-day was one on which a dancer was academically enrolled at UNCSA, regardless of whether any dance activities occurred on that day. The last academic term that a student was observed was determined by the last date on which he or she had an entry in UNCSA's EHR system. A student stopped accumulating time at-risk when an injury occurred and started accumulating time at-risk again once the injury resolved. For students who did not graduate, it was not possible to obtain their exact withdrawal date during the semester from UNCSA. Therefore, it was assumed that the student was enrolled at UNCSA for the entire duration of the last academic term. The dance style (ballet or contemporary) for each student for the duration of her or his enrollment was defined as each dancer's dominant style at the time of matriculation to UNCSA. Based on clinicians' notes in the EHRs where dance style is mentioned, we estimate that less than 5% of dancers changed styles during their studies at UNCSA. A student who enrolled in both the high school and college programs was counted as two separate, independent entities for the purposes of analysis.

Covariates

Prior studies of general populations have found possible correlations between injury and anthropometric measures,[36-39] mental health history,[40,41] history of risk taking behaviors,[42,43] and prior history of injuries.[44-47] For our study, data on potential predictors of injury were obtained from two sources: a pre-matriculation student health questionnaire and anthropometric assessments conducted by the UNCSA SHS at time of matriculation.

Anthropometric Covariates

Anthropometric measures included BMI and body fat percentage (BF%). Measurements to calculate BMI and BF% were collected by UNCSA SHS staff when each dancer enrolled at UNCSA. Multiple UNCSA SHS staff members collected this information, and each dancer was only assessed one time for both BF% and BMI. BF% was calculated from skinfold caliper measurements using the Sloan body density (BD) equations by sex and Siri BF% equation.[48,49] BMI and BF% were routinely calculated and recorded from Fall 2009 to Spring 2013. Beginning in Fall 2013 routine collection of BMI and BF% at UNCSA ended.

Other Covariates

All remaining measures were derived from self-reported information provided by the students using a standardized health questionnaire prior to enrollment at UNCSA. The questionnaire was used by UNCSA SHS for administrative purposes and included measures of mental health history, risk-taking behavior, and injury history. Mental health history included family history of alcohol or drug problems; family history of psychiatric illness; family history of suicide; self-reported history of depression; self-reported history of excessive worry, anxiety, or obsession; and self-reported history of treatment for attention-deficit disorder or attention deficit hyperactivity disorder. History of risk taking behaviors included history of alcohol use, illegal drug use, smoking, and not wearing a seat belt. Prior history of injury included concussion, frequent or severe headache, dizziness or fainting spells, severe head injury, knee problems, recurrent back pain, neck or back injury, and history of broken bones.

To account for possible variations in injury rate by time, two variables were parameterized as time-varying covariates: age and history of injury while at UNCSA. Age was defined as age at the beginning of the semester. History of injury was conceptualized in two ways: 1. as a dichotomous variable indicating whether a student was injured during their previous semester at UNCSA and 2. as a variable accounting for cumulative number of injuries for all prior semesters at UNCSA. Each dancer had one observation per semester they were enrolled at UNCSA.

Data Analysis

Institutional Review Board (IRB) approval was obtained from the IRBs at University of North Carolina at Chapel Hill and Winston-Salem State University. IRB determined that this study was exempt from obtaining informed consent. Incidence rate ratios (IRRs), p-values, and 95% confidence intervals (CIs) were calculated for all potential predictors. All results were considered statistically significant at $p < 0.05$.

The rate of incident injury was the outcome measure of interest. Exploratory analysis indicated that the effects of BF% and BMI were best specified as categorical parameters in models. Negative binomial (NB) regression was used to generate IRRs and 95% CIs. Robust standard errors, estimated using generalized estimating equations (GEE), were used to account for the fact that one student could contribute multiple injuries over the period of follow-up. Model fit was assessed using standard metrics of overdispersion (chi-square divided by degrees of freedom), Quasi-Akaike information criterion (QICu) scores, and through comparisons to Poisson models. An a priori decision was made to stratify all models by sex because the requirements in dance vary by sex.

Models predicting injury rates were built using forward selection. To build multivariable models, categorical variables were eligible for inclusion if 1. the univariate distribution had at least five observations in each category for the sex being modeled and 2. the crude model resulted in an estimate with $p < 0.25$. The most parsimonious predictive model for each sex was that with the lowest QICu score. For the time-varying covariates of age and history of injury at UNCSA, variables were parameterized both as continuous and categorical variables in all steps to determine which was the best fit for the models.

Results

There were 480 dancers at UNCSA who began enrollment during or after Fall 2009 and were followed up through either the end of their studies at UNCSA or Spring 2015. Accumulatively, the dancers were followed for 232,489 person-days with 208,714 person-days at-risk for sustaining an injury (dancers did not contribute time-at-risk while injured). There were 371 (77%) female dancers, 311 (65%) ballet dancers, and 289 (60%) high school dancers (Table 1).

Injury Distribution

There were 1,084 injuries observed in the cohort during the study, of which 1,014 (93.5%) were dance-related. For the remainder of this Results section, analyses are limited to only the dance-related injuries, and the term "injury" is used to refer specifically to dance-related injuries. Out of 480 dancers, 118 (24.6%) sustained no in-

Table 1 Characteristics of Dancers, University of North Carolina School of the Arts, Fall 2009-Spring 2015*

	Total	Female	Male
TOTAL	480 (100%)	371 (77%)	109 (23%)
Program			
High school	289 (60%)	242 (65%)	47 (43%)
College	188 (39%)	129 (35%)	59 (54%)
Unknown	3 (1%)	0 (0%)	3 (3%)
Style			
Ballet	311 (65%)	249 (67%)	62 (57%)
Contemporary	164 (34%)	119 (32%)	45 (41%)
Unknown	5 (1%)	3 (1%)	2 (2%)
Number of injuries (N missing = 0)	2.1 (2.2)	2.1 (2.3)	2.3 (2.2)
Body mass index (N missing = 175)	20.0 (2.2)	19.4 (2.0)	21.7 (2.1)
Body fat percentage (N missing = 175)	16.8 (5.0)	18.9 (3.1)	9.7 (3.3)
Distribution of select self-reported measures (N missing = 37)			
Family history of alcohol or drug problems (yes)	41 (9%)	29 (8%)	12 (12%)
Family history of psychiatric illness (yes)	33 (7%)	26 (8%)	7 (7%)
Family history of suicide (yes)	10 (2%)	9 (3%)	1 (1%)
History of depression (yes)	12 (3%)	10 (3%)	2 (2%)
History of excessive worry, anxiety, or obsession (yes)	18 (4%)	14 (4%)	4 (4%)
History of treatment for ADD or ADHD (yes)	31 (7%)	17 (5%)	14 (14%)
History of concussion (yes)	13 (3%)	10 (3%)	3 (3%)
History of frequent or severe headache (yes)	30 (7%)	24 (7%)	6 (6%)
History of knee problems (yes)	32 (7%)	25 (7%)	7 (7%)
History of recurrent back pain (yes)	17 (4%)	12 (3%)	5 (5%)
History of back injury (yes)	7 (2%)	6 (2%)	1 (1%)
History of broken bone (yes)	89 (20%)	67 (20%)	22 (22%)
History of alcohol use (yes)	7 (2%)	2 (1%)	5 (5%)

*Numbers displayed as N (%) or mean (SD).

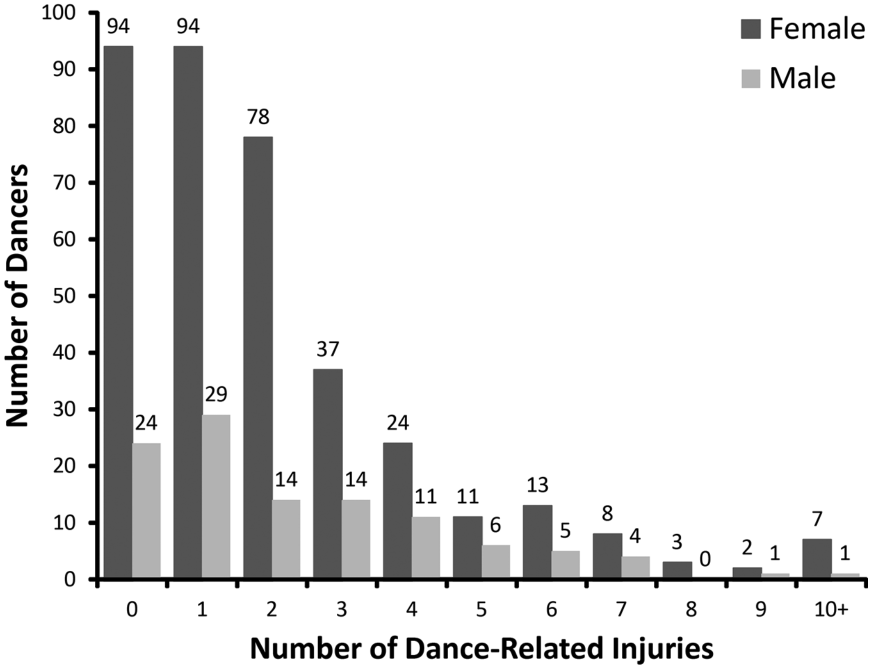

Figure 1 Distribution of number of dance-related injuries by sex, University of North Carolina School of the Arts, Fall 2009 to Spring 2015.

juries, and 123 (25.6%) sustained one injury (Fig. 1). The maximum number of injuries sustained by a UNCSA dancer was 15 (this dancer was followed for 2.6 years in our study). Out of the 1,014 injuries, the five leading diagnosis categories were general complaints of a non-specific nature (e.g., pain, disorder, injury: 38.6%), tendon-related conditions (i.e., tendinitis, tenosynovitis, enthesopathy: 15.5%), strains (12.7%), sprains (10.2%), and various syndromes (5.9%). Most injuries (79.5%) were to the general region of the lower extremity. The five specific body locations that were injured most frequently were the ankle (24.2%), foot or toe (19.5%), hip or thigh (15.4%), back (13.5%), and knee (13.0%). Most injuries (67.9%) were due to overuse (Table 2).

Injury Rates

The overall injury rate was 4.86 per 1,000 dancer-days. Injury rate did not differ by sex (male versus female IRR: 1.06; 95% CI: 0.87, 1.29), program (college versus high school IRR: 0.96; 95% CI: 0.81, 1.13), or dance style (contemporary versus ballet IRR: 0.97; 95% CI: 0.82, 1.16). There were variations in injury rate by age at time of injury. Similarly, the incidence of overuse injury did not differ by sex, program, or style, but there were variations of overuse injury rate by age at time of injury. Although the overall and overuse rates did not differ by sex, dance style, or program, there were differences in incidence of specific injuries by these three characteristics.

Hypotheses 1, 2, and 3 Results

Contemporary dancers had a lower rate of lower extremity injuries than ballet dancers (IRR: 0.81; 95% CI: 0.67, 0.97), and the rate of upper extremity injuries was higher in contemporary dancers compared to ballet dancers (IRR: 2.14; 95% CI: 1.07, 4.28). Male dancers had more upper extremity injuries than female dancers (IRR: 2.58; 95% CI: 1.31, 5.11), but the rate of lower extremity injuries did not differ by sex (IRR: 0.93; 95% CI: 0.76, 1.15; reference = female).

Hypothesis 4 Results

Similar results were found for the comparison of college to high school dancers. Upper extremity injury rates were higher in college students than high school students (IRR: 2.63; 95% CI: 1.29, 5.35), but their lower extremity injury rates were similar (IRR: 0.88; 95% CI: 0.74, 1.05; reference = high school). Among high school students, ballet and contemporary dancers had approximately the same upper extremity injury rate (0.10 and 0.09 per 1,000 person-days, respectively), whereas contemporary dancers had higher injury rates than ballet dancers among college students (0.32 and 0.18 per 1,000 person-days, respectively). Furthermore, male dancers had more traumatic injuries than female dancers (IRR: 1.54; 95% CI: 1.20, 1.98), and college students had more traumatic injuries than high school dancers (IRR: 1.41; 95% CI: 1.10, 1.98), (Table 3).

Female Predictive Models

Among females, model building using forward selection and QICu scores alone indicated that the best predictive model (QICu = 996.2) for injury rates included a self-reported history of depression (IRR: 1.65; 95% CI: 1.18, 2.31), age at time of injury (16 to 17 IRR: 0.89; 95% CI: 0.69, 1.14; 18 to 19 IRR: 0.88; 95% CI: 0.63, 1.24; 21 or older IRR: 0.69; 95% CI: 0.42, 1.14: reference = 15 or younger), number of injuries sustained at UNCSA prior to the semester of current injury (1 injury IRR: 1.18; 95% CI: 0.90, 1.55; 2 injuries IRR: 1.00; 95% CI: 0.72, 1.38; 3 or more injuries IRR: 0.77; 95% CI: 0.53, 1.13: reference = 0 injuries), BMI (18.5 to < 20 IRR: 1.02; 95% CI: 0.70, 1.49; 20 or higher: 1.28; 95% CI: 0.94, 1.74: reference = < 18.5), dance style (IRR: 0.83; 95% CI: 0.61, 1.13: reference = ballet), and self-reported history of back pain (IRR: 1.22; 95% CI: 0.83, 1.80). However, 136 of 371 females were missing anthropometric measures (i.e., BF% and BMI). Those who were missing these measures were significantly more likely to be in college ($p < 0.001$) and were marginally more likely to have a family history of suicide ($p = 0.09$). Therefore, if forward selection ended without selection of anthropometric measures, the most economical model (QICu = 1,394.2) included a self-reported

Table 2 Distribution of Dance-Related Injuries, University of North Carolina School of the Arts, Fall 2009-Spring 2015*

	Total	Female	Male
Total number of injuries	1014 (100%)	764 (75.3%)	250 (24.7%)
Diagnosis			
General complaints	391 (38.6%)	294 (38.5%)	97 (38.8%)
Syndromes	60 (5.9%)	48 (6.3%)	12 (4.8%)
Tendon-related conditions	157 (15.5%)	125 (16.4%)	32 (12.8%)
Other inflammation or swelling	32 (3.2%)	25 (3.3%)	7 (2.8%)
Sprains	103 (10.2%)	70 (9.2%)	33 (13.2%)
Cramps or spasms	30 (3.0%)	21 (2.7%)	9 (3.6%)
Shin splints	27 (2.7%)	25 (3.3%)	2 (0.8%)
Stress injuries	29 (2.9%)	25 (3.3%)	4 (1.6%)
Head injuries	9 (0.9%)	9 (1.2%)	0 (0%)
Contusions	18 (1.8%)	12 (1.6%)	6 (2.4%)
Strains	129 (12.7%)	88 (11.5%)	41 (16.4%)
Fractures	5 (0.5%)	3 (0.4%)	2 (0.8%)
Other injuries	24 (2.4%)	19 (2.5%)	5 (2.0%)
Body part			
Foot or toe	198 (19.5%)	167 (21.9%)	31 (12.4%)
Ankle	245 (24.2%)	187 (24.5%)	58 (23.2%)
Lower leg	75 (7.4%)	60 (7.9%)	15 (6.0%)
Knee	132 (13.0%)	93 (12.1%)	39 (15.6%)
Hip or thigh	156 (15.4%)	120 (15.7%)	36 (14.4%)
Back	137 (13.5%)	91 (11.9%)	46 (18.4%)
Arm	7 (0.7%)	3 (0.4%)	4 (1.6%)
Hand or wrist	6 (0.6%)	4 (0.5%)	2 (0.8%)
Shoulder	23 (2.3%)	13 (1.7%)	10 (4.0%)
Neck	11 (1.1%)	6 (0.8%)	5 (2.0%)
Head	11 (1.1%)	10 (1.3%)	1 (0.4%)
Trunk or abdomen	13 (1.3%)	10 (1.3%)	3 (1.2%)
Overuse injury			
Yes	689 (67.9%)	542 (70.9%)	147 (58.8%)
No	312 (30.8%)	212 (27.7%)	100 (40.0%)
Unknown	13 (1.3%)	10 (1.3%)	3 (1.2%)

*Numbers displayed as N (%).

history of depression (IRR: 1.76; 95% CI: 1.29, 2.39), age at time of injury (16 to 17 IRR: 0.91; 95% CI: 0.73, 1.14; 18 to 19 IRR: 0.81; 95% CI: 0.62, 1.07; 21 or older IRR: 0.62; 95% CI: 0.40, 0.96: reference = 15 or younger), number of injuries sustained at UNCSA prior to the semester of current injury (1 injury IRR: 1.11; 95% CI: 0.88, 1.42; 2 injuries IRR: 0.98; 95% CI: 0.72, 1.32; 3 or more injuries IRR: 0.77; 95% CI: 0.91, 1.17: reference = 0 injuries).

Male Predictive Models

Among males, the best predictive model (based on QICu scores) was a univariate model (QICu = 416.2) with family history of alcohol or drug problems (IRR: 1.36; 95% CI: 0.84, 2.21). However, among males, self-reported measures for family history of suicide, history of back injury, and history of illegal drug use were all statistically significant in univariate models but were not considered for multivariable models as fewer than five males acknowledged having a history of any one of these conditions. Additionally, neither of the time-varying covariates (i.e., age, history of injury at UNCSA) were predictors of injury rate.

Discussion

Overuse Injuries

This study found (not surprisingly) that the majority of injuries to dancers were due to overuse, and there were no differences in overuse injury rate by sex, program, or style. Because of limitations with this study (i.e., small number of males; one institution), studies in other populations are needed to determine whether strategies to reduce overuse injuries potentially can be applied to all groups of ballet and contemporary dancers and do not need to be targeted by subgroup as our results suggest. Although traumatic injuries accounted for less than one-third of injuries in our population, differences in traumatic injury rates were found by sex and dance style. These differences suggest that injury prevention strategies for traumatic injuries *do* need to be targeted by subgroup.

One possible method of reducing the injury incidence among dancers is to reduce the amount of repetition of extreme movements in which a dancer engages.[50] Although no studies have as yet investigated whether purposefully limiting the amount of select extreme movements in all dancers would result in decreases in population injury rates, this approach may be promising. Such a limitation would be analogous to limiting the pitch count in baseball, where it has been shown that throwing excessive pitches is associated with both elbow and shoulder pain.[51] However, implementing such a strategy to limit movements in dance would unquestionably face more barriers than doing so in competitive sports. In sports, objective results exist, where there are winners and losers after a competitive event. In dance, on the other hand, the purpose of training and rehearsals is to deliver an exemplary performance; an objective goal such as defeating a competitor does not exist. Without an objective barometer to draw on, leaders in the dance medicine and science world

Table 3 Injury Rates* and IRRs, University of North Carolina School of the Arts, Fall 2009-Spring 2015

	All Injuries		Upper Extremity Injuries		Lower Extremity Injuries		Overuse Injuries		Traumatic Injuries	
	Crude Rate	IRR (95% CI)	Crude Rate	IRR (95% CI)	Crude Rate	IRR (95% CI)	Crude Rate	IRR (95% CI)	Crude Rate	IRR (95% CI)
Overall	4.86		0.17		3.84		3.22		1.47	
Sex										
Female	4.75	ref	0.12	ref	3.87	ref	3.35	ref	1.30	ref
Male	5.21	1.06 (0.87, 1.29)	0.33	2.58 (1.31, 5.11)	3.73	0.93 (0.76, 1.15)	3.03	0.92 (0.73, 1.16)	2.04	1.54 (1.20, 1.98)
Program										
High School	4.81	ref	0.10	ref	3.98	ref	3.43	ref	1.22	ref
College	4.92	0.96 (0.81, 1.13)	0.27	2.63 (1.29, 5.35)	3.65	0.88 (0.74, 1.05)	3.05	0.87 (0.72, 1.05)	1.79	1.41 (1.10, 1.81)
Style										
Ballet	4.96	ref	0.12	ref	4.15	ref	3.39	ref	1.37	ref
Contemporary	4.71	0.97 (0.82, 1.16)	0.26	2.14 (1.07, 4.28)	3.32	0.81 (0.67, 0.97)	3.00	0.89 (0.73, 1.09)	1.62	1.19 (0.92, 1.67)
Age (at time of injury)										
12-14	4.54	1.06 (0.82, 1.39)	0.00	NE	4.11	1.22 (0.93, 1.60)	3.46	1.23 (0.92, 1.65)	1.05	0.73 (0.45, 1.19)
15-16	5.45	1.24 (1.04, 1.49)	0.13	NE	4.57	1.32 (1.09, 1.61)	3.96	1.39 (1.14, 1.70)	1.27	0.89 (0.64, 1.25)
17-18	4.36	ref	0.12	ref	3.43	ref	2.80	ref	1.46	ref
19-20	5.20	1.05 (0.85, 1.30)	0.28	NE	3.69	0.95 (0.75, 1.21)	3.22	1.09 (0.84, 1.40)	1.92	1.22 (0.88, 1.70)
21-25	4.30	0.84 (0.59, 1.20)	0.44	NE	3.01	0.73 (0.48, 1.09)	2.67	0.82 (0.53, 1.26)	1.60	1.05 (0.69, 1.62)

*Injury rate per 1,000 person-days. Abbreviations: CI = confidence interval, IRR = incidence rate ratio, NE = no estimate, ref = reference.

may need to develop strategies to deliver the message that limiting the repetition of extreme movements in training and possibly rehearsal is beneficial for the long-term health and longevity of dancers. Coaching strategies for increasing awareness of the mechanisms involved in overuse injuries may have applicability for this problem.

Injury Rates

The overall injury rate in the present study was 4.86 per 1,000 person-days. Our study is believed to be the first to use person-days as the denominator for calculating injury incidence rates; therefore, direct comparisons cannot be made with prior studies investigating dance injury rates. As hypothesized, ballet dancers had a higher incidence of lower extremity injuries and decreased incidence of upper extremity injuries relative to contemporary dancers. Furthermore, male dancers had a higher upper extremity injury incidence rate than female dancers, while there were no differences in lower extremity injury incidence rate by sex. Previous studies have also reported differences in injury location when comparing across dance genres.[29,34] These differences no doubt relate to the prevalence of movement types used across dance styles and between the sexes. For example, women lift other dancers in contemporary dance but usually not in ballet.[31] Also, in ballet only females dance en pointe, where the dancer is in full equinus position on the foot while in full ankle plantar flexion,[22,28,52] and it is mostly males who perform lifting movements and execute high jumps.[22,27]

One finding that ran counter to one of our hypotheses was our result that upper extremity injury rates were higher in college students than high school students (IRR: 2.63, 95% CI: 1.29, 5.35). Prior studies making direct comparisons between middle school and high school and university-aged dancers have not observed any difference in injury incidence.[20] The probable reason for this finding is that the majority of college dancers train in contemporary dance, whereas the majority of high school students train in ballet; hence, the disparity in upper extremity injury rate is likely a reflection of differences by dance style rather than program. Among high school students, injury rates were similar across styles, but the rates were somewhat higher in contemporary dancers than ballet dancers. However, these results need to be interpreted with caution as there were only 36 upper extremity injuries observed in our cohort, and the differences in rates could be due to random variability.

Multivariable Modeling

Using multivariable modeling, we found that the best predictive model (based on the low QICu score) for females was a self-reported history of depression, age at time of injury, number of injuries sustained at UNCSA prior to the current semester, BMI, dance style, and history of back pain. However, since those with missing BMI measures were significantly more likely to be in college and marginally more likely to have a family history of suicide, the best predictive model for this population was based on a sample of female dancers, not representative of all female dancers at UNCSA. The model with the lowest QICu score based on a sample most representative of female dancers at UNCSA included only self-reported history of depression, age at time of injury, and number of injuries sustained at UNCSA prior to the current semester. The key finding, regardless of which model was used, is that a history of depression was significantly associated with increased injury rates among females. Unlike the present study, where self-reported history of depression was ascertained prior to all injuries sustained at UNCSA, previous studies investigating the correlation of depression and injuries in sports have focused on depression after injuries, and to our knowledge, only one study has looked at all injuries (as opposed to focusing on concussions).[37] One possible reason for the relationship between history of depression and increased injury rate is that depression is associated with insufficient sleep,[53-55] and insufficient sleep may not allow for an athlete's body to recover adequately from stresses imposed on it by everyday training loads.[51] Sleep deprivation can also lead to deleterious effects seen in sports, including increased fatigue and decreased decision-making capabilities.[56] Therefore, it is possible that the UNCSA dancers who reported a history of depression experienced inadequate quantities of sleep, and their bodies could not recover fully from training load stresses, thus leading to increased injury. Further research should be done to confirm our finding of self-reported history of depression as a predictor of dance-related injury and to explore whether insufficient sleep is generally associated with injuries. Specifically, research should be conducted to determine whether insufficient sleep may lead to increased injury incidence and whether this possible association exists independent of a history of depression.

Among males, there was no multivariable model that better predicted injury rates than the best univariate model with a family history of alcohol or drug problems. Although, to the best of our knowledge, the present study is one of the largest studies of male dancers in ballet or contemporary dance, it is possible that we were limited in our power to detect characteristics that could be predictive of injury rates. One prior study of ballet dancers involved 179 males,[20] and the remaining studies vary from 4 to 86 males[25,57] (mean: 33.9; standard deviation: 25.7). None of our study's results are directly comparable with those from the previous studies.

In interpreting our models, it is important to note that self-reported health history, though routinely collected by academic institutions for administrative purposes,[58] may have limited utility in predicting injury rates. Nevertheless, our findings demonstrate that several factors—history of depression and family history of alcohol or drug problems—do have predictive capacity, suggesting that health care forms could gather these data to possibly help predict those dancers most at risk for sustaining specific injuries and implement strategies for injury prevention. Forms could also be improved to collect additional data to refine our predictive models for injury. For example, detailed information on history of dance training (e.g., primary dance style, years of dance experience, average number of hours of dance per week in the past year) could be of vital importance. Furthermore, educational efforts could be targeted toward dancers with either a history of injury or a family history of alcohol or drug problems to inform them of the increased risk of injury and provide guidelines on how to reduce and prevent injuries.

Strengths

This is one of the largest studies to date of dance injury with 480 dancers enrolled. Prior studies investigating injury incidence or prevalence among dancers have typically enrolled fewer than 200 dancers (range: 22 to 476 dancers).[15,16,18-22,25,28-30] The construction of a historical cohort study allows for injury incidence to be calculated; some studies in the past have been limited by using designs (e.g., case-control and case-series designs) that do not allow for a measure of occurrence (such as incidence or prevalence) to be calculated. We also limited the likelihood that loss-to-follow-up biased our results by only including dancers we could observe from the beginning of their enrollment at UNCSA. One previous study found that dancers who drop out of a program early have been found to sustain more injuries, have uncommon biomechanics, and an atypical psychological profile.[59]

All data for this study already existed in administrative records (i.e., EHRs). Therefore, we were able to construct a historical cohort study with outcome and covariate measures from pre-existing information at a fraction of the cost of typical prospective cohort studies. Records from off-campus locations were not available for this study, but treatment for injuries at UNCSA SHS is available to all UNCSA students as they are required to carry health insurance, thus limiting the likelihood that dancers would seek treatment for an injury outside of UNCSA without the knowledge of UNCSA SHS. Furthermore, most injuries to the dancers occurred while on-campus, further limiting the likelihood of a dancer seeking treatment without the knowledge of UNCSA SHS.

Limitations

This study also had limitations. We used person-days to calculate injury rates. More precise exposure information regarding exact number of hours spent dancing would have been helpful for comparing results to findings from prior studies and for minimizing potential misclassification of exposure information across demographic subgroups. Additionally, since students' attendance records were not available for this study, we assumed that dancers were enrolled for the entire duration of any given academic term, whereas some students likely dropped-out of UNCSA during the academic year.

Because this study was limited to pre-existing data sources, certain known risk factors for dance injury, such as biomechanics[60,61] and extrinsic risk factors (e.g., dance surface or type of footwear worn at time of injury),[62,63] were not addressed. Our definition of overuse was not validated by clinical examination: previous research suggests that it is difficult to implement a consistent operational definition of overuse in projects not specifically designed to address overuse injuries.[64]

The distribution of dancers missing anthropometric measurements was not random. Among female dancers, those missing anthropometric measurements were significantly more likely to be college dancers and were marginally more likely to have a family history of suicide. Therefore, the final multivariable model selected for this study did not include anthropometric measurements as inclusion of those measures could bias our results.

Despite our large sample size, the relatively small number of males (N = 109) limited our ability to develop predictive models stratified by sex. Also, we were unable to build parsimonious predictive models for specific types of injury as we did not observe a sufficiently large number of injuries to be powered to do so. Finally, this study occurred at one academic institution, so the results may not be generalizable to other institutions or other levels of dance (e.g., professional dance).

Conclusions

Despite its limitations, valuable information can be gleaned from this study. Strategies for traumatic injury prevention among dancers should be both sex- and style-specific as injury rates for specific body regions differ. We observed no differences in overuse injury rates by sex and style, suggesting that generic overuse prevention strategies may not need to be guided by these factors. One method could be to limit the volume of extreme movements in dance training and rehearsal, though research needs to be conducted to determine if such a strategy in practice would reduce the burden of injury. Furthermore, as the majority of injuries result from overuse, health care practitioners could educate dancers to the fact that adequate rest and recovery are necessary for optimizing artistic performance. Injuries are an issue that affects the health and well-being of dancers, but strategies can be implemented to reduce and mitigate the consequences of injuries, if not the injuries themselves.

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