INJURIES AND POSSIBLE DISORDERED EATING AMONG ELITE PRE-PROFESSIONAL BALLET AND CONTEMPORARY DANCERS

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ABSTRACT

Rebecca Kay-yun Yau: Injuries and Possible Disordered Eating Among Elite Pre-professional Ballet and Contemporary Dancers
(Under the direction of Stephen W. Marshall)

Injuries and eating disorders (EDs) are two of the most common health-related issues among ballet and contemporary dancers. Limited literature exists on injuries and EDs to pre-professional dancers, and prior literature has been constrained by methodological shortcomings. This dissertation examined injury incidence, injury predictors, possible disordered eating (PDE) prevalence, and PDE predictors in an adolescent/young dance population. Injury incidence rate ratios (IRRs) and PDE prevalence ratios (PRs) were estimated using negative binomial generalized estimating equations and log binomial regression, respectively. Among 480 dancers, 1,014 injuries were sustained. Most injuries were to the lower extremity and were overuse injuries. There were differences in upper extremity, lower extremity, and traumatic injury rates by demographic subgroups. Among females, the best predictive model for injury rates included history of depression (IRR: 1.76; 95%CI: 1.29, 2.39), age (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 prior injuries (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). Among males, the best predictive univariate model was better than any multivariable model. Overall PDE prevalence was 19% (23% and 6% among females and males, respectively). The best predictive model for PDE among females included body mass index (BMI 18.5-<20- PR: 0.42; 95%CI: 0.20, 0.85 /BMI ≥20- PR: 0.6; 95%CI: 0.36, 1.00; reference= <18.5) and a history of irregular menstrual periods (HIMP, PR: 1.58; 95%CI: 0.96, 2.61). Strategies for traumatic injury prevention among dancers should be both gender- and style-specific. No differences were observed in overuse injury rates by gender and style, suggesting that generic overuse prevention strategies may not need to be targeted by gender and style. HIMP and lower BMI were in the best predictive model for PDE among females. No predictors were

identified among males. Strategies can be implemented to reduce and mitigate the consequences of these injuries, if not the injuries themselves. Future studies could identify other predictors of PDE among both female and male dancers.

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TABLE OF CONTENTS

LIST OF TABLES……………………………………………………………………………………… xi

LIST OF FIGURES……………………………………………………………………………………xii

LIST OF ABBREVIATIONS…………………………………………………………………………… xiii

CHAPTER 1: INTRODUCTION…………………………………………………………………………1

CHAPTER 2: REVIEW OF THE LITERATURE……………………………………………………….3

2.1 Overview…………………………………………………………………………………….......3

2.1.1 Injury incidence………………………………………………………………………….... 4

2.1.2 Distribution of Injuries…………………………………………………………………………6

2.1.3 Overuse injuries…………………………………………………………………………….. 7

2.2 Eating disorders………………………………………………………………………………… 8

2.2.1 Prevalence…………………………………………………………………………………...9

2.2.2 Screening Tools…………………………………………………………………………….. 9

2.3 Significance…………………………………………………………………………………...14

CHAPTER 3: STATEMENT OF SPECIFIC AIMS…………………………………………………… 16

CHAPTER 4: METHODS……………………………………………………………………………..18

4.1 Study population…………………………………………………………………………….. 18

4.2 Study design……………………………………………………………………………………18

4.3 Data……………………………………………………………………………………………18

4.4 Identification of study cohort………………………………………………………………….. 19

4.5 Outcome variables……………………………………………………………………………...20

4.5.1 Injury……………………………………………………………………………………... 20

4.5.2 Possible disordered eating…………………………………………………………………..20

4.6 Explanatory variables…………………………………………………………………………..21

4.6.1 Physical characteristics………………………………………………………………………22

4.6.2 Mental health history…………………………………………………………………………… 22

4.6.3 History of risk-taking behaviors……………………………………………………………….. 23

4.6.4 Prior history of injuries……………………………………………………………………………. 23

4.7 Person-time…………………………………………………………………………………………….. 23

4.8 Data analysis…………………………………………………………………………………………… 24

4.9 Variable selection for multivariable models…………………………………………………….25

CHAPTER 5: INJURY RESULTS (PAPER 1)………………………………………………………...29

5.1 Background…………………………………………………………………………………………….. 29

5.2 Methods………………………………………………………………………………………………….30

5.2.1 Incident injuries…………………………………………………………………………………… 31

5.2.2 Time at risk………………………………………………………………………………………… 32

5.2.3 Predictors of injury…………………………………………………………………………………32

5.3 Data analysis…………………………………………………………………………………………… 33

5.4 Results………………………………………………………………………………………………….. 34

5.4.1 Injury counts……………………………………………………………………………………….. 34

5.4.2 Injury rates…………………………………………………………………………………………. 35

5.4.3 Multivariable modeling…………………………………………………………………………… 35

5.5 Discussion……………………………………………………………………………………………….36

5.5.1 Multivariable modeling…………………………………………………………………………… 37

5.5.2 Injury prevention strategies……………………………………………………………………….39

5.5.3 Strengths and limitations………………………………………………………………………… 40

5.5.4 Conclusions………………………………………………………………………………………... 41

5.6 Additional information……………………………………………………………………………….41

CHAPTER 6: PDE RESULTS (PAPER 2)…………………………………………………………… 49

6.1 Background……………………………………………………………………………………………...49

6.2 Methods………………………………………………………………………………………………… 49

6.3 Results…………………………………………………………………………………………………...50

6.4 Discussion……………………………………………………………………………………………….51

CHAPTER 7: DISCUSSION……………………………………………………………………………55
7.1 Summary of findings………………………………………………………………………………55
7.2 Injuries……………………………………………………………………………………………...55
7.2.1 Interaction…………………………………………………………………………………….. 57
7.2.2 Concussions………………………………………………………………………………….. 58
7.2.3 Injury duration………………………………………………………………………………… 59
7.2.4 Interrater reliability of overuse and traumatic injuries……………………………………… 60
7.2.5 Prior history of injury as a predictor of injury……………………………………………… 60
7.2.6 History of depression as a predictor of injury…………………………………………….....61
7.3 Possible disordered eating…………………………………………………………………………61
7.3.1 Female Athlete Triad………………………………………………………………………… 62
7.3.2 BMI……………………………………………………………………………………………..62
7.3.3 School-based committees……………………………………………………………………...64
7.3.4 Incident versus prevalent PDE……………………………………………………………….. 64
7.4 Strengths…………………………………………………………………………………………....66
7.5 Limitations…………………………………………………………………………………………67
7.6 Public health implications…………………………………………………………………………...69
7.7 Specific implications for UNCSA screening………………………………………………………71
7.8 Future research……………………………………………………………………………………72
APPENDIX 1: PRIOR STUDIES OF DANCE-RELATED INJURIES………………………………… 74
APPENDIX 2: SELECT PRIOR STUDIES UTILIZING THE EATING ATTITUDES TEST AND BULIMIC INVESTIGATORY TEST, EDINBURGH……………………………………………...80
APPENDIX 3: SAMPLE OF UNCSA HEALTH HISTORY FORM…………………………………… 86
APPENDIX 4: INJURY DURATION…………………………………………………………………… 87
APPENDIX 5: ADDITIVE AND MULTIPLICATIVE INTERACTION IN INJURY MODELS………………… 88
APPENDIX 6: SCREENING-RELATED CALCULATIONS FOR POSSIBLE DISORDERED EATING…...90
REFERENCES………………………………………………………………………………………...91

LIST OF TABLES

Table 4.1: List of explanatory variables……………………………………………………………………......26

Table 4.2: Length of academic terms (in days),
University of North Carolina School of the Arts, Fall 2009-Spring 2015…………………………27

Table 5.1: Characteristics of dancers,
University of North Carolina School of the Arts, Fall 2009-Spring 2015…………………………42

Table 5.2: Distribution of dance-related injuries,
University of North Carolina School of the Arts, Fall 2009-Spring 2015…………………………43

Table 5.3: Injury rates and IRRs,
University of North Carolina School of the Arts, Fall 2009-Spring 2015………………………… 44

Table 5.4: Mean injury duration (in days) by body part,
University of North Carolina School of the Arts, Fall 2009-Spring 2015………………………… 45

Table 5.5: Mean injury duration (in days) by injury diagnosis group,
University of North Carolina School of the Arts, Fall 2009-Spring 2015……………………….... 45

Table 5.6: Mean injury duration (in days) by specific injury diagnosis,
University of North Carolina School of the Arts, Fall 2009-Spring 2015.................................... 46

Table 6.1: Dancer characteristics,
University of North Carolina School of the Arts, Fall 2009-Spring-2015....................................53

Table 6.2: PRs of potential predictors of PDE among female dancers,
University of North Carolina School of the Arts, Fall 2009-Spring 2015…………………………54

LIST OF FIGURES

Figure 4.1: Conceptual model of covariates and outcomes……28

Figure 5.1: Distribution of number of dance-related injuries by gender,
UNCSA Fall 2009-Spring 2015……47

Figure 5.2: Distribution of injury duration,
UNCSA Fall 2009-Spring 2015……48

LIST OF ABBREVIATIONS

ADD	Attention deficit disorder
ADHD	Attention deficit hyperactivity disorder
AIC	Akaike information criterion
AN	Anorexia nervosa
BD	Body density
BF%	Body fat percentage
BITE	Bulimic Investigatory Test Edinburgh
BMD	Bone mineral density
BMI	Body mass index
BN	Bulimia nervosa
BSI	Bone stress injury
CI	Confidence interval
DE	Disordered eating
DIS	Dance Injury Study
DSM	Diagnostic Statistical Manual for Mental Health
EAT	Eating Attitudes Test
ED	Eating disorder
EDNOS	Eating disorder not otherwise specified
EHR	Electronic health record
EIC	Eating Issues Committee
GEE	Generalized estimating equations
HIMP	History of irregular menstrual periods
IADMS	International Association for Dance Medicine & Science
ICD	International Classification of Diseases
ID	Identification
IRB	Institutional Review Board
IRR	Incidence rate ratio

MM	Millimeters
N/A	Not applicable
NB	Negative binomial
NPV	Negative predictive value
OSFED	Other specified and unspecified feeding or eating disorder
PCA	Principal components analysis
PDE	Possible disordered eating
PI	Principal investigator
PPV	Positive predictive value
PR	Prevalence ratio
QICu	Quasi-Akaike information criterion
RERI	Relative excess risk for interaction
SCID	Structured clinical interview for DSM
SHS	Student Health Services
Triad	Female athlete triad
UNCSA	University of North Carolina School of the Arts
UK	United Kingdom
US	United States
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

Dancing is an art form that has been celebrated for centuries. There are many ways to classify dances systematically; one possible method is by the intent of the dance, which can be to please those who are participating in the actual dance, to please the gods, or to please other people. A dance can be placed into the category of theatrical dancing when a prominent reason for the dance is to please other people[1]. Ballet is one of the earliest forms of theatrical dance, and in its earliest form was brought from Italy to the French royal courts in the 1500s[1,2]. Prominent ballet dancers developed in the United States (US) in the 1700s and 1800s, but ballet did not become an established art form in the US until the 1900s[1]. It was also at this time that another form of theatrical dance developed in the US: contemporary dance. Key differences between contemporary dance and ballet include the types of movement: ballet focused on curved and symmetrical movements, while contemporary dancers often use angular asymmetric movements. Furthermore, ballet is choreographed such that no effort appears to be put forth by the dancers, whereas some choreographers in contemporary dance seek to emphasize this effort[1].

Irrespective of style, dancers undergo rigorous training. Professional dancers typically begin dancing at a very young age. One study conducted at a liberal arts high school with pre-professional dancers aged 14 to 18 years [mean (SD)=15.9 (1.0)] found that the student had a mean of 10.0 (SD=2.7) years of dance experience, with a mean of 6.0 (2.4) years of ballet training[3]. Training at a school with advanced dance curriculum can begin as early as secondary school. Specialized secondary schools equip students with professional-level dance training while maintaining a robust academic course load. Ballet and contemporary dance can both be focal points at these institutions[4].

Ballet and contemporary dance have become increasingly popular in the US since the mid-1900s[4,5]. In 2014, there were 11,000 professional dancers in the United States (US)[6], and three-quarters of professional dance companies in the US focus on ballet or contemporary dance[7]. Although no national estimates exist for the number of high school or university dancers, the number of dance programs (not limited to ballet and contemporary dance) at the university level have increased from 131 programs in

1966[8] to over 600 programs in 2015[9,10]. This increase in the number of programs suggests an increasing popularity of training to be a dancer. With this increase in number of dancers will also come an increase in burden of health-related concerns for dancers. This dissertation examines two of these concerns: injuries and possible disordered eating (PDE).

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 Overview

Two health-related issues associated with specialized athletic activity that are commonly identified as areas of concern are injuries and disordered eating (DE)[11,12]. Sport-related injuries occur relatively frequently in physically active populations[13–17]. Sport-related injuries place a large burden on society. Over one-quarter of all emergency department visits are due to injuries in the US[18]. Among children 18 years or younger, 20% of all injury-related emergency department visits are sport-related[19]. Sport-related injury emergency department visits account for the highest proportion of injury-related emergency department visits among those 5-14 and 15-24 years of age[20]. Sport-related injuries affect a much younger population than most other health-related issues. The median age of those visiting the emergency department for sport-related injuries is less than 24 years of age[13], which is younger than the average age of people affected by chronic conditions such as cancer[21], diabetes[22], or heart disease[23]. Effects of injuries at a young age are both physical and mental[24], and these effects can persist for years or appear decades later[15,25,26].

Eating disorders (EDs) are also a common issue in active populations. Elite athletes have a higher prevalence of EDs than the general population[27]. Athletes may be at increased risk for developing EDs because of societal pressures to meet an ideal body shape, a need to minimize body fat for performance reasons, or the psychological mindset of athletes that is "perfectionistic, goal-oriented, competitive, and intensely concerned with performance"[28]. Select groups of athletes have a higher likelihood of developing EDs due to a drive for thinness. A drive for thinness can result from two mechanisms[29,30]. The first mechanism is performance thinness, which represents the belief that attaining a lower weight will allow for performance improvements; this mechanism is likely a factor in endurance sports (e.g., cycling and long-distance running)[31], where extra body weight can be detrimental to performance[27]. The second mechanism is appearance thinness, which represents the belief that attaining a slender aesthetic leads to better results in adjudicated sports (e.g., diving or figure skating).

In dance, injuries and EDs are also of high concern[11]. Among female athletes, including dancers, the Female Athlete Triad (Triad) is an important health consideration. The Triad results from the interplay of three factors: low energy availability (where caloric intake is lower than necessary based on caloric expenditure), menstrual dysfunction (e.g., amenorrhea), and low bone mineral density (BMD). Low energy availability has physiological implications: the body begins to shunt energy away from vital body functions including cellular maintenance, growth, and thermoregulation. Low BMD can result in osteoporosis, a condition leading to weak bones which increases the risk of sustaining a fracture[32]. A recent review article investigated the prevalence of each of the three components of the Triad both separately and combined, and used DE as a proxy for low energy availability. Athletes in lean sports had a higher prevalence of all three Triad factors simultaneously compared with athletes in non-lean sports. Similarly, athletes in lean sports had a higher prevalence of two of the three Triad factors simultaneously. When investigating each of the three components separately, lean sport athletes had a higher prevalence of both low BMD and menstrual dysfunction, but the prevalence of DE was similar between lean and non-lean sport athletes[33]. One study investigating the effect of risk factors associated with the Triad, both individually and simultaneously, on the risk of developing either a bone stress injury (BSI; i.e., a stress reaction or stress fracture) found a positive correlation between number of risk factors associated with the Triad present and risk of developing a BSI. Specifically, 15-21% developed a BSI with one Triad-related component present, 21-30% developed a BSI with two Triad-related components present, and 29-50% developed a BSI when three Triad-related components were present[34]. The Triad is also related to EDs, as some EDs involved restrictive caloric consumption, which can lead to low energy availability[32]. Despite the fact the Triad is applicable only to females, experts have recently suggested that low energy availability can also negatively affect men[35]. Nonetheless, the Triad remains a key concept when considering both injuries and EDs among dancers.

2.1.1 Injury incidence

Injuries occur frequently in ballet and contemporary dancers. Prior studies investigating injury incidence have used various recall periods and definitions of injury (Appendix 1), but many studies have investigated one-year injury incidence proportion[36–39]; with estimates ranging from 69% to 82%[36,39]. Each of these studies obtained self-reported injury data through either a cross-sectional questionnaire or interview, and all but one study defined an injury as any event where the dancer either had to modify or stop dance activity for at least one session (i.e., practice, rehearsal, or performance). One study did not provide any definition of injury. Another study followed professional ballet dancers for nineteen weeks. Injuries were reported based on clinical assessment by a physiotherapist; the injury incidence proportion was 75% over the course of follow-up[40]. Another study investigated injuries among pre-professional ballet dancers at a boarding school for five academic years (one academic year was nine months in duration). An injury was defined as any incident where treatment was given by a physical therapist. Injury incidence proportion for any given academic year ranged from 32-51%. Over the five years of the study, 42% of dancers experienced at least one injury[41]. A similar study investigated injuries among dancers at a ballet school for seven academic years, where in injury was defined as any incident where orthopedic care was received. While injury incidence was not calculated for any single academic year, 44% of dancers experienced at least one injury over the course of the study[42].

Previous studies focusing exclusively on ballet or contemporary dancers have used a variety of denominator measures in calculating injury rates (Appendix 1). One denominator measure used by four studies was the number of dancers, which yields an average number of injuries per dancer. All four studies focused on ballet dancers and defined an injury as an incident reported or assessed by a physical therapist. Two of the studies focused on pre-professional dancers and the other two focused on professional dancers. Furthermore, these studies all utilized a cohort design, since dancers were followed through time to determine the number of injuries experienced. Three were prospective[40,43,44], and one was retrospective[41]. For the prospective studies, the follow-up time ranged from 19 weeks to one year; the number of injuries per dancer ranged from 1.42 to 6.8 per dancer; and the incidence proportion of injuries (i.e., number of dancers who sustained injuries during the follow-up time of the study) ranged from 75% to 100%. The retrospective cohort study used five years of data, and the injury rate per dancer was 0.55, with an incidence proportion of 42%. Both the injury incidence rate and proportion for this last study was likely different than the other studies due to the retrospective nature of the study.

When using hours of dance as the denominator, the observed injury incidence ranged from 0.62 to 4.7 per 1,000 hours of dance[3,36,41–43,45,46]. A select number of studies calculated injury incidence rates by gender, and generally females had a lower rate than males[42,43,45,46]. One study among professional ballet dancers that explored injury rate by setting found that for females, the injury rate in class, rehearsal, and performance was 4.94, 2.43, and 4.45 per 1,000 dance-hours, respectively. The corresponding rates for males were 7.54, 2.99, and 5.19, respectively[43]. However, a study among professional modern dancers that also explored injury rate by setting found that females had a higher injury rate than males. This study, also calculated injury rate based on the setting (class and rehearsal). For females, the injury rate in class and rehearsal was 0.75 and 0.58 per 1,000 hours, respectively. The corresponding rates for males were 0.40 and 0.52, respectively[36]. Injury incidence was also found to increase with age at one ballet school[42]. Injury rates based on reporting method vary: one prospective cohort study based in a high school dance program of both ballet and modern dancers found that self-reported injury rates (4.7 per 1,000 hours) were higher than injury rates calculated based on injuries reported to and treated by a physical therapist (2.9 per 1,000 hours)[3].

Only two studies in the literature used an alternate measure of athlete-exposure for calculating incidence rate. One of the studies defined an athlete-exposure as one dancer participating in one practice, rehearsal, or performance. This study was based at one ballet boarding school and used five academic years of data. There were 1.09 injuries per 1,000 athlete-exposures, or 0.77 injuries per 1,000 hours of dance[41]. The other study did not provide a definition for an athlete-exposure, and was based at a ballet school using six months of data. There were 3.52 injuries per 1,000 athlete-exposures, or 2.40 injuries per 1,000 hours of dance. These rates were also calculated by gender, with males having a higher injury rate than females[46].

2.1.2 Distribution of Injuries

Much of the movement in dance involves the legs; thus, it is not surprising that a majority of injuries to dancers are in the lower extremity (Appendix 1). Lower extremity injuries account for between 79%-91% of all injuries to dancers, while upper extremity injuries account for 2%-14% of all injuries[3,39,41,42,44,45,47]. The ankle is the most common location of lower extremity injury, accounting for a total of 22%-50% of all injuries[3,44,47]. The distribution of anatomic injury location differs by gender, though for both genders a majority of injuries are to the lower extremity[43,45].

Female and male dancers execute different movements while dancing. In ballet, only females dance *en pointe*, where the dancer is in full equinus position on the foot while in full ankle plantar flexion[45,48,49]. Only males perform lifting movements and execute high jumps in ballet[45,49]. Performance of different movements may account for part of the differential distribution in body location of injury. In contemporary dance, there are more similarities in the movements performed by females and males than ballet. For example, both females and males perform lifts in contemporary dance, while only males perform lifts in ballet[50].

2.1.3 Overuse injuries

Overuse injuries are the predominant type of injury in dancers (Appendix 1). Overuse injuries can be defined as injury due to repetitive microtrauma over time to the musculoskeletal system, while traumatic injuries can be defined as injury due to excessive stress on the musculoskeletal system associated with one specific event[49]. Most of the previous studies focused on ballet and contemporary dancers have found that a majority of injuries (57%-78%) resulted from overuse, as opposed to traumatic causes[36,40,42–45]. Five of these studies investigated ballet dancers (three professional, one pre-professional, one with students at a ballet school) and all defined injury as an incident where care from a healthcare professional (e.g., physical therapist) was necessary. One study investigated professional contemporary dancers, and used self-reported injury information from the past year. However, one study found that 44% of injuries sustained by ballet dancers were due to overuse[39]. The study population consisted of dancers participating in a dance festival in Brazil. Although various dance styles (not limited to ballet and contemporary dance) were represented at this festival, select results for the study were presented by style, including ballet. Dancers were asked to recall their injury experience in the year prior to the interview. Additionally, the proportion of injuries that are reported to be overuse possibly depends on the method and timing of ascertaining injuries. One study among pre-professional ballet and modern dancers found that 56% of self-reported injuries were due to overuse, while 49% of injuries that were seen at a clinic were due to overuse[3]. The Dance Injury Study (DIS) was based in the school formerly known as North Carolina School of the Arts (currently known as University of North Carolina School of the Arts), and found that 50% of injuries sustained during follow-up were due to overuse, while 60% of injuries prior to the start of the study were due to overuse[51]. It is worth noting that the distribution of overuse injuries may differ by anatomic location on the body. Injuries to the lower extremity and back were mostly due to overuse, while injuries to the upper extremity and head were mostly due to traumatic causes[42,45]. The proportion of injuries due to overuse appeared to be similar among females and males[42,43]. Typical traumatic injuries include sprains, strains, and fractures [52,53]. It is currently unknown whether the distribution of these traumatic injury diagnoses differs by anatomic location on the body.

2.2 Eating disorders

The impact of eating disorders (EDs) is increasing. Disability-adjusted life years (DALYs), a composite measure of years of life lost due to premature mortality and years lived with disability, due to EDs increased globally from 1.3 million in 1990 to 2.2 million in 2010. This increase is not solely due to population growth, as EDs comprised 25 DALYs per 100,000 population in 1990 and increased to 31 DALYs per 100,000 population in 2010[54]. EDs affect both physical and mental health. Those diagnosed with EDs are at increased risk of having comorbid conditions with disorders such as mood disorders (e.g., depression), impulse-control disorders, and substance use disorders[55]. EDs are costly to society: not only are there direct monetary costs related to treatment, a substantial amount of time is consumed in the month prior to admission in a treatment program. One study found that the average amount of time in the month prior to admission spent on ED-related issues was 91 hours, 72 hours, and 88 hours for mothers, fathers, and partners, respectively. The most substantial time costs resulted from time spent providing emotional support and care[56,57].

EDs are formally diagnosed using the Diagnostic Statistical Manual for Mental Health (DSM). The DSM was first published in 1952 by the American Psychiatric Association as a way of systematically classifying mental disorders that loosely parallels with the classification scheme in the International Classification of Diseases (ICD)[58]. The DSM-III was published in 1980, and was the first edition of the DSM to include specific diagnostic criteria for EDs. The Structured Clinical Interview for DSM (SCID) was also first developed in the revision for the DSM-III (DSM-III-R) which was published in 1987, and is utilized to diagnose EDs. In the DSM-III-R, there are three broad diagnoses for EDs: anorexia nervosa (AN), bulimia nervosa (BN), and eating disorder not otherwise specified (EDNOS). The DSM-IV was published in 1994; the main differences for ED diagnoses between DSM-III-R and DSM-IV is that AN is further classified two subtypes in DSM-IV: AN- restricting type and AN- binge-eating/purge type[59] and AN and BN are mutually exclusive diagnoses[60]. The DSM-5 was published in 2013[61]. The key changes from DSM-IV to DSM-5 were that 1) amenorrhea is no longer a criterion for being diagnosed with AN, 2) BN is no longer divided into subtypes, and 3) there is a new category for binge-eating disorder, which was previously included in the EDNOS category of the DSM-IV[62]. Furthermore, the EDNOS has been renamed to “other specified and unspecified feeding or eating disorder” (OSFED)[63].

2.2.1 Prevalence

EDs disproportionately affect female dancers. In the general population, the lifetime prevalence of EDs using DSM-5 criteria is estimated to be 4% for AN, approximately 2% for bulimia nervosa (BN), <1%-3% for binge-eating disorder (BED), and at least 2% for OSFED[64]. A meta-analysis of 33 studies published between 1966 and 2013 found that prevalence of having an ED was 12.0% among all dancers, and 16.0% specifically for ballet dancers. For ballet dancers, the prevalence of AN, BN, and EDNOS was 4%, 2%, and 14.9%, respectively[65]. Among professional ballet dancers, lifetime prevalence of having an ED ranged from 31% to 83%[66,67]. EDs are more common in females than males, both in the general population and among dancers[11,68–70].

Dancers face pressures that increase the likelihood of developing an ED. In addition to having ED-related psychopathological characteristics (e.g., body dissatisfaction) that are elevated[67], environmental factors also likely contribute to the probability of developing an ED[71,72]. Dancers face pressures to maintain lean bodies and low body weights from people including artistic directors, mentors, and male partners (for female ballet dancers)[73,74]. The perception also exists that maintaining a low body weight is paramount for aesthetic reasons in classical ballet[73–76].

2.2.2 Screening Tools

Screening tools have been developed to identify people who are likely to have an ED[77–79]. Although EDs are formally diagnosed with a SCID, a screening questionnaire is a useful tool to identify those who should undergo further, more resource-intensive diagnostic testing and interviews. Two such screening tools are the Eating Attitudes Test (EAT) and the Bulimic Investigatory Test Edinburgh (BITE).

2.2.2.1 Eating Attitudes Test

The EAT was developed in 1979 to screen for AN among females. Items on the EAT have six possible responses (always, very often, often, sometimes, rarely, never), and are scored on a four-point

Likert scale. For each item, the most extreme response in the "anorexic" direction was given three points, and the immediately adjacent responses were assigned two and one point, respectively. The three responses in the "non-anorexic" direction were collapsed into one category and given a score of zero. The initial version of the EAT contained 35 items and was administered to 32 participants being treated for AN (based on fulfilling the six Feighner criteria[80]) and 34 university students who had no history of psychiatric illness (i.e., controls). For 23 of the 35 items in this initial version, participants with AN scored significantly higher than controls, and these items were therefore considered "meaningful". The total score from these 23 items were correlated with group membership ($r=0.72$, $p<0.0001$). The second version of EAT included the 23 items from the initial version plus 17 new items. This second version was administered to a separate sample of 33 participants being treated for AN and 59 controls. The total score on the second version of the EAT was correlated with group membership ($r=0.87$, $p<0.0001$). This second version is the final version that is presently known as the EAT-40. The mean (standard deviation [SD]) EAT-40 score for participants with AN and controls was 58.9 (13.3) and 15.6 (9.3), respectively. To minimize false negatives for AN, Garner and colleagues suggest using a minimum cutoff score of 30, as all 33 participants with AN scored 30 or higher on the EAT-40. There was high internal consistency for the EAT-40 ($\alpha=0.79$ for participants with AN, and $\alpha=0.94$ for the combined sample of participants with AN and controls). Using varimax rotation, items on the EAT-40 were grouped into seven factors: food preoccupation, body image for thinness, vomiting and laxative abuse, dieting, slow eating, clandestine eating, and perceived social pressure to gain weight[81]. These factors were not formally used as subscales in the EAT-40.

A subsequent version of the EAT that had 26 items was developed[82]**.** The EAT-40 was administered to 160 females with AN (based on the Feighner 1972 criteria) and 140 female university students (i.e., controls). Using a scree test, it was determined that there were three factors that accounted for 40% of the variance in responses. Using an oblique rotation, it was determined that 26 items had factor loadings of 0.40 or more. The remaining 14 items were removed, and the EAT-26 was finalized with three factors. Garner and colleagues indicated a minimum cutoff score of 20 on the EAT-26 was equivalent to a cutoff score of 30 on the EAT-40. The total EAT-26 score was highly correlated with the EAT-40 score among both participants with AN and controls ($r=0.98$ and 0.97, respectively). The mean (SD) EAT-40 score for participants with AN and controls was 52.9 (23.0) and 15.4 (11.0), respectively. The corresponding EAT-26 scores were 36.1 (17.0) and 9.9 (9.2), respectively. Other versions of the EAT with different numbers of items and translations have also been created.

The EAT's psychometric properties have been explored in five previous studies (Appendix 2). Two studies focused exclusively on the EAT-40[83,84], and the remaining three studies included the EAT-26. One study sought to determine the validity of using cutoff scores for the EAT-26 to identify participants with EDs (AN, BN, or EDNOS). 30 students had diagnosed EDs and 99 students did not have EDs. Using a cutoff score of $\geq$ 20, the EAT-26 had six false positives and seven false negatives. For the EAT-26, the sensitivity, specificity, positive predictive value, and negative predictive value were 0.77, 0.94, 0.79, and 0.94, respectively[60]. Another study performed a confirmatory factor analysis to examine construct validity and internal consistency reliability of the EAT-26. The EAT-26 had poor model fit, and it was determined that the four-factor EAT-16 had the best fit[85]. A third study explored the factor structure of the EAT-26. An alternate scoring method was used where the responses of the non-anorexic side of the scale were not collapsed, so each item could have a minimum score of one and maximum score of six (as opposed to possible values of zero to three, as suggested by the developers of the EAT). Using the Comparative Fit Index and Root Mean Square Error of Approximation, it was determined that a the three-factor structure of EAT-26 fit poorly to the data, and the four-factor 16-item structure suggested by Ocker and colleagues[85] was a better fit[86].

A few studies have used the EAT simultaneously in dancing and non-dancing populations to screen for AN and other EDs (Appendix 2). Dancers generally had a higher mean EAT score or a greater proportion scoring above a pre-defined cutoff score than non-dancing controls. However, one study did find lower EAT scores among dancers compared to non-dancers, though this difference was not significantly significant[66]. Three studies utilizing the EAT-40 found that mean (SD) scores ranged from 21 (12) to 25.6 (14.6); 22%-33.7% scored $\geq$30[87–89]. In one of the studies, all dancers (n=69, 37.7% of sample) who scored $\geq$30 were interviewed, and 11 had AN. Targeted interviewing yielded one additional dancer who had AN and scored <30[89]. Another study investigated gender-specific EAT-40 scores. In both genders, ballet dancers had higher EAT-40 scores than age-matched controls; females had higher EAT-40 scores than males among both dancers and controls. Among dancers, the mean (SD) EAT-40 score for females and males was 19.00 (14.59) and 10.00 (3.81), respectively. Eight female dancers (21.6%) and no male dancers scored $\geq$30[90]. The one study that used the EAT-26 found the mean score among dancers was 13.55 (8.7), and did not differ significantly from non-dancers. Among the dancers, 16% scored $\geq$20 on the EAT-26. 15 dancers (31%) met the criteria for ever having AN under the DSM-III, 13 dancers (26%) met the criteria for ever having BN under the DSM-III, and 6 dancers (12%) met the criteria for BN under the DSM-III-R[66].

One study among dancers utilized the EAT-26 as a measure of DE attitudes and behaviors (Appendix 2). The DIS found that the overall mean EAT-26 score was 14.2, and females had higher scores than males (mean=15.4 and 5.3, respectively, p=0.01). Mean EAT-26 score did not significantly differ between ballet and contemporary dancers (16.2 and 13.8, respectively), nor did the scores differ by age (mean=11.8 and 16.5 for students aged 12-15 years and 16-18 years, respectively). 17% of students aged 12-15 scored $\geq$20, while 31% of students aged 16-18 scored $\geq$20[51].

2.2.2.2 Bulimic Investigatory Test Edinburgh

The BITE was originally developed to identify people who are binge-eaters. The instrument contains 40 questions: seven related to dieting behavior, 27 related to symptoms and behaviors associated with binge eating, and six related to specific information on the most significant behavior's frequency. The BITE was first pilot tested with 15 female binge eaters who were in different stages of treatment and 40 control subjects (13 males, 27 females). Based on scores from the 27 questions on symptoms and behaviors associated with binge eating, participants were divided into two groups, with a cutoff score of 20. The group with high scores was comprised of 14 binge eaters and two control subjects. Using chi-square tests, individual questions of the BITE were analyzed to determine whether the question significantly predicted group membership. Based on this pilot test, the BITE was subdivided into two subscales: The Symptom Subscale and Severity Subscale. The Symptom Subscale contains 30 questions: all 27 questions related to binge eating and three of the questions related to dieting behavior. The Symptom Subscale questions can be answered either "Yes" or "No", and has a maximum possible score of 30. For all but five of the questions, a "Yes" response is given one point; the remaining five questions are given one point for a "No" response. A score of 20 or higher on the Symptom Subscale was considered a positive screen by the author team, and was likely to fulfill DSM-III criteria for BN. The

Severity Subscale is comprised of six questions related to the frequency of the most significant behavior, and has a maximum possible score of 39. A score of five or higher on the Severity Subscale is considered clinically significant. Furthermore, a score of 25 or higher when combining both subscales is considered suggestive of severely DE[91].

After the BITE was pilot tested, a second study was performed among 32 females who met the DSM-III criteria for BN (but had not yet entered treatment) and 32 controls. Among participants with BN, all scored above 25 on the BITE [mean (SD)=36.19 (4.47)], all scored above 20 on the Symptom Subscale [mean(SD)=26.03 (2.25)], and all but two participants scored at least 5 on the Severity Subscale [mean(SD)=10.16 (3.63)]. None of the controls scored above the cutoff scores for either the Symptom Subscale [mean (SD)=2.96 (2.94)] or the Severity Subscale [mean (SD) = 0.44 (0.29)]. There were statistically significant differences in total BITE score ($p<0.001$), Symptom Subscale score ($p<0.05$), and Severity Subscale score ($p<0.05$) when comparing participants with BN to controls. Reliability of the Symptom Subscale and Severity subscale was 0.96 and 0.62, respectively. The EAT-40 was also administered to participants, and total EAT-40 scores were significantly correlated with BITE scores ($r=0.697$, $p<0.0001$)[91].

The test-retest reliability of the BITE was assessed with 10 females who met the DSM-III criteria for BN and 30 female controls. The BITE was administered two times 15 weeks apart to participants with BN and at least one week apart for controls. The mean (SD) score on the first and second administration for participants with BN was 34.4 (3.13) and 31.8 (5.39), respectively; the correlation between the scores was 0.68 ($p<0.0001$). The corresponding scores for controls was 3.33 (2.57) and 3.22 (2.27), respectively; the correlation between the scores was 0.86 ($p<0.05$)[91].

The BITE's psychometric properties have been explored to a limited extent (Appendix 2). A study explored the factor structure of the BITE using principal components analysis for each gender separately. Girls scored higher than boys on the BITE [mean (SD) = 9.86 (4.73) and 7.66 (4.73), respectively, $p<0.01$]. 3.9% of girls scored at least 20 while 0.6% of boys scored above this cutoff score. Based on Kaiser's criterion and a scree test, one factor summarized the relationships between the items for girls, while two factors summarized the relationships for boys[92].

The BITE has been used to screen for EDs in one previously published study (Appendix 2). The BITE was administered to women in a professional ballet company. None of the women had any ED at the time of the study, but three of 19 women (16%) had a lifetime history of AN. Two of these three dancers had elevated BITE scores of 16 and 24, respectively[93].

2.2.2.3 Eating Attitudes Test and Bulimic Investigatory Test Edinburgh in combination

A small number of studies have used both the EAT and BITE simultaneously to investigate EDs among dancers (Appendix 2). One study investigating dancers and non-dancers found that the mean (SD) EAT-26 score was different when comparing dancers to non-dancers [17.2 (10.1) and 11.2 (8.4), respectively, $p<0.001$]. There were 59 dancers (9.6%) who scored ≥20 on the EAT-26. The total BITE score differed between dancers and non-dancers [mean (SD) = 14.3 (7.3) and 9.7 (6.1), respectively; $p<0.001$]. There were 239 dancers (39.0%) who had a positive screen based on the BITE; 27 of these dancers also scored ≥ 20 on the EAT-26. The estimated prevalence of AN, BN, and EDNOS among dancers was 0.7%, 2.5%, and 4.8%, respectively[94]. A subsequent study was conducted and focused on the dancers, and the EAT-26 and BITE were re-administered. EAT-26 scores decreased from 17.2 (10.0) to 14.8 (9.2) from baseline to follow-up ($p<0.001$). Total BITE scores increased from 14.1 (7.2) to 15.3 (8.1) ($p<0.001$). Among dancers without any ED at baseline (n=204), 35 developed an ED. Multivariable Poisson regression indicated that a one-unit increase in BITE score increased the risk of incident ED by 8% (95% CI = 1%, 14%), while EAT-26 score was not associated with developing an incident ED[95].

2.3 Significance

Epidemiologic studies of injuries have utilized a variety of study designs including case series, prospective cohort studies, retrospective cohort studies, and cross-sectional studies. Studies of athletes have made extensive use of prospective cohort design. Advantages of this design for studies of athletes include being able to create cohorts from administrative or academic records, the relatively short period of follow-up needed to register injuries (i.e., months, not the decades required for studies on chronic conditions), and the fact that the predictive profile is established before the injuries occur[96]. Although prospective cohort studies are typically used to study incident outcomes, they can also be used to study prevalent outcomes, since a dynamic prospective cohort is essentially a longitudinal set of cross-sectional studies with a series of defined start and end times. Thus, a prospective cohort study allows for the investigation of both incidence of injuries and prevalence of PDE.

Prior studies on injuries among dancers have been limited by various methodological issues, and this dissertation addressed two of the key limitations in prior research. The first issue relates to small sample size: previous studies have enrolled between 22 -476 participants (mean=156, median=108). Small sample size increases the likelihood that random variation played a role in the study results. This dissertation overcame this limitation by investigating over 480 participants across six academic years. Another issue with prior studies was study design. Two prior studies utilized a case series design[47,53], which precluded the calculation of measures of occurrence such as incidence or prevalence. This study utilized a prospective cohort design, allowing for the calculation of measures of occurrence. Furthermore, a recent review article[97] found that only five studies have been conducted among pre-professional ballet dancers, and this study will add to the current literature base among both ballet and contemporary pre-professional dancers.

While many studies investigating either injuries or EDs have studied ballet dancers, to date few studies have investigated contemporary dancers. Three of these studies investigated populations comprised of both ballet and contemporary dancers[51,52,98]. The remaining two studies investigated either professional dancers[36] or female dance majors and minors[99]. Furthermore, prior studies investigating either EDs or DE patterns among dancers have mostly focused on females. Only three previous studies have investigated EDs or DE patterns among both males and females[70,90,100]; none of these studies were conducted in a population based in the US. Therefore, this study advanced the field both methodologically and substantively.

CHAPTER 3: STATEMENT OF SPECIFIC AIMS

This dissertation addresses four specific aims.

Specific Aim 1 (Injury incidence): Quantify incidence of musculoskeletal injuries in an adolescent/young adult dance population. Differences exist in types of movement used across dance styles and by gender (e.g., women lift other dancers in contemporary dance but usually not in ballet[50]). Previous studies have shown a difference in injury location when comparing across dance styles[50,98]. Direct comparisons between middle school and high school/university-aged dancers have not demonstrated any difference in injury incidence[42]. Therefore, dance style (ballet and contemporary), gender, and age (high school and college) are of interest as predictors of musculoskeletal injury incidence.

Hypothesis 1.1: Ballet dancers had an increased incidence of lower extremity and decreased incidence of upper extremity injuries compared to contemporary dancers.

Hypothesis 1.2: Male dancers had more upper extremity injuries than female dancers.

Hypothesis 1.3: There was no difference in lower extremity injury incidence by gender.

Hypothesis 1.4: There was no difference in injury distribution when comparing high school dancers to college dancers.

Specific Aim 2 (Injury predictors): Identify prospective predictors of sustaining musculoskeletal injuries in an adolescent/young adult dance population. The Triad is a syndrome where low energy availability, amenorrhea, and osteoporosis are present in a female. Presence of at least one condition gives an increased likelihood of observing the other conditions as well[101]. Cigarette smoking has been shown to be associated with increased incidence of lower extremity injury[102]. A prior history of injury has been shown to be a risk factor of subsequent injury in a variety of sports settings[103–105]. Overuse injuries are more common in dance than traumatic injuries[42,43], and differences exist in types of movement used across dance types and by gender (e.g., women lift other dancers in contemporary dance but usually not in ballet [50]).

Hypothesis 2.1: Low body mass index (BMI), prior history of injury, having PDE, being a current smoker, and amenorrhea (in females) were predictors of musculoskeletal injuries.

Hypothesis 2.2: Predictors of musculoskeletal injury differed by gender.

Specific Aim 3 (PDE prevalence): Measure prevalence of PDE [either: a) having a positive screen on the EAT-26 or BITE or b) being institutionally monitored] in an adolescent/young adult dance population. Ballet dancers have a certain body type/aesthetic that is considered ideal, while contemporary dancers faced less with this type of expectation[106]. In the general population, females have a markedly higher prevalence of EDs than men. Younger dancers face different pressures and hold different perceptions of body image than older dancers[100].

Hypothesis 3.1: Ballet dancers had a higher prevalence of PDE than contemporary dancers.

Hypothesis 3.2: Females had a higher prevalence of PDE than males.

Hypothesis 3.3: High school dancers had a higher prevalence of PDE than college students.

Specific Aim 4 (PDE predictors): Identify cross-sectional predictors of having PDE in an adolescent/young adult female dance population. By definition, AN, has its severity classified primarily based on BMI[107]. Furthermore, the Triad is a syndrome where low energy availability, amenorrhea, and osteoporosis are present in a female. Presence of at least one condition gives an increased likelihood of observing the other conditions as well[101]. Finally, cigarette smoking has been shown to be used as a weight control strategy [108].

Hypothesis 4.1: Low BMI, having a history of irregular menstrual periods (HIMP), and having a history of cigarette smoking were predictors of PDE in females.

CHAPTER 4: METHODS

Institutional Review Board approval for this study was obtained from the University of North Carolina at Chapel Hill (IRB #14-1044) and Winston-Salem State University (IRB # 2986-15-0030).

4.1 Study population

The study population was comprised of dancers who began enrollment at the University of North Carolina School of the Arts (UNCSA) School of Dance during or after Fall semester 2009 and were followed up through the end of their studies at UNCSA or the end of Spring semester 2015, whichever came first. The UNCSA dance program trains both high school and college students in either ballet or contemporary dance. The dance style that a dancer was focusing on at entry to UNCSA was considered the dance style for the entire duration of the study period. The small number of students (n=13) who were enrolled in both high school and college programs during the follow-up study were counted as two separate, independent participants in this study.

4.2 Study design

This study was a cohort study that followed UNCSA high school and college dancers. The two outcomes of interest were musculoskeletal injury rates and prevalence of PDE. EDs are conditions that typically have a more gradual onset, and early stages of EDs and PDE are difficult to identify. Therefore, incidence is difficult to calculate, and *prevalence* in a previously unscreened population is more clinically relevant, as the exact moment of *incidence* is challenging to pinpoint.

4.3 Data

All data were obtained through the UNCSA Student Health Services (SHS). UNCSA SHS is the sole location on-campus where all students receive clinical care; clinical records from off-campus locations were not obtained for this study. However, off-campus locations were assumed to account for essentially zero treatment for injuries and EDs. UNCSA SHS consists of a multidisciplinary team consisting of a physician, nurse practitioner, physician's assistant, nutritional services, counseling, physical therapist, and athletic trainers[109]. Select information from SHS were available as pre-entered data to the principal investigator (PI; BITE scores, EAT-26 scores, skinfold caliper measures, height, and weight). The remaining information was manually abstracted from Medicat (Atlanta, GA), the electronic health record (EHR) system used by UNCSA. Medicat was the EHR system used by UNCSA starting Fall 2009. Data obtained and abstracted were linked initially through student identification (ID) number. When student ID number was unavailable, data linkage was performed through any relevant information that was available (a combination of first name, last name, date of birth, age, and semester(s) of enrollment at UNCSA).

4.4 Identification of study cohort

UNCSA dancers were identified through two UNCSA rosters. The first roster was generated from Medicat by UNCSA SHS for dancers who had a record in Medicat through October 15, 2014. Only information for students in the School of Dance were included in the roster; information from students of other UNCSA schools (i.e., schools of Design & Production, Drama, Filmmaking, Music, and Visual Arts) were not included. This roster from Medicat included dancers who began enrollment prior to Fall 2009 and dancers who attended UNCSA exclusively for summer intensives; these dancers were excluded from the present study. This roster also captured all dancers enrolled through Spring 2015, as all dancers enrolled at UNCSA in Spring 2015 were also enrolled in Fall 2014 (written correspondence with Director of UNCSA Student Health Services, February 2015). Medicat only captures the current UNCSA school in which the student is enrolled. The first roster did not include any dancers who left the UNCSA School of Dance for another UNCSA school, resulting in potential under-ascertainment of the eligible study cohort.

Therefore, a second roster was obtained from UNCSA SHS to supplement the first roster. This second roster contained information from beginning-of-semester health screenings conducted for UNCSA dancers from Fall 2009 through Spring 2013. There were fewer than ten instances where a student was on the second roster for health screenings, but was not on the first roster from Medicat. In these cases, it was determined that the students had switched from the School of Dance to another school (e.g., to the School of Drama), and the Medicat roster excluded these students. Students who switched enrollment from the School of Dance to another school were included in the present study, as long as they began enrollment in the School of Dance during or after Fall 2009. Any injuries and person-time that occurred when these dancers were in a UNCSA school other than the School of Dance were excluded from this study.

4.5 Outcome variables

The clinical outcomes for the cohort were abstracted from the records in Medicat. The Medicat system was queried using last name.

4.5.1 Injury

Musculoskeletal injury, one of the two main outcomes of interest, was defined as any event where a dancer was seen at the UNCSA SHS and the dancer needed to modify or curtail their dancing activity for at least one day due to the injury. Injuries were characterized in a number of ways: body part (e.g., ankle, back, knee), diagnosis (e.g., strain, sprain, tendinitis), and type (traumatic vs. overuse).

An injury was classified as a traumatic injury by the PI if there was one clear event that caused the injury. All other injuries were classified as overuse injuries. For injuries where it was unclear if it was a traumatic or overuse injury, consensus was reached through discussions between the PI and a clinician certified in both athletic training and physical therapy. Subsequently, a validation study using 5% of the sample was performed to asses for intra-rater reliability of the classification of injury type; the PI and a physical therapist/musculoskeletal injury epidemiologist independently reviewed 51 records and classified injury types as traumatic, overuse, or unable to determine.

The start date of an injury was defined as the first day a dancer was seen at the UNCSA SHS, regardless of whether or not dance activity was modified after the initial visit. The end date of an injury was defined as either: a) the first day one of the medical providers noted that the dancer could either perform dance activity to tolerance or was cleared for dance activity (whichever came first) or b) the last day a dancer was seen at UNCSA SHS for the injury (i.e., if there was no indication anywhere that the dancer could either perform dance activity to tolerance or was cleared for dance activity).

4.5.2 Possible disordered eating

The presence of PDE, was defined as either a) the dancer being monitored by UNCSA SHS or b) a positive screen for DE on either the EAT-26 or BITE. The EAT-26 and the BITE were administered online to dancers prior to the beginning of the semester in both Spring 2014 and Fall 2014.

UNCSA SHS monitored students in multiple ways. At the beginning of the present study in Fall 2009, an Eating Issues Committee (EIC) was in place. The EIC was previously formed to address nutrition-related concerns of UNCSA, and “safeguard[s] the physical and psychological welfare of individual students suffering from eating related disorders” (written correspondence with Director of UNCSA Student Health Services, February 2015). The EIC met monthly, and emergency meetings were convened as necessary. The EIC’s permanent members included the Health Services Director, physician, registered dietitian, counselor, and athletic trainer (all members of the UNCSA SHS clinical team). Based on clinicians’ notes seen in Medicat, the last known meeting of the EIC was in October 2012. The EIC was replaced by another committee in 2013 that met more frequently about a variety of health concerns (not limited to eating issues; personal correspondence with UNCSA athletic trainer). For the entire duration of the present study (i.e., from Fall 2009 through Spring 2015), UNCSA SHS also monitored certain students’ weight by weighing them every time they visited SHS and/or weighing them blindly (i.e., the dancer did not know what their weight was after being weighed). A note was present in the EHR if a student was monitored by the EIC and/or being weighed regularly.

A dancer had a positive screen for DE on either the EAT-26 or BITE if he or she scored at least 10 on either instrument at least once. Traditionally, a cutoff score of 20 is used for positive screen for DE on the EAT-26 and the BITE. However, for the purposes of this study, a lower cutoff score of 10 was used because: a) all students who scored at least 10 on either the EAT-26 or the BITE were referred to the UNCSA dietitian for an appointment to discuss their eating habits and b) prior research shows that athletes are more likely to underreport the use of select weight control methods than non-athletes[110]. Since both the EAT and BITE were initially developed for a general population (i.e., not athletes specifically), a lower cutoff score for a positive screen is likely appropriate for this study, as dancers engage in specialized athletic activities. For similar reasons, for dancers who completed the instruments in both semesters, the higher of the two scores (indicating more disordered eating habits) was used for the purposes of this study.

4.6 Explanatory variables

Explanatory variables included demographic characteristics, physical characteristics, mental health history, history of risk-taking behaviors, history of injury, and history of ED (Table 4.1).

One source of data was the health history form, a document that every UNCSA student completed prior to enrollment at UNCSA (Appendix 3). Health history forms were scanned into the EHR database by UNCSA as part of standard operating procedures, and data were manually entered by the PI into Microsoft Excel. Data were entered based on the responses that students provided. However, for the question of whether or not a student wears a seatbelt, there was one student whose response was recoded from "no" to "yes". Specifically, this student indicated on the form "no" for two consecutive items (whether or not they regularly exercised and whether or not they wore a seatbelt). Given that the population being studied comprises of elite pre-professional dancers, it was assumed that all participants regularly exercised, and thus we assumed the dancer (n=1) who answered "no" for both regularly exercising and wearing a seatbelt did not carefully review the form and marked "no" for not wearing a seatbelt in error. Furthermore, this dancer selected "no" for every single item on the health history form.

4.6.1 Physical characteristics

Physical characteristics included anthropometric measures, history of frequent vomiting, and HIMP. Anthropometric measures to calculate BMI and body fat percentage (BF%) were collected by UNCSA SHS staff when a dancer began enrollment at UNCSA. BMI was calculated as:

$$BMI = \text{weight (in kilograms)}/\text{height (in meters)}^2$$

Body fat percentage (BF%) was calculated from the Sloan body density (BD) equations by gender and Siri BF% equation[111,112], where:

$$BD_{Female}=1.0764 - [0.00081 * \text{iliac crest skinfold}] - [(0.00088 * \text{tricep skinfold}]$$

$$BD_{Male}= 1.1043 - [0.001327 * \text{thigh skinfold}] - [0.00131 * \text{subscapular skinfold}]$$

$BF\% = (495/BD) - 450$, and all skinfold measurements were measured in millimeters

Prior studies investigating the association between anthropometric measures and injuries have yielded mixed results[113–116], while by definition low BMI serves as one criterion for being diagnosed with certain types of EDs[107]. BMI and BF% were routinely calculated and recorded from Fall 2009-Spring 2013. Beginning in Fall 2013, routine collection of BMI and BF% at UNCSA ended.

4.6.2 Mental health history

Mental health history included measures on both personal mental health history and family history of mental health disorders. Personal mental health history included history of depression; excessive worry, anxiety, or obsession; and treatment for attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD). Family history of mental health disorders included history of alcohol or drug problems, psychiatric illness, and suicide. Prior research has shown that elite athletes who are injured are more likely to experience psychological consequences, including depression[117,118]; however, limited literature exists on whether athletes with worse mental health measures are more likely to sustain injuries. Furthermore, those diagnosed with EDs are at increased risk of having comorbid conditions with disorders including mood disorders (e.g., depression), impulse-control disorders, and substance use disorders[55]. Additionally, a family history of mental health disorders can be used as a proxy for mental health disorders of a given individual, as those with a family history of mental health disorders are more likely themselves to develop mental health disorders[119–121].

4.6.3 History of risk-taking behaviors

History of risk-taking behaviors included history of alcohol use, illegal drug use, smoking, and not wearing a seatbelt. Multiple studies have been conducted investigating the association between risk-taking behaviors and physical activity-related injuries with inconsistent results[122,123]. Risk-taking behaviors have been shown to be associated with abnormal eating patterns indicative of PDE or an ED[124,125].

4.6.4 Prior history of injuries

Prior history of injuries included history of knee problems, recurrent back pain, neck injury, back injury, and broken bones. For Specific Aim 2 (injury predictors), prior history of injury while enrolled at UNCSA was also considered. Across different types of injuries, the single factor most strongly associated with sustaining an injury is a history of previous injury[126–129]. Furthermore, prior history of injuries is likely to be associated with PDE especially among females, as the Triad results from the interplay of low energy availability, menstrual dysfunction, and low BMD[32].

4.7 Person-time

Injury rates were calculated in person-days for Specific Aims 1 and 2. Person-days of enrollment at UNCSA were calculated based on the length of academic terms at UNCSA provided by the academic calendars obtained from UNCSA's website[130]. The length of each term (in days) is provided in Table 4.2 separately for the high school and college programs. The last academic term that a student was observed was determined based on the last date that a student had an entry in Medicat. For all students, it was assumed that the student was enrolled at UNCSA for the entire duration of the last academic term, since it was not possible to obtain a student's exact withdrawal date from UNCSA for the students who did not graduate.

4.8 Data analysis

All data analyses were performed with SAS 9.3 (Cary, NC). All results were considered statistically significant at $p<0.05$. To address Specific Aims 1 (injury incidence) and 2 (injury predictors), Poisson and negative binomial (NB) regression were used to generate incidence rates and incidence rate ratios (IRRs). Robust standard errors with an exchangeable working correlation matrix were generated using generalized estimating equations (GEE). Quasi-Akaike information criterion (QICu) scores (with an additional penalty for the number of parameters in each model) were used to determine if Poisson models or NB models were the best fit. Multivariable regression was used to generate IRRs for the outcome of injury for Aim 2 (injury predictors) for all dancers. An a priori decision was made to stratify all models by gender because the dancing activities performed in ballet vary by gender. Evaluation of the model with interaction terms compared with models without interaction terms was used to assess departures from perfect multiplicativity of joint effects. Specifically, QICu scores and Wald tests for the interaction term were used. Interaction tables were used to calculate relative excess risk of interaction (RERI) to assess deviation from perfect additivity of joint effects[131,132].

For Specific Aim 2 (injury predictors), 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. Each dancer had one observation per semester enrolled at UNCSA. For example, if a dancer was enrolled for three semesters, there were three observations for this dancer. 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 or not a student was injured during their previous semester at UNCSA and 2) as variable accounting for cumulative number of injuries for all prior semesters at UNCSA.

To address Specific Aim 4 (predictors of PDE), log binomial regression was used to generate prevalence ratios (PRs). Multivariable models were built only for women, since men have a low documented prevalence of EDs. However, bivariate analyses were conducted for men to look at potential predictors of PDE. Multivariable log binomial regression was used for the outcome of screening positive for ED symptoms for Specific Aim 4 among females only. Log binomial modeling was used to estimate prevalence ratios (PRs) and 95% CIs. Interaction terms were used to determine if model results should be stratified by dance type (ballet/contemporary) or program (high school/college). Likelihood ratio tests were used to evaluate the models with interaction terms compared with models without interaction terms to assess for departures from perfect multiplicativity of joint effects. Bivariate analysis using a chi-square test was conducted among males only to determine if any predictors PDE exist in this population.

For all specific aims, exploratory analyses were conducted to determine whether the continuous measures of BF% and BMI were best specified as categorical or continuous measures in models. For all categorical measures, dummy variable coding was used in the modeling.

4.9 Variable selection for multivariable models

A potential conceptual model for the relationship of covariates and the two outcomes of injury and PDE is shown in Figure 4.1. General domains of variables (excluding the two outcome measures) included: physical characteristics, history of injury, history of ED, mental health history, and health risk behaviors. For categorical variables, a variable was eligible for inclusion in multivariable models if: 1) the univariate distribution had at least five observations in each category for the gender being modeled and 2) the crude model resulted in an estimate with $p<0.25$. If any general domain did not have a variable with $p<0.25$ in crude modeling, then the variable in the domain with the smallest p-value was eligible for inclusion. Model building then proceeded in a forward stepwise procedure by domain. The best multivariable model was selected in part using statistical criteria, based on the concept that the preferred model would have a low QICu score (Specific Aim 2, injury predictors) or AIC score (Specific Aim 4, PDE predictors). The final models for each aim were chosen based on a combination of both statistical criteria and substantive area knowledge.

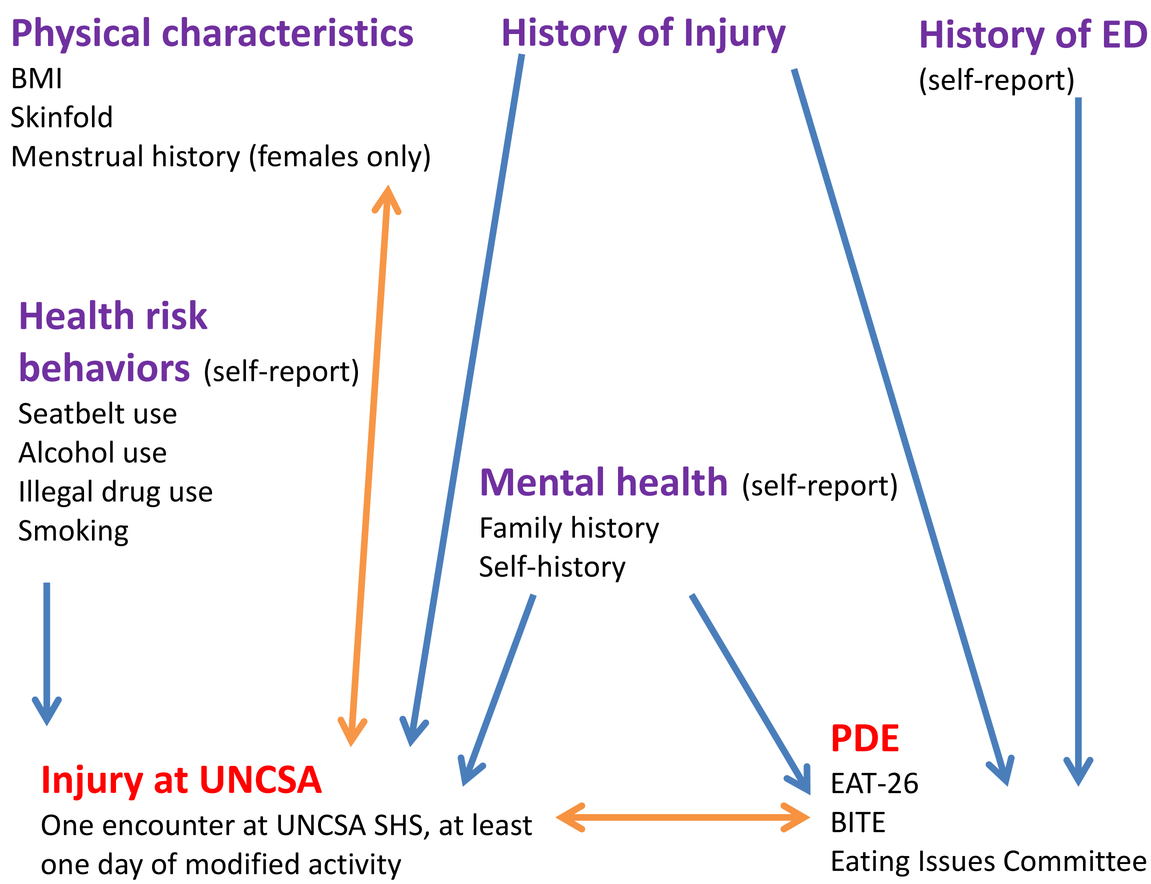
Table 4.1. List of explanatory variables

DEMOGRAPHIC CHARACTERISTICS	
	Gender
	Program
	Style
PHYSICAL CHARACTERISTICS	
	Body mass index
	Body fat percentage
	History of frequent vomiting
	History of irregular menstrual periods
MENTAL HEALTH HISTORY	
	Family history of alcohol/drug problems
	Family history of psychiatric illness
	Family history of suicide
	History of excessive worry, anxiety, or obsession
	History of treatment for ADD or ADHD
	History of depression
HISTORY OF RISK-TAKING BEHAVIORS	
	History of alcohol use
	History of illegal drug use
	History of smoking
	History of wearing a seatbelt
HISTORY OF INJURY	
	History of concussion
	History of frequent or severe headache
	History of severe head injury
	History of knee problems
	History of recurrent back pain
	History of back injury
	History of neck injury
	History of broken bone
History of eating disorder	

Table 4.2. Length of academic terms (in days), University of North Carolina School of the Arts, Fall 2009-Spring 2015

	High School		College	
	Fall	Spring	Fall	Spring
2009-2010	103	142	87	142
2010-2011	103	141	87	141
2011-2012	116	129	116	128
2012-2013	118	128	118	128
2013-2014	125	124	118	124
2014-2015	125	124	118	124

Figure 4.1: Conceptual model of covariates and outcomes



Legend: bidirectional arrows are orange, directed arrows are blue

CHAPTER 5: INJURY RESULTS (PAPER 1)

5.1 Background

Injuries from specialized athletic activities place a high burden on society. Injuries occur relatively frequently in the general population[133,134], but are especially common in physically active populations, such as athletes[13–17]. Over one-quarter of all emergency department visits are due to injuries in the United States (US)[18]. Among children 18 years or younger in the US, lifetime costs (both medical costs and work loss costs) associated with being treated at an emergency department for an injury in 2010 was $49.9 billion[135]. Furthermore, among those 18 years or younger, 20% of all injury-related emergency department visits are sport-related[19]. Sport-related injury emergency department visits account for the highest proportion of injury-related emergency department visits among those 5-14 and 15-24 years of age[20]. In addition to economic costs, effects of injuries at a young age are both physical and mental[24], and these effects can persist for years or appear decades later[15,25,26].

One form of specialized and creative athletic activity is dancing, and injuries occur frequently in ballet and contemporary dancers[36,39]. 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[3,36,41–43,45]. Among elite adolescent athletes, one review article found that injury incidence ranged from 1.6 (female gymnastics) to 6.4 (female soccer) per 1,000 hours of activity[136]. Much of the movement in dance involves the legs, and a majority of injuries to dancers are in the lower extremity[3,39,41,42,44,45,47]. Although this is true for both females and males, the distribution of anatomic injury location differs by gender[43,45]. Excelling in dance requires intensive practice, and overuse injuries, which can be defined as injuries due to repetitive microtrauma over time to the musculoskeletal system[49], are the predominant type of injury (comprising of 57-78% of injuries sustained) in dancers[36,40,42–45], with one cross-sectional study reporting that overuse injuries accounted for 44% of injuries sustained[39].

While many studies investigating injuries have studied ballet dancers, to date few studies have investigated contemporary dancers. Two of these studies investigated populations comprised of both ballet and contemporary dancers[52,98]. The remaining two studies focusing on contemporary dancers investigated either professional dancers[36] or female dance majors and minors[99]. None of these prior studies involved pre-professional male dancers studying either ballet or contemporary dance. Furthermore, only three studies focus on pre-professional dancers[3,41,44]. Two of these studies were based in the US: one was limited by small sample size (n=39)[3] and the other focused exclusively on ballet dancers[41]. The remaining study was based in the United Kingdom[44]. A better understanding of the injury incidence and predictors of injury in dancers is important because it is one of the most salient health problems relevant to dancers[11].

Therefore, the goal of this study was to 1) provide a descriptive epidemiology of the incidence of musculoskeletal injuries in an adolescent/young adult dance population and 2) 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[42,50,98], we hypothesize that 1) ballet dancers will have an increased incidence of lower extremity and decreased incidence of upper extremity injuries compared to contemporary dancers, 2) male dancers will have more upper extremity injuries than female dancers, 3) there will be no difference in lower extremity injury incidence by gender, and 4) there will be no difference in injury distribution when comparing high school dancers to college dancers. We also hypothesized that predictors for dance injury differ by gender, and therefore built parsimonious predictive models separately for males and females.

5.2 Methods

We selected the University of North Carolina School of the Arts (UNCSA) School of Dance 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 healthcare record. The closed nature and near-complete follow-up of this population facilitate the historical reconstruction of a prospective cohort study with clinically-verified incident injuries as the endpoint of interest.

We conducted a historical cohort study with incident injury as the outcome of interest. The study population was comprised of dancers who began enrollment at the UNCSA School of Dance during or after Fall 2009, and the dancers were followed up 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.

The outcome of interest, incident injury, was ascertained through detailed review of UNCSA health records. An incident injury was defined as any event which required care from UNCSA clinicians and limited dancing activity for at least one 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.

5.2.1 Incident injuries

Incident injuries were identified through a detailed review of the UNCSA Student Health Services (SHS) electronic health record (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.

Injury was defined as any event where a dancer was seen at the UNCSA SHS and the dancer needed to modify or curtail their dancing activity for at least one day due to the injury. Injuries were characterized in a number of ways: body part (e.g., ankle, back, knee), diagnosis (e.g., strain, sprain, tendinitis), and type (traumatic vs. overuse). A traumatic injury was defined as an injury where there was one specific event leading to the injury, while an overuse injury was defined as injury due to repetitive microtrauma over time to the musculoskeletal system[49]. 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 injuries. An intraclass correlation (ICC) coefficient, assuming that the two investigators represented a random sample of a potential population of raters, was calculated[137]. Overall, there was agreement on the classification of overuse for 49/51 (96%) of the injuries. The intraclass correlation 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 that a dancer was seen at the UNCSA SHS for initial care for that episode of injury. The end date of an injury was defined as either: a) 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 b) the last day a dancer was seen by UNCSA SHS clinical staff for care of the injury, whichever came first.

5.2.2 Time at risk

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. The last academic term that a student was observed was determined based on the last date that a student 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 a student's 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/his enrollment was defined as each dancer's dominant style at the time of matriculation to UNCSA. Based on clinician's 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.

5.2.3 Predictors of injury

Prior studies in general populations have found possible associations with injury and anthropometric measures[113–116], mental health history[117,118], history of risk taking behaviors[122,123], and prior history of injuries[126–129]. 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 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. BF% was calculated from the Sloan body density (BD) equations by gender and Siri BF% equation[111,112]. BMI and BF% were routinely calculated and recorded from Fall 2009-Spring 2013.

Beginning in Fall 2013, routine collection of BMI and BF% at UNCSA ended. 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; history of depression; history of excessive worry, anxiety, or obsession; and history of treatment for attention-deficit disorder or attention-deficit/hyperactivity disorder. History of risk taking behaviors included history of alcohol use, history of illegal drug use, history of smoking, and history of not wearing a seat belt. Prior history of injury included history of concussion, history of frequent or severe headache, history of dizziness or fainting spells, history of severe head injury, history of knee problems, history of recurrent back pain, history of neck injury, history of 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. Each dancer had one observation per semester they were enrolled at UNCSA. For example, if a dancer was enrolled for three semesters, there were three observations for this dancer. 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 or not 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.

5.3 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. 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 gender because the dancing activities performed in ballet vary by gender.

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 gender being modeled and 2) the crude model resulted in an estimate with $p<0.25$. The most parsimonious predictive model for each gender was the model 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.

5.4 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. 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 5.1).

5.4.1 Injury counts

There were 1,084 injuries observed in the cohort during the study; 1,014 (93.5%) were dance-related. For remainder of the results section, analyses were limited only to the dance-related injuries, and the term “injury” will be used to refer specifically to dance-related injuries. Out of 480 dancers, 118 (24.6%) sustained no injuries and 123 (25.6%) sustained one injury. The maximum number of injuries sustained by a UNCSA dancer was 15 (n=1), sustained during a 2.6 year follow-up period (Figure 5.1). Out of the 1,014 injuries, the five leading diagnoses 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%) (Table 5.2).

5.4.2 Injury rates

The overall injury rate was 4.86 per 1,000 dancer-days. Injury rate did not differ by gender (male vs. female IRR: 1.06; 95% CI: 0.87, 1.29), program (college vs. high school IRR: 0.96; 95% CI: 0.81, 1.13), or dance style (contemporary vs. 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 gender, program, or style; there were variations with overuse injury rate by age at time of injury.

Although the overall and overuse rates did not differ by gender, dance style, or program, there were differences in incidence of specific injuries by these three characteristics. 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 gender (IRR: 0.93; 95% CI: 0.76, 1.15; reference=female). 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 0.9 per 1,000 person-days, respectively), while 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 5.3).

5.4.3 Multivariable modeling

Among females, model building using forward selection and QICu scores alone indicated that the best predictive model 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-<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, 136/371 females were missing measures for anthropometric measures (i.e., BF % and BMI). Those who were missing anthropometric 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 parsimonious model included a self-reported 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).

Among males, the best predictive model (based on QICu scores) was a univariate model 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 endorsed having a history of any one of these conditions. Additionally, none of the time-varying covariates (i.e., age, history of injury at UNCSA) were predictors of injury rate.

5.5 Discussion

The overall injury rate in the present study was 4.86 per 1,000 person-days. 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 more upper extremity injuries than female dancers, while there were no differences in lower extremity injury incidence rate by gender. Previous studies have also reported differences in injury location when comparing across dance types[50,98]. These differences may relate to differences in types of movement used across dance types and by gender. For example, women lift other dancers in contemporary dance but usually not in ballet [50]. Furthermore in ballet, only females dance *en pointe*, where the dancer is in full equinus position on the foot while in full ankle plantar flexion[45,48,49]. Only males perform lifting movements and execute high jumps in ballet[45,49].

One finding that ran counter to one of our hypothesis 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/university-aged dancers have not observed any difference in injury incidence[42]. The probable reason for this finding is that a majority of college dancers train in contemporary dance, while a majority of high school students train in ballet; the difference 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 style, but the rates were 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 observed in the rates could be due to random variability.

5.5.1 Multivariable modeling

Using multivariable modeling, we found that the best predictive model (based on the low QICu score) for females a 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 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 history of depression was ascertained prior to all injuries sustained at UNCSA, previous studies investigating the association 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)[117]. One possible reason for the association of history of depression and increased injury rate is that depression is associated with insufficient sleep[138–140], and insufficient sleep may not allow for an athlete’s body to adequately recover from stresses placed on the body from everyday training loads[141]. Furthermore, sleep deprivation can lead to deleterious effects seen in sports including increased fatigue and decreased decision-making capabilities[141]. 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 history of depression as a predictor of dance-related injury, and to explore whether or not insufficient sleep is associated with injuries.

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 as there was a relatively small number of male dancers (n=109) in our study. One prior study of ballet dancers involved 179 males[42], and the remaining studies involved between 4-86 males[44,142] (mean=33.9, standard deviation=25.7); none of our study's results are directly comparable with studies from these previous results.

In interpreting our models, it is important to note that self-reported health history, though routinely collected by academic institutions for administrative purposes, may have limited utility in predicting injury rates. Self-reported health history has been used in clinical settings and institutional settings[143], typically to gain a complete picture of prior health history in order to better understand potential risk for developing future problems[144,145]. Nevertheless, our findings demonstrate that some factors—history of depression and family history of alcohol or drug problems—do have predictive capacity, suggesting that healthcare forms and administrative processes could gather these data to possibly predict those at risk for sustaining increased numbers of specific injuries (e.g., lower extremity, upper extremity) and implement strategies for injury prevention in those most at risk. Forms could also be improved to collect additional data to further refine our predictive models for injury. For example, detailed information on history of dance training prior to UNCSA (e.g., primary dance style, years of dance experience, average number of hours of dance per week in the past year) could be vital information. Furthermore, education efforts can be targeted towards dancers with either a history of injury or a family history of alcohol or drug problems to inform them about the increased risk of injury, and guidelines on how to reduce and prevent injuries can be provided.

5.5.2 Injury prevention strategies

This study found that a majority of injuries to dancers were due to overuse, and there were no differences in overuse injury rate by gender, 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 gender and dance style. These differences in our results 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[146]. Although no studies exist investigating whether or not purposefully limiting the amount of select extreme movements in all dancers will result in decreases in population injury rates, this approach can be promising. Such a limitation would be analogous to limiting the pitch count in baseball, where it has been shown that throwing more pitches is associated with both elbow and shoulder pain[147]. However, implementing such a strategy to limit movements in dance may face more barriers than doing so in competitive sports (such as baseball). In sports, objective results exist, where there are winners and losers after a competitive event. However, in ballet and contemporary dance, the purpose of practice and rehearsals is to deliver an exemplary performance; an objective goal such as defeating a competitor does not exist. Without an objective barometer of competition results to demonstrate the need to limit the number of repetitions of extreme movements in dance to reduce the injury burden in dancers, leaders in the dancing world may need to develop strategies to deliver the message that limiting extreme movements in practice and possibly rehearsal is beneficial for the long-term health and longevity of dancers and their careers. Coaching strategies such as increased awareness of overuse injuries and preventive strategies for overuse injuries may have applicability for this problem.

5.5.3 Strengths and limitations

This is one of the largest studies to date of dance injury, with 480 dancers enrolled in our study. Prior studies investigating injury incidence or prevalence among dancers have typically enrolled fewer than 200 dancers (range=22-476)[3,36,39–45,52,98]. The prospective design of a cohort study allows for injury incidence to be calculated; some studies in the past have been limited by using designs (e.g., case-control, case-series) 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 for whom 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 different biomechanics, and have a different psychological profile[148].

This study also had limitations. Only injuries that received medical attention at UNCSA SHS were captured in this study. Any injury for which the dancer received all care outside of UNCSA SHS would not be captured in this study. However, it is likely that only a small number of injuries were not captured by the UNCSA SHS EHR, as UNCSA SHS is the sole provider of health care at UNCSA, and seeking care off-campus during the academic year is unlikely. More precise exposure information regarding number of exact hours spent dancing would have been helpful in this research. Additionally, this study assumed that dancers were enrolled the entire duration of any given academic term, when some students likely dropped-out of UNCSA during the academic term. Because this study was limited to pre-existing data sources, certain known risk factors for dance injury such as biomechanics[149,150] and extrinsic risk factors (e.g., dance surface or type of footwear worn at time of injury)[151,152], were not addressed in this study. 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[153]. Furthermore, 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 any inclusion of anthropometric measures could bias our results. Despite our relatively large sample size, the small number of males (n=109) limited our ability to develop predictive models stratified by gender. Also, we were unable to build parsimonious predictive models for specific types of injury, as we did not observe a sufficiently high number of injuries to be powered to do so. Finally, this study occurred at one academic institution; the results may not be generalizable to other institutions or other levels of dance (e.g., professional dance).

5.5.4 Conclusions

Despite these limitations, valuable information can be gleaned from this study. Strategies for traumatic injury prevention among dancers should be both gender- and style-specific, as injury rates for specific body regions differed. Efforts should also be made to reduce the burden of injuries on dancers. We observed no differences in overuse injury rates by gender and style, suggesting that generic overuse prevention strategies may not need to be targeted by gender and style. One method could be to limit the volume of extreme movements in dance practice and rehearsal, though research needs to be conducted to determine if such a strategy in practice does reduce injury burden. 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 these injuries, if not the injuries themselves.

5.6 Additional information

Additional information on injury duration can be found in Appendix 4. Additional information on additive and multiplicative interaction can be found in Appendix 5.

Table 5.1: 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%)
Age (at entry to UNCSA)	16.4 (2.0)	16.1 (1.7)	17.4 (2.5)
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/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)

Table 5.2: 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 injuries	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 (%)

Table 5.3: 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	
Gender										
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

Table 5.4: Mean injury duration (in days) by body part, University of North Carolina School of the Arts, Fall 2009-Spring 2015

	Number of injuries	Mean (SD)	Range
Total	1,014	20.4 (39.0)	1-443
Foot or toe	198	22.0 (34.4)	1-235
Ankle	245	27.2 (43.1)	1-387
Lower leg	75	14.3 (20.7)	1-100
Knee	132	28.3 (64.4)	1-443
Hip or thigh	156	13.1 (23.3)	1-185
Back	137	15.4 (31.5)	1-244
Arm	7	5.7 (5.4)	1-15
Hand or wrist	6	8.3 (5.9)	1-15
Shoulder	23	13.0 (19.9)	1-81
Neck	11	10.5 (19.7)	1-64
Head	11	11.9 (14.5)	1-35
Trunk or abdomen	13	13.3 (4.0)	1-13

Table 5.5: Mean injury duration (in days) by injury diagnosis group, University of North Carolina School of the Arts, Fall 2009-Spring 2015

	Number of injuries	Mean (SD)	Range
Fracture	5	70.4 (67.7)	1-143
Stress injury (including stress fracture or stress reaction)	29	51.1 (46.2)	1-218
Sprains	103	29.8 (61.0)	1-443
Other inflammation or swelling	32	26.4 (47.8)	1-235
Tendinitis, Tenosynovitis, Enthesopathy, or Enthesopy	157	22.4 (39.9)	1-387
Syndrome	60	20.7 (31.6)	1-150
General complaint	391	18.1 (34.8)	1-284
Concussion or headache	9	14.1 (15.3)	1-35
Shin splints	27	11.2 (12.1)	1-59
Strain	129	9.7 (14.2)	1-93
Contusion	18	6.1 (9.4)	1-40
Cramp or spasm	30	5.0 (5.4)	1-22
Other	24	47.4 (65.6)	1-276

Table 5.6: Mean injury duration (in days) by specific injury diagnosis, University of North Carolina School of the Arts, Fall 2009-Spring 2015

	Number of injuries	Mean (SD)	Range
Knee sprain	7	144 (189.2)	9-443
Os trigonum syndrome	6	59.0 (63.8)	4-150
Lower leg stress fracture or stress reaction	5	53.2 (41.4)	21-100
Ankle tendinitis or tenosynovitis	14	42.8 (59.9)	1-212
Toe stress fracture or stress reaction	7	41.1 (28.5)	7-79
Foot stress fracture or stress reaction	14	40.3 (30.5)	1-102
Plantar fasciitis	17	39.1 (61.2)	1-235
Ankle sprain	56	28.6 (28.5)	1-143
Ankle stiffness	13	27.7 (55.6)	1-204
Knee chondromalacia	9	27.7 (37.3)	6-114
Achilles or peroneal tendinitis	73	25.0 (47.9)	1-387
Back sprain	6	24.3 (41)	1-105
Foot strain	7	21.7 (20.1)	2-64
Patellofemoral pain syndrome or stress syndrome	11	19.5 (33.3)	1-113
Hip enthesopathy or enthesopy	20	17.5 (27.4)	1-114
Iliotibial band syndrome	8	15.3 (7.1)	8-29
Knee tendinitis	18	14.3 (13.3)	1-46
Foot sprain	7	13.6 (22.1)	1-62
Head injury	11	11.9 (14.5)	1-35
Hip or thigh tendinitis	9	11.8 (12.8)	1-35
Shin splints	27	11.2 (12.1)	1-59
Hip or thigh strain	74	9.3 (13.1)	1-69
Back strain	21	8.2 (7.8)	1-22
Toe sprain	18	7.7 (10.6)	1-46
Foot contusion	6	7.3 (5.9)	1-16
Foot tendinitis	10	6.1 (8.9)	1-30
Calf strain	9	5.9 (5.8)	1-16
Back spasm	22	5.8 (5.8)	1-22
Ankle injury or pain, not further specified	68	24.7 (43.0)	1-276
Foot injury or pain, not further specified	51	20.5 (29.8)	1-120
Shoulder injury or pain, not further specified	13	17.3 (25.4)	1-81
Hip or thigh injury or pain, not further specified	39	17.2 (34.1)	1-185
Toe injury or pain, not further specified	26	16.6 (22.9)	1-85
Back injury or pain, not further specified	67	14.3 (25.0)	1-163
Knee injury or pain, not further specified	59	14.0 (37.1)	1-284
Lower leg injury or pain, not further specified	19	12.5 (16.5)	1-54

Figure 5.1. Distribution of number of dance-related injuries by gender, University of North Carolina School of the Arts, Fall 2009-Spring 2015

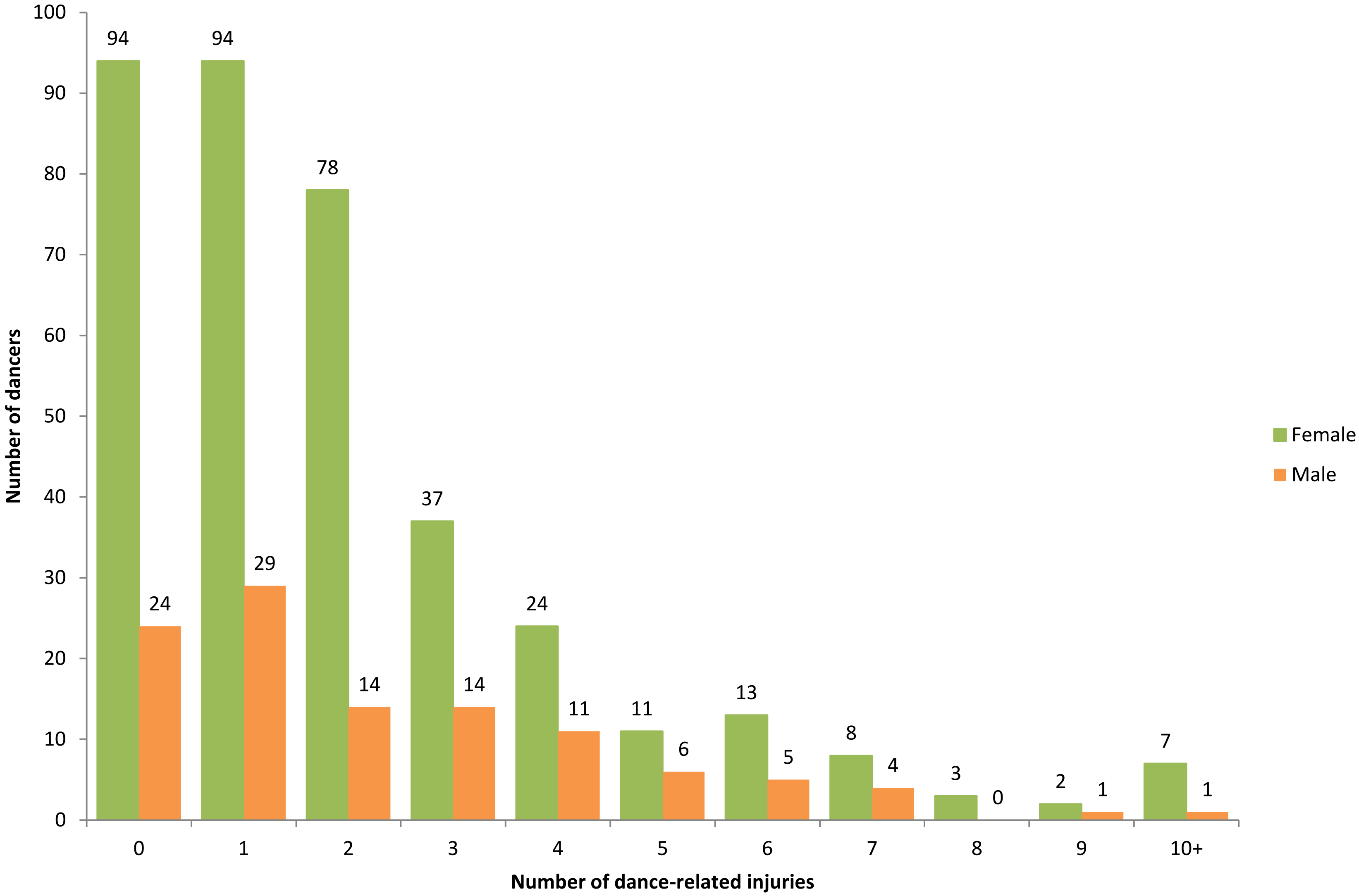
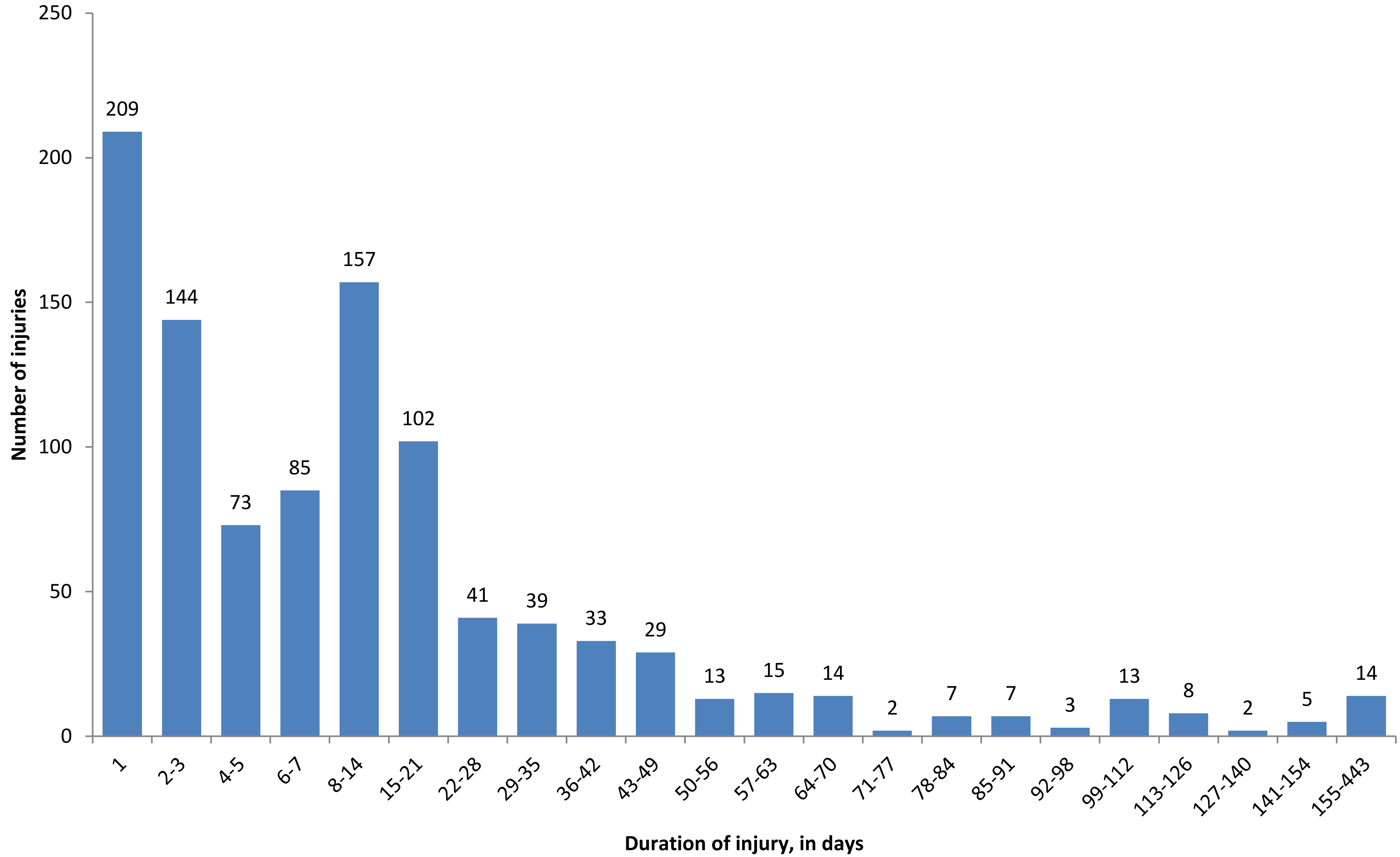


Figure 5.2. Distribution of injury duration, University of North Carolina School of the Arts, Fall 2009-Spring 2015



CHAPTER 6: PDE RESULTS (PAPER 2)

6.1 Background

Dancers undergo rigorous training, and the number of individuals specializing in dance appears to be increasing. Although no estimates exist for the number of high school or university dancers in the United States, the number of dance programs at universities has increased from 131 programs in 1966[8] to over 600 programs in 2015[10]. With an increase in number of dancers will come an increase in burden of health-related concerns for dancers, including eating disorders (EDs) and disordered eating (DE).

A meta-analysis found that the point prevalence of having an ED was 12.0% among all dancers, and 16.4% among ballet dancers[65]. Among professional ballet dancers, lifetime prevalence of having an ED ranged from 31% to 83%[66,67]. Dancers face various pressures and exhibit attitudes associated with an increased likelihood of developing an ED[67,71,72,76], yet reliable risk profiles for this group do not yet exist. This study's objective is to identify potential predictors for having possible DE (PDE) among pre-professional dancers.

6.2 Methods

The study population was comprised of high school and college ballet and contemporary dancers who began enrollment at the University of North Carolina School of the Arts (UNCSA) during or after Fall 2009 and were followed up through the end of their studies at UNCSA or Spring 2015, whichever came first. Data were obtained through UNCSA Student Health Services (SHS) either as pre-entered data or through manual electronic health record (EHR) review. The Institutional Review Boards of the University of North Carolina at Chapel Hill and Winston-Salem State University approved this study.

The presence of PDE was defined as either a) the dancer being monitored by UNCSA SHS's Eating Issues Committee (EIC, as documented in the EHR) or b) a positive screen (score ≥ 10) for DE on either the Eating Attitudes Test: 26-item version (EAT-26)[82] or Bulimic Investigatory Test Edinburgh (BITE)[91]. The EIC addresses nutrition-related concerns of UNCSA, and "safeguard[s] the physical and psychological welfare of individual students suffering from eating related disorders" (personal correspondence). Traditionally, a cutoff score of 20 is used for positive screen for DE on the EAT-26 and BITE. However, for this study, a lower cutoff of 10 was used because a) all students who scored at least 10 on either instrument were referred to the UNCSA dietitian to discuss their eating habits and b) prior research[110] shows that athletes are more likely to underreport using extreme weight control methods than non-athletes. The EAT-26 and BITE were administered online to dancers prior to the beginning of the semester in both Spring 2014 and Fall 2014. For dancers who completed the instruments both semesters, the higher of the two scores was used for this study.

Log binomial regression was used to generate prevalence ratios (PRs) and 95% confidence intervals (CIs) to identify predictors of PDE. General domains of explanatory variables included: demographic characteristics, anthropometric characteristics, history of injury, history of ED, mental health measures, and health risk behaviors (Table 6.1). Demographic characteristics were abstracted from EHRs. Anthropometric measures to calculate BMI and body fat percentage (BF%) were collected at the beginning of enrollment at UNCSA. BF% was calculated from the Sloan body density equations by gender and Siri BF% equation[111,112]. All remaining explanatory measures were self-reported on a health history form completed by all UNCSA students prior to enrollment.

Analyses were performed with SAS 9.3 (Cary, NC). Results were considered statistically significant at $p<0.05$. Bivariate analyses were conducted for men to determine if any predictors of PDE exist. Multivariable models were built only for women, since men have a low documented prevalence of EDs. For categorical variables, a variable was eligible for inclusion in multivariable models if 1) the univariate distribution had at least five observations in each category and 2) the crude model resulted in an estimate with $p<0.25$. Model building proceeded in a forward stepwise procedure by domain. The final multivariable model was selected based on a low Akaike information criterion (AIC) score and substantive knowledge about EDs and dancers. Results are reported as PR(95% CI), p-value (unless otherwise noted).

6.3 Results

Of 480 dancers in this study, most were female (77%), ballet dancers (65%), and in high school (60%). Overall prevalence of PDE was 19% [23% and 6% among females and males, respectively: 0.28(0.14, 0.60), <0.001; reference=female]. No predictors of PDE were identified among males. Among females, PDE prevalence did not significantly differ by style [0.75(0.49, 1.17), 0.21; reference=ballet] or program [0.79 (0.52, 1.21), 0.28; reference=high school] (Table 6.2).

Model building using forward selection and AIC scores alone indicated that the best predictive model for PDE among females included BMI [18.5-<20- PR: 0.42/ ≥20- PR: 0.60; reference= <18.5) and history of irregular menstrual periods (HIMP, PR: 1.58). The final model included BMI [18.5-<20- 0.38(0.18, 0.80), 0.01/BMI ≥20- 0.53(0.29, 0.96), 0.04], HIMP [1.61(0.97, 2.67), 0.06], and style [1.30(0.70, 2.41), 0.40; reference=ballet]. This final model adjusted for style, since it has been previously shown to be associated with varying ED prevalence.

6.4 Discussion

The current study is the largest to date investigating EDs or DE among dancers. Prior studies enrolled, on average, fewer than 100 dancers[65]. This study also investigated PDE patterns among male dancers; although, two prior studies have investigated male dancers and their eating patterns[14,15], this study was the first US-based study to do so. In our study of a pre-professional dance population, the prevalence of PDE among females and males was 23% and 6%, respectively. Findings indicate that DE patterns may be difficult to detect. Among females, after adjusting for dance style, the only potential predictors for PDE identified were lower BMI and HIMP (HIMP was not statistically significant).

One prior study in Germany[100] similarly found that males display fewer attitudes and behaviors associated with anorexia nervosa (AN) than female dancers. Conversely, another study in the United Kingdom[15] found that DE attitude prevalence was similar among females and males (7.3% vs. 7.6%). Our observation of a higher prevalence of PDE in females suggests females are disproportionally affected or better identified with existing screening measures (EAT-26, BITE).

Screening tools have been developed to identify those who are likely to have an ED. Although EDs are formally diagnosed with a Structured Clinical Interview for DSM Disorders, a screening questionnaire is useful for identifying those who should undergo further, more resource-intensive diagnostic testing and interviews. Two such screening tools are the EAT-26 and the BITE. We used a lower cutoff score of 10 (as opposed to the traditional cutoff of 20) to address potential issues with underreporting of weight control methods in dancers[110]. Since both the EAT and BITE were initially developed for a general population (i.e., not athletes specifically), a lower cutoff score for a positive screen may be appropriate for use with dancers. Alternatively, screening tools for DE and EDs may need to be specifically developed for dancers.

Lower BMI (related to low energy availability) and HIMP comprise two of the three conditions seen in the Female Athlete Triad (Triad) and were most predictive of PDE in our sample. Data on low bone mineral density (BMD, the Triad's third component), were unavailable. However, dancers with lower BMI and HIMP ideally may be screened for low BMD, given its relation to injury. Prior research among athletes participating in sports emphasizing endurance, low body weight, or aesthetics found that 5% have low BMD and at least one other component of the Triad[33]. Low BMD is a risk factor for stress injuries[154] and a precursor to osteoporosis[155], which increases the risk of fractures[156], precluding any weight-bearing activity including dancing. Although prior studies among dancers have investigated attitudes and behaviors associated with EDs and DE, to the best of our knowledge, only one study[157] explicitly explored risk factors for EDs and DE among ballet or contemporary dancers. The current study's finding that having HIMP may be related to increased PDE prevalence is consistent with the prior study's finding that dancers with amenorrhea were more likely to have AN[157].

This study had some limitations. First, formal diagnosis for EDs was not assessed. Only methodologically sound ED screening tools for use with non-clinical populations (i.e., EAT-26, BITE)[82] were available for analysis. Secondly, the EAT was originally developed only for females, and therefore may not be a valid screening tool for males. Thirdly, social desirability may have led to lower scores on the EAT-26 at BITE. Past studies suggest people who are unwilling to admit having an ED may score lower on the EAT [81]. However, we addressed this issue by lowering our cut-off for those classified as experiencing PDE. Finally, as this study occurred at one academic institution, results cannot be generalized to other institutions or other levels of dance (e.g., professional).

Findings from this study indicate that low BMI and HIMP were possible predictors of PDE among female dancers. Additional research should be conducted to investigate the role of the TRIAD and to identify additional predictors of PDE among female and male dancers.

Table 6.1: Dancer characteristics, University of North Carolina School of the Arts, Fall 2009-Spring 2015*

	Total	Female	Male
TOTAL	480 (100%)	371 (77%)	109 (23%)
Possible disordered eating			
Yes	91 (19%)	84 (23%)	7 (6%)
No	389 (89%)	287 (77%)	102 (94%)
Eating Attitudes Test-26 score (N missing=231)	3.9 (5.7)	4.1 (6.1)	3.1 (3.1)
Bulimic Investigatory Test Edinburgh score (N missing=231)	4.4 (5.3)	4.5 (5.6)	4.0 (3.9)
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%)
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 self-reported measures (N missing=37)			
Family history of alcohol/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 severe head injury (yes)	1 (0%)	1 (0%)	0 (0%)
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 neck injury (yes)	3 (1%)	3 (1%)	0 (0%)
History of broken bone (yes)	89 (20%)	67 (20%)	22 (22%)
History of frequent vomiting (yes)	2 (0%)	2 (1%)	0 (0%)
History of irregular periods (yes)	N/A	60 (17%)	N/A
History of eating disorder (yes)	4 (1%)	4 (1%)	0 (0%)
History of alcohol use (yes)	7 (2%)	2 (1%)	5 (5%)
History of illegal drug use (yes)	2 (0%)	1 (0%)	1 (1%)
History of smoking (yes)	5 (1%)	3 (1%)	2 (2%)
History of wearing a seatbelt (no)	1 (0%)	1 (0%)	0 (0%)
History of alcohol use (yes)	7 (2%)	2 (1%)	5 (5%)

*Numbers displayed as N(%) or mean (SD)
Abbreviations: ADD=attention deficit disorder, ADHD= attention deficit hyperactivity disorder, N/A= not applicable

Table 6.2: PRs of potential predictors of PDE among female dancers, University of North Carolina School of the Arts, Fall 2009-Spring 2015

	PR	95% CI	p-value
Program (reference=high school)	0.79	0.52,1.21	0.28
Style (reference=ballet)	0.75	0.49,1.17	0.21
Body mass index (reference= <18.5)			
18.5-<20	0.35	0.17,0.71	0.004
≥20	0.53	0.32,0.88	0.02
Body fat percentage (reference=<17.31)			
17.31- <19.67	0.80	0.47,1.37	0.41
≥19.67	0.66	0.37,1.18	0.17
Family history of alcohol/drug problems (reference=no)	1.04	0.53,2.04	0.91
Family history of psychiatric illness (reference=no)	0.99	0.48,2.05	0.98
Family history of suicide (reference=no)	0.47	0.07,3.01	0.43
History of depression (reference=no)	1.30	0.49,3.41	0.60
History of excessive worry anxiety or obsession (reference=no)	1.24	0.53,2.90	0.62
History of treatment for ADD or ADHD (reference=no)	0.75	0.26,2.13	0.58
History of concussion (reference=no)	0.85	0.24,2.99	0.81
History of frequent or severe headache (reference=no)	0.89	0.40,1.98	0.77
History of knee problems (reference=no)	1.61	0.92,2.83	0.10
History of recurrent back pain (reference=no)	1.07	0.40,2.92	0.89
History of back injury (reference=no)	1.44	0.46,4.54	0.53
History of neck injury (reference=no)	1.43	0.29,7.19	0.66
History of broken bone (reference=no)	1.11	0.70,1.77	0.66
History of frequent vomiting (reference=no)	2.16	0.53,8.75	0.28
History of irregular periods (reference=no)	2.14	1.46,3.14	<0.001
History of alcohol use (reference=no)	2.16	0.53,8.75	0.28
History of smoking (reference=no)	1.43	0.29,7.19	0.66

CHAPTER 7: DISCUSSION

7.1 Summary of findings

Among 480 dancers, 1,014 injuries were sustained, with an overall injury rate of 4.86 per 1,000 person-days. Most injuries were to the lower extremity and were overuse injuries. There were differences in upper extremity, lower extremity, and acute injury rates by demographic subgroups. Among females, the best predictive model for injury rates included a 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 current semester (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). Among males, the best predictive univariate model was better than any multivariable model. The overall PDE prevalence was 19% (23% and 6% among females and males, respectively). The best predictive model for PDE among females included body mass index (BMI 18.5-<20- PR: 0.42; 95%CI: 0.20, 0.85 / BMI ≥20- PR: 0.6; 95%CI: 0.36, 1.00; reference= <18.5) and HIMP (PR: 1.58; 95% CI: 0.96, 2.61).

7.2 Injuries

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 more upper extremity injuries than female dancers, while there were not any differences in lower extremity injury incidence by gender. Differences exist in types of movement used across dance types and by gender. For example, women lift other dancers in contemporary dance but usually not in ballet[50]. Furthermore, in ballet, only females dance *en pointe*, where the dancer is in full equinus position on the foot while in full ankle plantar flexion[45,48,49]. Only males perform lifting movements and execute high jumps in ballet[45,49].

Previous studies have shown a difference in injury location when comparing across dance styles[50,98]. One of the studies was previously based at UNCSA, and found that cervical and upper-back strains occurred twice as often in contemporary dancers as ballet dancers; low-back strains, strained hamstrings, and shin splints occurred twice as often in ballet dancers than contemporary dancers. Another study from four professional companies and university programs found that ballet dancers had a rate of anterior cruciate ligament injuries two times as high as contemporary dancers. Although the present study did not look at specific injury diagnoses, we found that contemporary dancers had higher rates of upper extremity injury and lower rates of lower extremity injuries than ballet dancers.

Using multivariable modeling, we found that the best predictive model for increased injury rates for females included a history of depression, age at time of injury, and number of injuries sustained at UNCSA prior to the current semester. A history of depression was significantly associated with increased injury rates among females. Unlike the present study, where history of depression was ascertained prior to all injuries sustained at UNCSA, previous studies investigating the association 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)[117]. Further research should be done to confirm our finding of history of depression as a predictor of dance-related injury. Age at time of injury and number of injuries sustained at UNCSA prior to the current semester at UNCSA were also in the best predictive model. It is interesting to note that in the model, as age increased, the injury rate generally decreased (based on decreasing IRRs relative to the referent category of 15 years or younger at time of injury), though only the IRR comparing those 21 or older at time of injury to those 15 years or younger was statistically significant. A prior study that directly compared middle school and high school/university-aged dancers did not demonstrated any difference in injury incidence[42]. In our study, injury rates were not significantly different when comparing by program (i.e., high school versus college), but there appears to be a possible trend for decreasing injury rates when looking at specific age categories.

Among males, there was not any multivariable model that better predicted injury rates than the best univariate model. One possible reason is that there was a relatively small number of male dancers (n=109) in our study, thus limiting our power to detect any characteristics that could be predictive of injury incidence. Another reason may be that self-reported health history, though routinely collected by academic institutions for administrative purposes, may have limited utility in predicting injury rates for males. Self-reported health history has been used in clinical settings and institutions settings[143], and is used to gain a complete picture of prior health history in order to better understand potential risk for developing future problems[144,145]. To the best of our knowledge, no prior research has investigated the utility of using administrative self-reported data to develop predictive models for a specific health condition, such as injury. Therefore, future research should address this particular knowledge gap.

7.2.1 Interaction

There were three two-way interactions explored: gender * program, gender * style, and program * style. There was no evidence of deviation from perfectly additive interaction for any of the interactions, and there was evidence of deviation from perfectly multiplicative interaction when looking at program * style. Specifically, it appeared that college contemporary dancers had elevated incidence injury rates, compared to rates expected if investigating either program or dance style alone. Additional analysis demonstrated that among eight dancers experiencing ten or more injuries, half (n=4) were college contemporary dancers. In the present study, college contemporary dancers accounted for 23% of the study population. After excluding all dancers who experienced at least ten injuries from analysis, the evidence of multiplicative interaction attenuated: the QICu score for the model without the interaction term was lower than the model with the interaction term (328.4 vs. 328.6), and the p-value for the interaction term was 0.08. Nonetheless, reasons for *why* college contemporary dancers at UNCSA constitute a disproportionate number of dancers who are most frequently injured should be investigated.

The overall lack of evidence of interaction for the other two-way interactions should not be interpreted to mean that interaction does not exist. Rather, it should be viewed as an inconclusive result; there was likely insufficient power to detect any significant two-way interactions in this study. To detect multiplicative interaction with sufficient power, a study needs to be four times as large as a study designed to detect main effects[158]. An even larger sample size is needed to detect additive interaction[159]. In the present study, we observed 1,014 dance-related injuries; 77% of the study's person-time was observed among females, and 23% was observed among males. Assuming Poisson regression was used, there was 80% power to detect an IRR of 1.25, when comparing females to males. The actual IRR observed in the study was 1.08, and GEE NB regression was used, meaning that there was less than 80% power to detect an IRR of 1.25, since the standard errors generated in NB regression are slightly wider than Poisson regression. There is also an additional decrease in power since GEE (as opposed to regular regression) was used to account for clustering of repeated events (in this study, injuries) within dancers. Therefore, since the study was not sufficiently powered to observe any main effects for the characteristics that we used for investigating interactions, there was generally insufficient power to observe departures from either perfectly additive or multiplicative interaction.

7.2.2 Concussions

Recognition of the potential long-term consequences of sports-related traumatic brain injuries is increasing, and this topic is also relevant to dance health. In the present study, there were 11 head injuries to 480 dancers, accounting for 1.1% of all dance-related injuries (11/1,014). Eight of these injuries were recorded as concussions, and the three remaining head injuries were likely concussions based on narrative descriptions of the injuries and symptoms. Of the eleven dancers who sustained head injuries, 10 were female, 6 were in high school, and 5 were ballet dancers (4 female high school ballet, 2 female high school contemporary, 1 female college ballet, 3 female college contemporary, 1 male college contemporary). The mean (SD) duration of injury for the dancers with a head injury was 11.9 (14.5) days, with a median of 3 days.

The only prior report on dance-related concussions is a case-series of 11 dancers with concussions found from a retrospective chart review of 5.5 years in a concussion clinic[160]. Ten of the dancers were female, and five different styles of dance were represented among the dancers. There were a variety of causes of injury: "Three of the concussions occurred during stunting, diving, or flipping, and another three followed unintentional drops while partnering. Two concussions resulted from slips and falls, and two others were caused by direct blows to the head. One dancer developed symptoms after repeatedly whipping her head and neck forward and back in a choreographed dance movement"[160]. In the present study at UNCSA, six head injuries resulted from sustaining contact with another dancer (e.g., being kicked in the head or being hit by an elbow), two head injuries resulted from hitting inanimate objects (piano and a steel pole), two head injuries resulted from either tripping or falling while dancing, and one head injury resulted from issues with a mechanized prop skirt. Altering the choreography of a dance piece solely for the purposes of minimizing the potential of head injuries during partnering may require too much artistic compromise. However, ensuring that dancers have sufficient space in classes to freely perform movements without the risk of contacting another dancer or object (e.g. piano) would be a useful prevention strategy. For example, during exercises where dancers utilize a large range of motion, ensuring that dancers have a certain amount of space (e.g., five feet) between them and the next closest dancer could reduce the number of injuries. Of course, much of dance involves partnering, where two people by definition need to dance in close proximity; precautions ensuring adequate space is available for each dancer are not useful in this situation.

In high school and college sports, estimates of the incidence rate of concussion range from 7 per 100,000 athlete-exposures to 94 per 100,000 athlete-exposures[161,162], and this rate varies by sport. Typically, one athlete-exposure represents one athlete participating in one practice or competition. An analogous measure for dancers would be a dancer-exposure, where one dancer-exposure represents one dancer participating in one class, rehearsal, or performance. In the present study at UNCSA, it was not possible to obtain precise information on dancer-exposure. However, assuming that each dancer on average danced in between 1-1.5 dance-related activities per person-days observed, the rate of concussion ranged from 3.5 to 5.3 concussions per 100,000 dancer-exposures. This range is on the low end of the rate found in other sports, which can be due to either a) underreporting of concussions to UNCSA SHS or b) the fact that dance is generally a non-contact activity, where there are fewer opportunities for the head to experience contact with another object. Despite the relative infrequency of concussions, these injuries have been shown in sports to have both short-term[163] and long-term[164] cognitive effects, especially in young athletes. At present, a variety of organizations, including the Centers for Disease Control and Prevention and the American Medical Society for Sports Medicine have published resources related to management of sports concussions and return-to-play guidelines[165–167]. However, dance-specific guidelines currently do not exist, and efforts should be made to either create dance-specific protocols or to adapt sports protocols for the dance setting.

7.2.3 Injury duration

Half of all injuries lasted one week or less (Figure 5.1). Injury duration varied by dance style. In addition to the fact that lower extremity injuries comprise the overwhelming majority of injuries (79.5%), these injuries also lead to longer mean duration of dance activity modification (Table 5.4). Strategies to reduce the burden of lower extremity injuries should encompass all three levels of prevention (primary, secondary, and tertiary prevention)[168]. Particular attention should be devoted to prevention strategies reducing both the incidence (i.e., primary prevention) and duration (i.e., secondary and tertiary prevention) of the injuries, which would lead to the overall decrease in prevalence of lower extremity injuries, as the prevalence odds of a problem are equal to the incidence multiplied by duration of the problem[132].

7.2.4 Interrater reliability of overuse and traumatic injuries

A study of interrater reliability was conducted for a subset of 51 injuries to determine the reliability of classification of whether or not an injury was overuse. Overall agreement on injury ratings was 49/51 (96%), and the intraclass correlation (ICC) was 0.93, meaning that 93% of the variation in the ratings was due to variation within raters. The Cohen's Kappa[169] [which accounts for the possibility of agreement by chance and ranges from zero (where agreement between raters is no better than chance alone) to one (there was perfect agreement between raters)] was 0.92, indicating excellent agreement beyond chance alone. For one of the injuries with discordant ratings, the discordance occurred because the first rater missed the portion of the narrative description of the injury describing specifically when the injury occurred; thus, the injury was improperly classified as an overuse injury (as opposed to a traumatic injury). A recent systematic review found that research investigating high school and college athletic injuries uses a wide range of definitions for the term "overuse", and has been used to describe both a diagnosis and mechanism of injury. Furthermore, "there is no consensus regarding the definition or use of the term 'overuse'"[153]. Nonetheless, in the present study, the judgment of whether an injury resulted from an overuse mechanism was concordant for 96% of injuries.

7.2.5 Prior history of injury as a predictor of injury

Two explanatory variables were classified as time-varying covariates: age and history of injury at UNCSA. For the multivariable model for males, none of the time-varying covariates were included in the final model. For females, the final multivariable model selected included a history of depression, cumulative number of injuries in prior semesters, and a self-reported history of knee problems. Only a history of depression was a significant predictor of injury rates. Much of the prior research in sports injury has suggested that prior history of injury is one of the key predictors in sustaining a future injury. Although the current study's findings indicated that neither self-reported measures of injury at time of matriculation nor clinician-determined measure for injuries (the time-varying covariate of history of injury at UNCSA) were significant predictors of injury rates, the fact that both types of measures did appear in the final multivariable model suggests that there may be some use in utilizing these measures as predictors of injury rates.

7.2.6 History of depression as a predictor of injury

The current study's results indicate that female dancers with a history of depression (i.e., both dancers who previously had depression but are no longer depressed and dancers who are currently depressed, as defined by the dancers themselves) are more likely to have an increased injury rate than female dancers without a history of depression. A small proportion (3%) of female dancers endorsed having a history of depression. Although prior research has shown that elite athletes who are injured are more likely to experience psychological consequences, including depression[117,118], no prior research has investigated whether or not those who are depressed are more likely to develop injuries. One possible reason for the association of history of depression and increased injury rate in our study is that depression is associated with insufficient sleep[138–140], and insufficient sleep may not allow for an athlete's body to adequately recover from stresses placed on the body from everyday training loads[141]. Furthermore, sleep deprivation can lead to deleterious effects seen in sports, including increased fatigue and decreased decision-making capabilities[141]. 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.

7.3 Possible disordered eating

The prevalence of PDE among females and males was 22.6% and 6.4%, respectively. DSM-diagnosed EDs have a low prevalence, and DE is generally more prevalent than EDs in the population. Given that we only identified one significant predictor of PDE among females in our study, it appears that DE patterns may be difficult to detect in elite pre-professional dancers. Among females, potential predictors of PDE were lower BMI and having a HIMP (although this finding was not statistically significant).

The best multivariable model for PDE among females included lower BMI, HIMP, and dance style. Although this model was not the best model based solely on AIC scores, this final model was chosen since dance style has been shown to be associated with varying prevalence of PDE. One interesting finding is that, while in univariate modeling contemporary dancers had a lower prevalence of PDE than ballet dancers [PR(95% CI)=0.75 (0.49, 1.17)], in the final model the opposite was true — contemporary dancers had a higher prevalence of PDE than ballet dancers [PR(95% CI)=1.30 (0.70, 2.41)], holding BMI and HIMP constant; however, neither of these findings were statistically significant. One possible explanation for this reverse association is random variation. Another reason is that differences in PDE prevalence between ballet and contemporary dancers are related to variations in BMI and HIMP across ballet and contemporary dancers (i.e., confounding).

7.3.1 Female Athlete Triad

Lower BMI (a characteristic related to low energy availability- one of the three conditions that comprise the Triad) and having a HIMP (the second condition of the Triad) were both related to increased prevalence of PDE in the present study. The third component of the Triad, low BMD, was not measured for this study. A low BMI at a certain threshold (generally BMI <17.0, though "clinical history or other physiological information"[107] may increase this threshold to 18.5 or higher) is one of the criteria for being diagnosed with AN. Those with AN have low energy availability due to a lower amount of calories consumed. One study found that patients hospitalized with AN consumed over 600 calories per day fewer than normal controls[170].

Dancers with a lower BMI and a HIMP may need to be screened for low BMD: in a previous study, 5.6% of athletes participating in lean sports (i.e., sports that emphasize endurance, low body weight, or aesthetics) had both DE and low BMD, 3.3% of athletes participating in lean sports had both menstrual dysfunction and low BMD, while 1.5-6.7% of athletes participating in lean sports had all three Triad components (conceptualized as DE, menstrual dysfunction, and low BMD)[33]. Low BMD is a risk factor for stress injuries[154] and a precursor to osteoporosis[155]. Osteoporosis increases the risk of developing fractures[156], precluding any weight-bearing activity such as dancing. Thus, screening for low BMD may also be critical in ensuring that the risk of sustaining injuries is minimized.

7.3.2 BMI

When trained clinicians engage in discussions about eating habits with dancers with PDE, a holistic approach needs to be taken for the benefit of the dancer's health. Although discussions about reaching a healthy weight can be useful, focusing solely on the number on a scale alone is not sufficient, as EDs and DE are multifactorial issues that result both in and from different cognitive (e.g., belief that one needs to be thin to be attractive versus be thin to enhance performance), emotional (e.g., binge eating as an emotion regulation strategy, such as way to cope with stress), physical (e.g., eating results in gastrointestinal distress), and behavioral features (e.g., restriction, self-induced vomiting, binge eating, extreme levels of exercise)[107] for different people. In the general population, various factors have been found to be associated with EDs and PDE (e.g., dieting, low self-esteem, parental overweight)[171]. Furthermore, EDs and PDE are not limited to those with low BMI, as AN is the only ED where BMI is a diagnostic criterion[107]. In the present study, 13/23 (57%) female dancers with BMI <17.0 [considered significantly low body weight by the World Health Organization (WHO) and American Psychiatric Association[107]] had PDE. Although this proportion generally decreased with increasing BMI, a sizeable proportion (36/181, 19.8%) of dancers with what is traditionally considered "normal" BMI (BMI=18.5- <25) had PDE. There were two female dancers with BMI ranging from 25.0-25.5, and neither of these dancers had PDE. This distribution is consistent with past research, as specific DSM-diagnosed EDs are associated with the entire spectrum of BMI (i.e., underweight, normal, overweight, and obese)[172].

Dancers with "normal" BMI still feel self-imposed and external pressure to maintain or lose weight. Ideal body types exist for dancers[106] and other issues related to eating habits exist. The need to achieve an ideal body type stems from both internal (i.e., from the dancer themselves) and external pressures (from sources other than the dancer)[73,74]. While external pressures may be exacerbating the internal pressures to achieve an ideal weight, discussions on strategies to alleviate the internal pressure is one of the more feasible discussions to be held. Therefore, instead of focusing on an outcome of achieving a certain weight or shape, discussions centered around root causes of DE patterns (i.e., *why* a dancer engages in these behaviors and genetic and biological factors) and their serious consequences can potentially help the dancer understand the reasons for the behaviors and associated severity, perhaps facilitating motivation to change eating toward healthier eating patterns.

Only one previous study has investigated EDs or DE among male dancers. Using the EAT-40 (German version), this study found that male ballet students had significantly lower scores than both female ballet students and male controls (non-dancers)[90]. In our study, male dancers had lower EAT-26 scores and BITE scores than female dancers.

7.3.3 School-based committees

Although multiple studies have investigated the effect of school-based intervention programs on preventing and mitigating the effects of EDs and DE patterns at both the high school and college level[173,174], limited literature exists on the utility of having a school-based committee to monitor for EDs and DE patterns. One study based at a Canadian residential ballet school implemented systemic school-wide changes to reduce DE patterns. One change made was the initiation of focus group meetings occurring multiple times annually to identify factors that could contribute to developing DE patterns (e.g., preoccupation with body weight and shape). After implementing the systemic changes, the proportion of students who scored >20 on the EAT-26, binged in the past year, vomited in the past year, and used laxatives in the past year all declined[175].

In Fall 2015 (after this study ended), there were at least 25% of UNCSA dance students (both female and male) who had DE, and approximately 30% of the students with DE had a diagnosable ED (written correspondence with UNCSA athletic trainer, October 2015). During the present study, 91/480 dancers (19.0%) had PDE. The increased prevalence of PDE (after the study) is not necessarily indicative of an actual increase in prevalence. Rather, it is likely an indication that PDE is now better identified in the UNCSA dancers, as better rapport has reportedly been built between the dancers and UNCSA SHS staff (personal correspondence with UNCSA SHS staff). This rapport and trust needs to continue to grow to allow for early identification of problematic ED symptoms for the purposes of intervention, ultimately to reduce the burden of EDs and DE among UNCSA dancers. Then, the possibility of implementing systemic school-wide changes (within the School of Dance, as opposed to all of UNCSA) is possible as a potential avenue to reduce PDE and DE patterns.

7.3.4 Incident versus prevalent PDE

The prevalence of PDE in this study among females and males was 22.6% and 6.4%, respectively. From an epidemiological perspective, those who had PDE in our study likely consisted of both “incident” cases (i.e., dancers who did not have PDE prior to matriculation at UNCSA, and developed PDE while at UNCSA) and “prevalent” cases (i.e., dancers who already had PDE before matriculation at UNCSA)[132]. A manual review of EHRs for the 56 female dancers who were monitored by the EIC showed that 26 of the dancers were monitored by the EIC within two months of matriculating at

UNCSA, and the remaining 30 were monitored after three or more months at UNCSA. Although there is not an established benchmark that describes that length of time needed to develop EDs or PDE, it seems improbable that the 26 dancers who were monitored within two months of being at UNCSA were completely free of ED or DE symptoms before arriving at UNCSA. Among the remaining 28 female dancers who had PDE (based on EAT-26 or BITE scores $\geq$ 10), 10 dancers had scores above the cutoff score at the beginning of the first semester of enrollment at UNCSA. Thus, 36/84 (43%) female dancers appeared to be "prevalent" cases of PDE (i.e., they likely had PDE before arriving at UNCSA), and the remaining 57% (n=48) could possibly be classified as "incident" cases of PDE.

An "incidence proportion" of PDE can be calculated with the available information. Assuming there were 48 "incident" cases of PDE and 36 cases of "prevalent" PDE and that there were 371 female dancers total in our population, there were 335 (371-36) female dancers who could be considered free of PDE at the beginning of the study. An additional three dancers were considered to not be disease free at the beginning of the study, as they marked "yes" to having a history of EDs on the health history form. Therefore, there were 332 female dancers free of PDE at the beginning of the study. The overall "incidence proportion" of PDE was 14% (48/332). On the surface, it appears that either "incidence proportion" or prevalence could be used as the measure of occurrence for PDE (i.e., how frequently PDE occurs in our population), since both measures essentially involve a numerator with number of PDE cases (either total of PDE cases or number of new PDE cases) and a denominator as the number of people in the study (either total number of people or number of people who were disease-free). However, since it is difficult to pinpoint the exact moment of incidence for PDE and EDs, the more appropriate measure to use in the present study is prevalence, as calculated in the results.

The outcome measure of PDE was constructed based on a combination of a few characteristics: institutional monitoring by UNCSA SHS and having a positive screen on the EAT-26 or the BITE. UNCSA SHS had the EIC, which was in existence at the beginning of our study in Fall 2009. However, the EIC was replaced in 2013 by a different committee not focused exclusively on eating issues (personal correspondence with UNCSA athletic trainer). The last semester that the EIC convened was Fall 2012. For the duration of the study, UNCSA SHS also monitored select dancers' weights by weighing these dancers at every visit to SHS, or weighing them blindly such that the dancer did not know their weight after being weighed. Out of 44 dancers who were discussed by the EIC, 23 (52%) also were weighed regularly by SHS, as noted in the EHR. An additional 12 dancers were weighed regularly by the SHS after the EIC was disbanded. The EAT-26 and the BITE were both administered to all dancers in Spring 2014 and Fall 2014, and are screening tools generally used to assess ED symptoms. The fact that our outcome of PDE was a combination of different characteristics also likely contributed to the fact that both "incident" and "prevalent" cases of PDE were captured.

7.4 Strengths

This study had some key strengths. This study investigated both ballet and contemporary dancers; very limited research exists on contemporary dancers. Prior studies investigating injury incidence among dancers have enrolled, on average, fewer than 200 dancers (range=22-476)[3,36,39–45,52,98]; having included 480 dancers, the present study is the largest study to date. Furthermore, the prospective cohort design of the current study allows for injury incidence to be calculated; some studies in the past have been limited by using designs (e.g., case-control, case-series) 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 whom we could observe from the beginning of their enrollment at UNCSA. The first term that dancers were observed in this study was Fall 2009, and only dancers who began enrollment in Fall 2009 or later were included in the study. If a dancer was enrolled at UNCSA Spring 2009 or before, then the dancer was not included in this study. One previous study found that dancers who drop out of a program early have been found to sustain more injuries, have different biomechanics, and have a different psychological profile[148]. Therefore, by following only students who we could observe from the start of their studies at UNCSA, we minimized the likelihood of disproportionately including or excluding dancers who may have different biomechanics and psychological profiles.

The International Association for Dance Medicine and Science (IADMS) has put forth a recommended definition of injury: "an anatomic tissue-level impairment as diagnosed by a licensed health care practitioner that results in full time loss of activity for one or more days beyond the day of onset"[176]. IADMS recommends that events that do not meet all of the criteria in the definition be classified as musculoskeletal complaints. Based on the IADMS definition, this study investigated musculoskeletal complaints, as it was not limited to events resulting in full time loss of activity; this study included events where activity needed to be *modified* for at least one day. While a more stringent injury definition of time loss demarcates more serious injury incidents, using an activity modification definition allows for more events to be included, thus increasing the power to detect potential characteristics that are predictive of increased injury rates.

For the injury aims, we reviewed EHRs to ascertain injuries to dancers. Many prior studies rely on dancer recall of injuries, and therefore were prone to recall bias. This study did not rely on the memory of any individual for detecting injuries. All dancers' EHRs were reviewed for the entire study period; thus all injuries that met this study's definition of injury were captured in this study.

Prior studies investigating EDs or DE patterns were mostly limited to females, and enrolled, on average, fewer than 100 dancers (range=10-347)[66,67,70–72,75,76,87,100,157,177–183]. To the best of our knowledge, two prior studies included male dancers[70,100]. In the present study, 249/480 participants completed screening tools for ED symptoms (i.e., the EAT-26 and BITE), and all participants were investigated for the outcome of PDE. This study also investigated PDE patterns among male dancers; two prior studies have investigated male dancers and their eating patterns[70,100], but this study was the first US-based study to do so. Furthermore, changes in DSM criteria since the EAT was first developed in the 1980s mean that the EAT is now best used as a screening tool to identify DE, as opposed to the original intent of identifying AN specifically[184]. This study applied the EAT-26 (and BITE) in a manner such that DE patterns in general were screened for, as opposed to AN or any other specific ED diagnosis.

7.5 Limitations

Our study also had a few limitations of note. The data collected for this study were from clinical EHRs. The main purpose of EHRs at UNCSA is not to provide data for research purposes, but to ensure that adequate information exists to understand the health-related issues the students are experiencing, and to coordinate care across multiple providers. Therefore, while the information is useful for clinical purposes, some of it is not adequately complete for research purposes.

Only injuries that received medical attention at UNCSA SHS were captured in this study. Any injury where a dancer received care exclusively outside of UNCSA SHS was not captured in this study.

However, it is likely that only a small number of injuries were not captured by the UNCSA SHS EHR, as UNCSA SHS is the sole provider of health care at UNCSA.

In this study, an injury was defined as any incident where a dancer needed to modify any dance-related activity for at least one day. The start date of injury was the first time the dancer was seen at UNCSA SHS for the injury (regardless of when the activity modification began), and the end date of the injury was defined as the date when a UNCSA SHS clinician noted that the dancer could either participate in dance activity to tolerance or was cleared for activity (whichever date was first). However, for different dancers, activity to tolerance may hold different meanings; thus, when a dancer is allowed to dance to tolerance, different dancers may dance through different pain thresholds.

Furthermore, precise exposure information regarding number of hours spent dancing were unavailable; therefore, injury rates were likely underestimated with NB regression, as this study assumed that dancers were enrolled the entire duration of any given academic term, when some students likely dropped-out of UNCSA in the middle of an academic term. Additionally, injuries are a multifactorial problem typically with multiple causes. Certain known risk factors for injuries, including biomechanics[149,150] and extrinsic risk factors[151,152], were not addressed in this study.

We assumed that the primary style of dance the dancer focused on was the style at time of enrollment into UNCSA. However, approximately 5% (21/480) of students switched styles during their time at UNCSA. Dancers who switch style generally switch from ballet to contemporary dance, as the training for contemporary dance is considered to be less physically demanding in musculoskeletal terms than ballet, and many dancers who switch sustain a variety of injuries while at UNCSA. Therefore, dancers who switch styles may be intrinsically different than dancers who start and end in the same style of dance. Since a small proportion of dancers switched styles during the study, we anticipate bias did not affect our results.

We investigated PDE, and did not explore formal diagnosis for any ED. EDs are formally diagnosed through SCIDs, and SCIDs have not been performed by UNCSA SHS on the complete population of dancers. However, SCIDs are lengthy and burdensome, taking 1.5-3 hours to complete, and not likely feasible to implement in a clinic with limited resources and staff. Further, SCIDs must be administered by professionals specially trained in the delivery of the SCID. Less time-consuming assessments are more ideal for screening for eating disorders in clinical practice (see below 7.6 Public health implications section for further detail). Thus, the EAT-26 and BITE were administered, and a positive screen for ED symptoms was used as part of the outcome of interest (PDE), as opposed to a DSM-diagnosed ED. Previous studies have suggested that, despite the fact the EAT cannot be used to formally diagnose an ED in non-clinical populations, it can be used in non-clinical settings as a screening tool[82]. Additionally, the EAT-26 and BITE were only administered for two semesters (out of 12 semesters of this study); thus, less than half of dancers in this study completed these screening instruments. To increase the number of dancers in the study for this outcome, we also investigated for all dancers whether or not a dancers was institutionally monitored by UNCSA SHS (either being discussed by the EIC or being regularly weighed). This composite outcome (i.e., EAT-26/BITE scores and institutional monitoring) may represent slightly different domains and manifestations of PDE patterns, but allowed for the inclusion of the maximum possible number of dancers in this study.

The EAT was originally developed only for females, and therefore may not be a valid instrument to use among males. Furthermore, the EAT was developed among college students; wording on the EAT may not be understood by younger populations or those with limited reading ability[185]. However, literacy issues were not expected in this population, as the high school students at UNCSA also undergo a rigorous academic curriculum meeting standards for the state of North Carolina[186]. Prevalence of EDs is low, and prevalence of ED symptoms is also likely low. Many of the positive screens for ED symptoms are likely to be false positives, since the positive predictive value of a screening test depends on the condition that is being screened for[168]. Nonetheless, EDs are conditions that can have lifelong impacts, and the harms of a false positive on a screen for ED symptoms outweigh the harms of a false negative.

7.6 Public health implications

Implementing a screening program for PDE is sensible. According to a report commissioned by the WHO, two of the key criteria for whether or not a health condition should be considered for screening are that a) the cost of conducting a screening test to identify cases should be reasonable relative to potential costs of medical care for the condition and b) the condition should be treatable[187,188]. PDE is a strong candidate for screening, as the cost for a screening test is relatively low. PDE can be conceptualized as the nascent stages of an ED, and screening tools for EDs are generally conducted with questionnaires which are inexpensive (as opposed to, for example, screening tests using biological specimens), and prevention or early detection of an ED can save thousands of dollars that could be spent on treatment when an ED is in more advanced stages. Furthermore, PDE is a suitable condition for screening since treatment options are widely available.

While PDE is a suitable condition for screening, using the predictors that we identified for females (HIMP and lower BMI) would not be reasonable as the test used for screening. The presence of both HIMP and lower BMI (<18.5) in a dancer cannot be interpreted as definite presence of PDE. Among 208 female dancers who had information available for both BMI and HIMP, 10 had BMI <18.5 and HIMP, 63 had only BMI <18.5, and 20 had only a HIMP. If treating the presence of both underweight BMI and HIMP as a positive screen for PDE, it is possible to calculate sensitivity [number of dancers who are true positives (those who have low BMI, HIMP, and have PDE) divided by the number of dancers who have PDE], specificity [number of dancers who are true negatives (those who do not have both low BMI and HIMP, and also do not have PDE) divided by the number of dancers who do not have PDE], positive predictive value [PPV, number of dancers who are true positives divided by the number of dancers who screen positive (those who have both low BMI and HIMP)], and negative predictive value [NPV, number of dancers who are true negatives divided by the number of dancers who do not screen positive (those who do not have both low BMI and HIMP)] of this “screening test”. The sensitivity, specificity, PPV, and NPV was: 0.058, 0.955, 0.300, 0.753, respectively[189] (Appendix 6).

While the specificity and NPV (0.955 and 0.753, respectively) were reasonably robust, the sensitivity and PPV (0.058 and 0.300) were poor. Although established criteria for what consists of a “good” screening test does not exist, the low specificity and PPV indicate that the combination of HIMP and low BMI alone would not be adequate as screening criteria for the screening test. Among the female dancers, only 5.8% of those who have PDE would be detected by the screening test, and 30.0% of the dancers who screen positive would truly have PDE. Nonetheless, a variety of screening tools for EDs have been developed in the general population and can be used among dancers for PDE. However, research needs to be conducted to determine if better tools can be developed specifically for use among dancers.

For injuries, primary, secondary, and tertiary prevention strategies should be implemented to reduce the burden of injuries, and especially lower extremity injuries. These strategies would reduce both the incidence and duration of injuries, and therefore lower the overall prevalence of the injuries. Furthermore, interventions need to be tailored by subgroups of dancers for certain types of injuries. Interventions focusing on upper extremity injuries should be focused on males, college students, and contemporary dancers. Lower extremity injury interventions should focus on ballet dancers, and acute injuries should be tailored towards male dancers and college students. However, when addressing overuse injuries, specific strategies do not need to be developed by subgroup.

7.7 Specific implications for UNCSA screening

In the current study, the purpose of model building was to determine if any characteristics could predict either increased injury rate or increased PDE prevalence. The final models were the most parsimonious models based on the data available. Building parsimonious models is an important undertaking, as these models determine which characteristics are the most salient in predicting a health outcome. In an age when health questionnaires are being used more and more frequently, the number of items is ever-burgeoning. However, limiting the number of questions reduces respondent burden especially in terms of time taken to complete the questionnaire. Therefore, in this study, we attempted to identify the factors that were most important in predicting our outcomes. The findings of our study demonstrate that items on the UNCSA health history form related to a history of depression and irregular periods are important to keep for the purposes of helping identify female dancers who may need extra care to prevent injuries and PDE.

In this study, we considered two sets of anthropometric measures as predictors of injuries and PDE: BMI and skinfold measures. Between the two measures, only BMI appeared to be a predictor of one of the study outcomes: PDE (specifically among females). Height and weight measures used to calculate BMI can continue to be collected, and skinfold measures do not need to be collected. Only height and weight are needed to calculate BMI, while skinfold caliper measurements require multiple, more invasive measurements than collecting height and weight. Furthermore, skinfold measures are used in equations to calculate BF%, and someone trained specifically in taking these measurements needs to measure the skinfold sites. Measurement readings for the same subject can vary across different people measuring the skinfold: this problem with standardization suggests that there is a greater potential for biased calculations for BF% compared with BMI. Thus, since BMI appeared to be predictive of one of the study outcomes (whereas BF% was not) and measuring height and weight are relatively simple, any use of anthropometric measures for exploring injuries or PDE should center around BMI measures, not BF%.

7.8 Future research

While screening tools for EDs exist for general populations, future research should focus on screening tools that can be used specifically among dancers. First, testing should be done to determine whether or not screening tools that already exist are valid and reliable within the dancing population. The development of gender-specific tools also should be explored. While the screening tools that do currently exist are relatively low-cost, developing a tool that utilizes information that is already routinely collected from dancers can further reduce the cost (especially of time) of such tools.

Acute injuries differed by gender and dance style, and research focusing on incident specific characteristics (e.g., type of shoe, location of injury, activity, activity being performed) should be routinely recorded in medical charts so that research can determine if the presence of any incident-specific characteristic increases the injury rate. Although the present study suggests the overwhelming majority of injuries are due to overuse, determining whether any incident-specific characteristics are associated with increased injury rate would help inform interventions that could be targeted by gender and style, since overuse injuries did not differ by gender or style. Future studies should also continue to explore whether a history of depression (both having a past history of depression and current depression) is a predictor of increased injury rates, as the current research investigating both depression and injury investigates depression as a sequelae of injury, rather than injury as a sequelae of depression. Additionally, as insufficient sleep is associated with depression, future research could investigate whether or not insufficient sleep is associated with increased injury rates.

This study contributes to public health through finding ways to optimize healthy physical activity in the form of dance. Although injuries and EDs are relatively common among dancers, early detection and prevention of these two conditions is important, as long-term consequences can arise from these problems. Just as the present study applied epidemiologic methods to determine injury rates, PDE prevalence, and potential predictors of these two outcomes, future studies should continue to use epidemiologically sound methodology to advance the state of literature in two important health topics, injuries and EDs, among an understudied population, dancers.

APPENDIX 1: PRIOR STUDIES OF DANCE-RELATED INJURIES

Author, Year	Study population	Methods	Injury definition and reporting	Injury incidence	Key results
Allen 2012[43]	Female [n=27, age= 25(6), BMI=18.9 (1.6)] and male [n=27, age=23(5), BMI=22.2(1.4)] dancers in one professional ballet company; unknown location	Prospective cohort study with one performance year of follow-up, year unknown. There were 2/52 dancers excluded since an injury was sustained outside of dancing	"Any injury that prevented a dancer from taking a full part in all dance-related activities that would normally be required of them for a period equal to or greater than 24 hours after the injury was sustained" (time-loss definition) was reported by in-house physiotherapists on a standardized injury assessment form.	Rate (95% CI): Overall: 4.44 (4.00, 4.93) per 1000 dance-hours, Females: Overall: 4.14 (3.57, 4.81), Class: 4.94 (3.70, 6.59), Rehearsal: 2.43 (1.88, 3.14), Performance: 4.45 (3.22, 6.14), Males: Overall: 4.76 (4.12, 5.51), C: 7.54 (5.91, 9.61), R: 2.99 (2.35, 3.80), P: 5.19 (3.81, 7.08).	*All dancers had at least one injury, mean number of injuries=6.8 per dancer *No correlation between age and injury incidence or number of injuries *68% overuse in females, 60% overuse in males *Intrinsic/extrinsic factors: 64% due to intrinsic factors in females, 66% due to intrinsic factors in males *Anatomic distribution: Female: 17% lower leg, 15% ankle, 10% foot, 16% lumbar, 5% knee, 13% neck. Male: 19% lower leg, 13% ankle, 8% foot, 12% lumbar, 9% knee, 10% neck
Bowling 1989[52]	Female [n=80, BMI=18.52] and male [n=61, BMI=20.97] dancers in seven professional ballet or modern dance companies; UK	Cross-section questionnaire mailed in spring 1987. Response rate=75% (141/188)	Definition not provided. Self-report of injury that ever affected their dancing. More detailed information was collected for injuries sustained in the past six months.	84% reported at least one lifetime injury that affected their dancing, 48% reported currently having at least one chronic injury that caused continuing problems.	*Anatomic distribution of injuries in past six months: 26% back/neck, 19% ankle, 12% knee, 10% thigh/leg, 16% foot/toes, 5% upper limb, 12% other *Injury mechanism for injuries sustained in the past six months: 60% muscle/ligament sprain, strain, tear, or pull; 12% muscle/tissue bruising, swelling, or inflammation; 12% fracture; 16% dislocated joint *No differences in injury experience by age, sex, BMI, or dance style
Byhring 2002[40]	Professional female [n=27, age=26 (5.7), BMI=18.6 (0.8)] and male [n=14, age=27 (4.6), BMI= 21.9 (0.8)] dancers in one national ballet company; Norway	Prospective cohort study with 19 weeks of follow-up in autumn 1998. Participation rate= 80% (41/51)	"An injury that occurs as a result of participation in dancing, leads to reduction in the level of training, and requires a need for advice or treatment", assessed and registered by the physiotherapist working for the national ballet	75% had at least one injury during follow-up	*Mean number of injuries=3.2 per dancer *78% overuse *Anatomic distribution: The three most common locations were leg, knee, and hip

Campoy 2011[39]	Female and male ballet dancers (n=258) participating in the 26th Dance Festival of Joinville; Brazil	Cross-section questionnaire administered in 2008	"Any pain or musculoskeletal condition resulting from training and competition sufficient to alter the dancer's normal training routine in terms of form, duration, intensity or frequency". Self-reported for the past 12 months.	76.4% reported at least one injury in the past 12 months	*44% overuse *Anatomic distribution: 29% ankle/foot, 28% thigh/leg, 22% knee, 14% upper limbs, 7% trunk/hip
Ekegren 2014[44]	Female (n=154) and male (n=112) students (age=17.2 (1.21), range=15-23) in three pre-professional ballet schools; London	Prospective cohort study with one academic year of follow-up, year unknown. Participation rate=100%	"Anatomic tissue-level impairment as diagnosed by a license health-care practitioner that results in full time loss of activity for one or more days beyond the day of onset. 'Activity' means participation in a class, rehearsal, or performance". Reported by on-site physiotherapists.	**Rate** (95% CI): 1.38 (1.24, 1.52) per 1000 dance-hours (95% CI=1.24, 1.52); 1.87 (1.68, 2.06) per 1000 dance exposures **Proportion**: 76%	*378 injuries, 1.42 injuries per dancer *Incidence rate and proportion did not differ by gender *72% overuse *Anatomic distribution: 77% lower extremity, 16% trunk, 3% head and neck, 3% upper extremity. Among lower extremity injuries, 33% ankle, 22% lower leg (shin and calf), 20% foot, 13% knee, 10% hip/groin, 2% thigh *Injury mechanism: 46% structure and ligament, 30% muscle, tendon, myofascia, 19% bone fracture/stress injury, 5% other
Frusztajer 1990[178]	Female ballet dancers with stress fracture in the past year (n=10), ballet dancers without stress fractures in the last three years (n=10), non-dancers who had never had a stress fracture (n=10); unknown location	Age and height for weight matched case-control study, year unknown	Clinical interview about stress fractures, medical record review	Not applicable	*BMI: dancers with stress fracture [18(1.7)], dancers without stress fracture [19 (1.3)], non-dancers [19 (1.9)], differences not statistically significant *EAT-26 scores: dancers with stress fracture [16.1(10.0)], dancers without stress fracture [10.5 (7.0)], non-dancers [10.1(7.3)], differences not statistically significant

Gamboa 2008[41]	Female [n=288] and male [n=71] dancers [age=14.7 (1.9), range=9-20]enrolled at a pre-professional ballet boarding school; Washington DC	Retrospective cohort study for five academic years (excluding summer months): 2001-2006.	A dancer sought at least one treatment from an in-house physical therapist. Medical record review for five academic years	**Rate**: 1.09 per 1000 athlete-exposures, 0.77 per 1000 dance-hours **Proportion**: 55%	*151 dancers sustained 198 injuries *For each academic year, the proportion of overuse injuries was 88%, 86%, 69%, 77%, 55% *Anatomic distribution: 53.4% foot/ankle, 21.6% hip, 16.1% knee, 9.4% back *Injury not associated with age or menstrual history
Garrick 1997[53]	Female (n=3,082) and male (n=878) ballet dancers treated at a multidisciplinary sports clinic; California	Case series of 3,798 injuries treated over 17 years, years unknown.	None provided. Medical record review.	Not applicable	*44% overuse in females, 34% overuse in males *Anatomic distribution: Females: 7% lumbar spine, 10% hip, 20% knee, 8% leg, 18% ankle, 28% foot, males: 11% lumbar spine, 6% hip, 23% knee, 10% leg, 15% ankle, 20% foot *Injury mechanism: Females: 8% fracture, 9% sprain, 24% strain, 44% overuse, Males: 7% fracture, 13% sprain, 27% strain, 34% overuse
Hamilton 1989[76]	Female [n=14, age=29.23 (5.25)] and male [n=15, age=29.93 (4.25)] soloists or principals (age range=22-41) in two professional ballet companies; New York City	Cross-section questionnaire, year unknown. Participation rate=48% (29/60)	No definition provided. Self-reported for lifetime.	Not reported	*Lifetime prevalence of overuse syndromes was 77% for women and 50% for men *Lifetime prevalence of stress fractures was 31% for women and 21% for men.
Leanderson 2011[42]	Female [n=297] and male [n=179] dancers (age range=10-21 years) in one public ballet school; Stockholm	Retrospective cohort study, 1988-1995, participation rate=100%	No definition provided. Reporting for any injury where any orthopedic care was received.	**Rate**: Girls: Overall: 0.8 per 1000 activity-hours, ≤10: 0.3, 11-14: 0.7, 15-21: 0.9 Boys: Overall: 0.8 per 1000 activity-hours, <10: 0.5, 11-14: 0.6, 15-21: 1.1, **Proportion**: 44%	*210 dancers sustained 438 injuries *77% overuse for both girls and boys *Anatomic distribution: 52% foot/lower leg, 21% knee, 13% back, 11% hip/thigh, 4% upper extremity/other *Injury not associated with age

Luke 2002[3]	Female [n=34] and male [n=5] pre-professional dancers (age=15.8 (1.0), range=14-18) in one liberal arts high school with mostly classical ballet training; Massachusetts	Prospective cohort study, year unknown. Participation rate=39/55 (71%)	No definition provided. There were two methods of reporting: 1) biweekly self-report survey, 2) injury where a dancer visited a physical therapist	4.7 injuries per 1000 dance-hours for self-reported injuries, 2.9 injuries per 1000 dance-hours for injurie seen by a physical therapist.	*71 injuries seen by a physical therapist *56% overuse for self-reported injuries, 49% overuse for injuries seen by a physical therapist *Anatomic distribution for self-reported injuries: 50% ankle, 12%hip, 12% back, 11% foot, 7% lower leg, 7% knee, 1% arm/hand *Injury mechanism: Self-reported injuries: 56% overuse, 23% sprain/strain, 4% fracture, 4% soft-tissue injury, 13% other/missing, Injuries seen by a physical therapist: 49% overuse, 46% sprain/strain, 3% soft-tissue injury, 1% neurologic
Nilsson 2001[45]	Female and male dancers (n=108, mean age=28.3, age range=17-47) in a professional ballet company; Stockholm	Cohort study with five seasons of follow-up (retrospective for two seasons, prospective for three seasons), 1988-1993.	None provided. Injuries from the first three seasons seen by an orthopedic consultant were recorded on a form. Injuries from the last two seasons where medical consultation was sought were recorded on a similar form.	Overall: 0.62 per 1000 activity-hours, Female: 0.56 per 1000 activity-hours, Male: 0.70 per 1000 activity hours	*98 dancers sustained 390 injuries *57% overuse *Anatomic distribution: Total: 54% ankle/foot, 2.8% lower leg, 11.0% knee, 3.8% though/groin, 17.9% back/gluetal region, 7.2% upper extremity, 1.9% misc. Female: 62% ankle/foot, 4.3% lower leg, 5.8% knee, 3.4% though/groin, 16.8% lower back/gluetal region, 4.8% upper extremity, 2.9% miscellaneous. Men: 46.2% ankle/foot, 1.1% lower leg, 18.7% knee, 4.4% thigh/groin, 19.2 %lower back/gluteal region, 9.9% upper extremity, 0.5% miscellaneous
Quirk 1984[47]	Ballet dancers treated by one orthopedic surgeon; Melbourne	Case series of 2,113 injuries, year unknown.	None provided. Medical record review.	Not applicable	*Anatomic distribution: 22% ankle, 20% foot, 17% knee, 9% hip, 9% lower back, 8% lower leg, 4% though, 11% other location
Rovere 1983[98]	Female (n=162) and male (n=56) dance students; North Carolina	Cohort study, September 1982-May 1983	An incident meriting the attention of a physician at the sports medicine unit of a medical school, medical record review	85% (185/218)	*352 injuries total (309 dance-related injuries) sustained by 185 students *Anatomic distribution of all injuries (n=352): 22% ankle, 18% spine, 15% foot, 15% knee, 14% hip, 5% shin splints, 11% other *Cervical and upper-back strains occurred twice as often in modern dancers as ballet dancers *Low-back strains, strained hamstrings, and shin splints occurred twice as often in ballet dancers than modern dancers

Shah 2012[36]	Female [n=135] and male [n=49] dancers (age= 30.1 (7.3), range=18-55) in professional modern dance companies or freelance modern dancers; US	Cross-sectional survey, year unknown. Participation rate=184/640 (29%)	"Medical problem that occurred as a result of participation in dance class, rehearsal, or performance, such that the dancer missed or had to decrease his/her level of participation ". Self-report of number of injuries in past 12 months, more detailed information collected on the two most severe injuries (in terms of lost time).	**Proportion**: Overall, 82%; female, 83%; male, 78% **Rate**: Overall: 0.59 per 1000 dance-hours Class: 0.67 per 1000 dance-hours Rehearsal: 0.56 per 1000 dance-hours;	*112 females sustained 223 injuries, 49 males sustained 61 injuries *57% overuse *Anatomic distribution: 18% ankle, 17% low back, 16% knee, 10% foot, 9% hip, 8% neck, 8% great toe, 7% shoulder, 6% upper back, 3% groin, 3% small toes, 2% chest, 1% abdomen, 1% hand, 1% head, 1% shin, 1% wrist, arm <1% *Injury incidence not associated with gender
Waller 1989[51]	Female [n=95, age= 25(6), BMI=18.9 (1.6)] and male [n=13, age=23(5), BMI=22.2(1.4)] dancers in one pre-professional arts school studying ballet or modern dance; North Carolina	Prospective cohort study with two academic terms of follow-up in fall and winter 1987. Participation rate=80% (108/135)	Dance-related injury, as defined by the respondent. Two methods of reporting: self-report on a questionnaire and medical record review	72% reported at least one injury during follow-up, 74% were seen by student health services for an injury during the study period	*50% overuse *Anatomic distribution: 26%foot/toes, 19% ankle/achilles, 14% leg/shins, 14% hip, 12% back/neck, 11% knee, 4% upper body, *Injury *Mechanism: 36% muscle/tendon/ligament sprain, strain, tear, or pull, 24% tendonitis, 10% sprained/twisted joint, 9% shin splints, 19% other, 3% no diagnosis *Previous injury history: 81% experienced at least one dance-related injury in the previous three years *Menstrual history: 85 females had reached menarche, 55% (n=47) had at least three months of secondary amenorrhea, 26% (n=22) had at least six months of secondary amenorrhea *Health risk behavior: 16% reported smoking cigarettes regularly, 20% used alcohol more than once a month *EAT-26: Mean score associated with gender (females=15.4, males=5.3), not associated with dance style (ballet=13.8, modern=16.2) or age (12-15 year old=11.8, 16-18 year old=16.5) *Dance style: 90% of modern dancers and 71% of ballet students medically treated for an injury *Injury associated with older age, BMI, and previous injury history

Wanke 2012[151]	Work accident records from one state ballet school (n=843) and six theatres (n=1,438); Berlin	Review of standardized work accident reports, year(s) unknown. All dancers had an education based on classical ballet.	Not applicable	Not applicable	*Slipping (from lack of grip or dirt on the flooring from liquid, props, or costume parts accounted for 53.1% and 42.5% of floor-related accidents *Stickiness or unevenness of the floor accounted for 18.4% and 11.3% of floor-related accidents *Stepping into foreign substances (e.g., construction material or props) accounted for 4.3% of floor-related accidents among professional dancers; *Ankle sprain from inadequate flooring accounted for 10.6% and 26.3% of floor-related accidents Having a raked stage "did not have any influence on the total number of acute injuries"
Wanke 2013[152]	Female (n=1079) and male (n=872) dancers employed by six theatres; Berlin	Review of Berlin State Accident Insurance reports for 17 years. Among the six theatres, the primary types of dance were ballet (n=3), show dance (n=2), and contemporary dance (n=1)	Not applicable	Not applicable	*35.7% experienced injuries due to exogenous factors (40.4% and 32.1% among males and females, respectively) *48.5% of acute injuries were caused by exogenous factors (49.1% and 47.9% among males and females, respectively) *Among males injured due to exogenous factors, 42.6% due to a partner/another dancer, 24.6% due to the floor, 14.2% due to props, 7.5% due to the stairs or doors, and 4.1% due to costumes *Among females injured due to exogenous factors, 39.4% were due to a partner or another dancer, 32.1% were due to the floor, 13.6% were due to props, 7.6% were due to the stairs or doors, and 3.9% were due to costumes
Weigert 2007[99]	Female [n=22, age=20.4 (1.8), age range=18-26] dance majors and minors at a university with a modern dance focus; Wisconsin	Cohort study with two semesters of follow-up to determine impact of a screening program for injury prevention. Participation rate=22/30 (73%).	None provided. Injuries reported two ways: self-report at the end of each semester and medical record review.	**Incidence proportion:** Self-report: 67% for first semester and 77% for second semester; medical record review: 30% for first semester, 36% second semester	*None relevant to this dissertation

APPENDIX 2: SELECT PRIOR STUDIES UTILIZING THE EATING ATTITUDES TEST AND BULIMIC INVESTIGATORY TEST, EDINBURGH

Author, Year	Study population	Study aim(s)/hypothesis	Methods	ED definition, instrument	Key results
Abraham 1996[87]	Female dancers at a highly competitive ballet school (n=60), students from two private schools (n=216); Australia	Study characteristics of AN, BN, and EDNOS among young ballet dancers in full-time ballet training	Cross-sectional survey with private school students as a control group, year unknown	Questions based on DSM-III-R criteria (self-report), EAT-40	*Dancers: 5 (8.3%) AN, 1 (1.6%) BN 5 (8.3%) EDNOS, Students: 0 AN, 3 (1.4%) BN, 9 (4.2%) EDNOS; *Mean EAT scores (SD): Dancers [21 (12)] scored significantly higher than students [17 (11)] on the EAT-40 (p=0.02), 13 (22%) dancers scored above 30, 26 (13%) students scored above 30; *BMI: 19 (32%) dancers <18, 4 (2%) students <18; *Menstrual characteristics: Dancers: 4 had primary amenorrhea, 31 had secondary amenorrhea
Belon 2011[86]	Caucasian (n=126) or Hispanic (n=109) Female psychology students (mean age=21.1, age range=18-40, mean BMI=22.6, BMI range=15.3-37.3); New Mexico	Examine factor structure of EAT-26	The EAT was scored using an alternate scoring method where the responses of the non-anorexic side of the scale were not collapsed, so each item could have a score between one to six. The EAT distribution was not normal, therefore the data were log transformed	Not applicable, EAT-26	*For Caucasian women, CFI=0.71, RMSEA=0.12, *For Hispanic women, CFI=0.69m RMSEA=0.12, *A four-factor 16-item version of the EAT is a better fitting measure than the EAT-26 among both Caucasian and Hispanic women
Carter 1984[83]	While females (n=162, mean age=19.3, age range=18-39) recruited from introductory psychology courses; US	Evaluate utility of the EAT as a screening tool to detect AN and BN in a female college population, 2) Examine test-retest reliability of the EAT	A SCID was performed, and the EAT-40 was completed. Subjects were divided into four groups based on EAT-40 scores, and 14 random subjects from each group completed the EAT-40 again 2-3 weeks later .	DSM-III SCID, EAT-40	*21.6% (n=35) scored 30+ on EAT-40, *2/35 (6%) subjects who scored 30+ on the EAT-40 had AN, *4 subjects had BN *Test-retest reliability=0.84

Evers 1987[88]	Female dance students enrolled in intermediate or advanced dance technique class [n=21, age=21.4 (3.3)], females not currently enrolled in dance classes [n=29, age=19.3 (1.1)]; Iowa	Measure and evaluate dietary intake and symptoms of AN in a group of university dancers and controls	A 3-day food record was used to measure dietary intake and the EAT-40 was administered	None, EAT-40	*Mean(SD) EAT score for dancers and controls was 21.8 (16.0) and 18.4 (12.1), respectively, differences not statistically significant, *7 dancers (33.3%) and 4 non-dancers (13.8%) scored at least 30 on the EAT (p<0.005)
Garner 1980[89]	Ballet students [n=183, age=18.6 (0.3)] from three national caliber professional dance schools, fashion students [n=56, age=21.4 (0.5)], patients with AN [n=68, age=23.2 (0.8)], normal controls [n=81, age=21.5 (0.3)] who were undergraduate university students within 10% average weight for height, conservatory music students [n=35, age=15.2 (0.3)]; Canada	"Examine a population of professional dance students and fashion models, who by career choice must focus increased attention and control over their body shapes. Since they should encounter, in a more intense form, the demand for dieting which is experienced by most females in our culture, we predicted that [AN] and 'anorexic like' symptoms would be overrepresented in these dancers and models"	All participants completed the EAT and provided weight, age, menstrual, and height histories. Ballet students and normal controls who either 1) scored at least 30 on the EAT or 2) past weight fluctuations or history of amenorrhea were clinically interviewed	Based on a clinical interview, EAT-40	*EAT Score [mean(SD) and N (%) scoring at least 30: For dancers overall (n=183): 25.3 (1.1), 69 (38%), dancers in highly competitive programs (n=103): 27.6 (1.5), 46)45%), dancers in a general academic track (n=80): 23.2 (1.5), 23 (29%), *Number (%) of cases of AN: Dancers overall: 12 (7%),dancers in highly competitive programs 8 (8%), dancers in a general academic track 4 (5%), *More competitive dance program associated with higher EAT score (p=0.03)

Holderness 1994[66]	Female dancers performing in national and regional ballet companies [n=50, age=20.96 (4.5), age range=13-31 BMI=19.16 (1.9)] and non-dancers recruited from private high schools and colleges and private practice [n=56, age= 22.87(4.4), BMI=20.47 (2.0)]; New York	Report associations between eating disorders and: 1) substance use and 2) depressive symptoms.	Subjects were recruited as part of a longitudinal study on bone density problems. Those with hypothalmic amenorrhea were excluded. Physiological data were collected through an interview with either a physician or nurse practitioner.	DSM-III and DSM-III-R SCID, EAT-26	*Among 49 dancers, 15 (31%) were ever diagnosed with AN, 13 (26%) were ever diagnosed with BN based on DSM-3, 6 (12%) were ever diagnosed with BN based on DSM-3-R. These numbers and percentages were 8 (15%), 17 (31%), and 8 (15%) in 54 non dancers *Mean (SD) EAT-26 score: 13.55 (8.7) for dancers, 13.79 (12.2) for non-dancers
Mintz 2000[60]	Women in an introductory psychology course from a large Midwestern public university [n=136, age=19.4 (2.69), age range=18-41, 88% white]; US	Examine criterion validity of the EAT to diagnose EDs in general	1,391 participants filled out a revised version of the Weight Management Questionnaire (Q-EDD) to operationalize DSM-IV criteria for BN and EDNOS. All women who indicated that had an ED (n=59) and a random sample of women without ED (n=120) were asked to participate in the study. 76% agreed to participate. The time between filling out the Q-EDD and study participation ranged from 1 to 3 months.	DSM-IV SCID; EAT-40	*There were 8 participants with AN or BN, 22 participants with EDNOS*All results presented in EAT-40/EAT-26 order. *Criterion validity: EAT-40: overall 0.91 accurate, 0.23 false negative (7/30), 0.05 false positive (5/99); EAT-26, overall 0.90 accurate, 0.23 false negative (7/30), 0.06 false positive (6/99). *Sensitivity= 0.77, 0.77; *Specificity=0.95, 0.94 *Positive predictive value=0.82, 0.79 *Negative predictive value=0.93, 0.94
Nascimento 2012[93]	Female [n=19), age=34.46 (8.85), BMI=19.25 (0.91)] dancers from one ballet company of a state theater; Rio de Janeiro	"Evaluate the prevalence and the clinical features of [EDs, body dysmorphic disorder], and broadly defined body image disturbances".	Subjects were interviewed with a series of questionnaires. 19/35 (54%) of female dancers in the company participated in the study.	DSM-IV SCID, BITE (Brazilian version)	*Two dancers previously diagnosed with AN had "elevated scores" (16 and 24, respectively). Three dancers (6%) had a lifetime history of AN.

Neumaker 1998[90]	Female [n=37, age=15.27 (1.39), age range=13-18)] and male [n=20, age=15.03 (1.24), age range=13-17] students at the Public Ballet School, Female [n=95, age=15.52 (1.43)] and male [n=61, age=14.96 (1.26)] high school students, female patients fulfilling ICD-10 criteria for AN and EAT-40 score >30 [n=19, age=14.89 (1.41)]; Berlin	"Undertak[e] an age-differentiated analysis of attitudes to eating and pertinent behaviours in female and male ballet students and of investigating differences between them...and female AN patients"	Dance students had an age-matched comparison group from a high school in Berlin.	Not applicable, EAT-40-German version	*Age-specific EAT total scores are higher among female ballet students than 1) female controls and 2) male ballet students; *EAT scores of male ballet students were higher than male controls, *8 female ballet dancers and 7 female controls scored over 30 on the EAT, *Mean(SD) EAT scores: female ballet: 19.00 (14.59), female controls 12.44 (11.11), Male ballet 9.45 (4.59), male controls 7.51 (4.24)
Ocker 2007[85]	CFA: female college students enrolled in a mandatory health and fitness course (n=785, age= 21.80 (3.88), age range=18-34, 39.75% Caucasian, 20.25% Hispanic, 17.58% African-American, 17.07% Asian], Cross-validation: Female college students enrolled in health and fitness classes (n=298, age= 21.21 (3.42), age range=17-43, 37.85% African-American, 26.85% Caucasian, 21.14% Hispanic, 12.42% Asian]; US	Examine construct validity and internal consistency reliability of EAT-26, and EAT-20 using confirmatory factor analysis (CFA)		Not applicable, EAT-26	*The three-factor model of the EAT-26 was the poorest fit of all models tested in the study, RMSEA=0.11, SRMR=0.11, CFI=0.73, *Factor loadings ranged from -0.14 to 0.97, *Inter-factor correlations ranged from -0.04 to 0.74, *A four-factor 16-item version of the EAT is the best fit (compared to the EAT-26 and a four-factor 20-item version of the EAT)

Ricciardelli 1999[92]	Girls (n=427) and boys (n=350) age 12-17 from 12 state high schools; New South Wales	"Examine the factor structure of [the BITE] in adolescent girls and boys".	Cross-section survey; "students completed the BITE during class time as part of a larger survey on eating attitudes and gender".	Not applicable, BITE	*Mean (SD) BITE symptom subscale score was significantly higher in girls [9.86 (4.73)] than boys [7.66 (4.73)], p<0.01, *3.9% of girls and 0.6% of boys scored at or above the clinical cutoff score (>20), 41.3% of girls and 27.1% of boys scored in the subclinical range (10-19), *One factor described the interrelationships between BITE items for girls, two factors were necessary for boys
Tseng 2007[94]	Female dance [n=613), BMI= 19.4 (1.6)], and non-dance [n=1,181), BMI= 20.4 (2.8)] students; Taiwan	Investigate prevalence of individual EDs and evaluate correlates of EDs Among female dance students and female high school students in Taiwan.	Cross-section study. Surveys administered to all participants January-March 2003 .Dancers were senior high school students enrolled in the gifted dance class in the only 12 schools that offer this class. Non-dancers were chosen from the same school or from a nearby school, as some schools did not offer regular high school classes. SCID for EDs were conducted May-September 2003 for all students who has a positive screen for AN or BN. SCID also conducted for a random sample of students who did not screen positive. 285 SCIDs were conducted. Participation rate=613/655 (93.6%) for dancers, 1,181/1,251 (94.4%) for non-dancers	DSM-IV SCID, A positive screen for AN was defined as EAT >20 and BMI <18.5, positive screen for BN was defined as BITE symptom score >15 or severity score >5; EAT-26 (Chinese version) and BITE (Chinese version)	*Dancers scored significantly higher than non-dancers on total EAT score, total BITE score, BITE symptom score, and BITE severity score (p<0.01 for all measures) *EAT-26 score (SD): Dancers [17.2 (10.1)], non-dancers [11.2 (8.4)] *Total BITE score: dancers [14.3(7.3)], non-dancers [9.7(6.1)], BITE symptom score: Dancers [11.4(5.2)], non-dancers [8.4 (4.8)] *BITE severity score: Dancers [2.9 (3.2)], non-dancers [1.3(2.1)] *Weighted one-year prevalence of ED among dancers: 0.7% for AN, 2.5% for BN, 4.8% for EDNOS, 8.0% for any ED *Weighted one-year prevalence of eating among non-dancers: 0.1% for AN, 1.0% for BN, 0.7% for EDNOS, 2.0% for all EDs *Among 613 dancers, 27 (4.4%) had a positive screen on both the EAT-26 and BITE, 32 (5.2%) had a positive screen on the EAT-26 only, 212 (34.6%) had a positive screen on the BITE only *Among 1,181 non-dancers, 13 (1.1%) had a positive screen on both the EAT-26 and BITE, 22 (1.9%) had a positive screen on the EAT-26 only, 168 (14.2%) had a positive screen on the BITE only.

Tseng 2013[95]	Female dance students [n=583, age=15.8 (0.9), age range=14-19)]; Taiwan	"1)[E]xamine the changes in ED status over 1 year and 2)…determine whether any features are prospectively associated with the development of EDs over a 1-year interval and to evaluate the feasibility of using a questionnaire to identify those at risk in a sample of girl dance students in Taiwan.	Prospective cohort study with one year of follow-up. Students filled out a baseline questionnaire and had a SCID for EDs conducted. A follow-up questionnaire was administered March-May 2004. Out of 285 participants who were given a SCID in 2003, 245 were also given a SCID in 2004 [mean(SD) interval between SCIDs=331.5 (91.6) days. range=189-565 days. Poisson regression to analyze risk factors for incident EDs.	DSM-IV SCID, A positive screen for AN was defined as EAT >20 and BMI <18.5, positive screen for BN was defined as BITE symptom score >15 or severity score >5; EAT-26 (Chinese version) and BITE (Chinese version)	*58 dancers met diagnostic criteria for EDs at follow-up: 4 AN, 17 BN, 3 binge-eating disorder, 2 menstruating AN, 18 subthreshold BN, 14 purging disorder *Among 204 girls with no ED at baseline, 35 (17%) developed at incident ED *Among 45 participants with an ED at baseline, four did not respond to follow-up questionnaires. 18/41 responders (44%) had recovered from their ED and did not have an ED diagnosis, 23 (56.1%) had clinical or subthreshold ED diagnoses at follow-up *Girls in 12th grade at baseline were less likely to develop an incident ED than girls in 10th grade, [adjusted risk ratio (ARR) (95% CI)=0.09 (0.02, 0.41)] *Girls with higher BITE score were more likely to develop an incident ED [ARR (95% CI) for one-unit increase in BITE= 1.08 (1.01, 1.14)]
Waller 1989[51]	Female [n=95, age= 25(6), BMI=18.9 (1.6)] and male [n=13, age=23(5), BMI=22.2(1.4)] dancers in a pre-professional arts school studying ballet or modern dance; North Carolina	"1) Establish incidence rates for dance related injuries…and 2) identify risk factors for injury that could be targeted for intervention"	Prospective cohort study investigating dance-related injuries with two academic terms of follow-up in fall and winter 1987. Participation rate=80% (108/135)	Not applicable, EAT-26	*Mean EAT-26 score: overall: 14.2; Females (15.4) scored significantly higher (5.3) than males (p=0.01) *Mean EAT-26 score did not differ between ballet (16.2) and modern (13.8) dancers *Mean EAT-26 score did not differ between students 12-15 years old (11.8) and 16-18 years old (13.8) *17% of students aged 12-15 scored ≥20 *31% of students aged 16-18 scored ≥20
Wells 1985[84]	Girls (n=901, age range=12-18) from three girls' secondary schools with boarding establishments; Christchurch	Examine factors measured by the EAT in adolescent schoolgirls.	The EAT was scored using original scoring method (0-3) and also an alternate method where responses of the non-anorexic side of the scale were not collapsed; each item could score between 1-6. Principal components analysis determined factor structure	Not applicable, EAT-40	*Mean EAT score=12.1, *34/749 (4.5%) girls who answered all 40 EAT questions scored 30 or more, *Using the alternative scoring method, a six-factor structure of the EAT-40 appeared to be better than the four-factor structure (clearer separation in eigenvalues of the PCA).

APPENDIX 3: SAMPLE OF UNCSA HEALTH HISTORY FORM

Date received at UNCSA:	Entered in Medicat:	Ins	Imm	Personal

REPORT OF MEDICAL HEALTH HISTORY *(Please print in black ink)*

LAST NAME (print) FIRST NAME MIDDLE/MAIDEN NAME Date of Birth (mo/day/year)

PERMANENT ADDRESS CITY STATE ZIP CODE EMAIL ADDRESS CELLPHONE NUMBER

CLASS YOU ARE ENTERING (circle)
High School : 9 10 11 12
College : 1 2 3 4 5 6

PREVIOUSLY ENROLLED HERE ❑YES ❑NO
IF YES, DATE _______________

ENTERING (circle all): FALL SPRING SUMMER
DANCE DRAMA MUSIC FILM D&P/VA YEAR_________

All students must complete

All students are required to either enroll or waive out of the University selected health insurance by going to www.BCBSNC.com/UNCSA

❑ I have chosen to enroll in the insurance plan. **OR**

❑ I have chosen to waive out of the BCBS insurance plan and I have attached copies of both my insurance and prescription cards.
(**Note you must still go to www.BCBSNC.com/UNCSA to waive out**.)

EMERGENCY Contact Name (RELATIONSHIP) Phone numbers to contact in emergency

EMERGENCY Contact Name (RELATIONSHIP) Phone numbers to contact in emergency

FAMILY & PERSONAL HEALTH HISTORY *(Please print in black ink)* *To be completed by student*

The following health history is confidential, does not affect your admission status and, except in an emergency situation or by court order, will not be released without your written permission. *Please attach additional sheets for any items that require fuller explanation.*

Has any person, related by blood, had any of the following?

	Yes	No	Relationship		Yes	No	Relationship		Yes	No	Relationship
High blood pressure				Cholesterol or blood fat disorder				Cancer (type):			
Stroke				Diabetes				Alcohol/drug problems			
Heart attack before age 55				Glaucoma				Psychiatric illness			
Blood or clotting disorder								Suicide			

Have you ever had or have now the following? (If yes, indicate the year.)

	Yes	No	Year		Yes	No	Year		Yes	No	Year		Y	N	Year
High blood pressure				Hay fever				Jaundice or hepatitis				Kidney stones			
Rheumatic fever				Allergy injection therapy				Rectal disease				Protein or blood in urine			
Heart trouble				Arthritis				Severe or recurrent abdominal pain				Hearing loss			
Pain or pressure in chest				Concussion				Hernia				Sinusitis			
Shortness of breath				Frequent or severe headache				Easy fatigability				Severe menstrual cramps			
Asthma				Dizziness or fainting spells				Anemia or Sickle Cell Anemia				Irregular periods			
Pneumonia				Severe head injury				Eye trouble besides need glasses				Sexually transmitted disease			
Chronic cough				Paralysis				Bone, joint, or other deformity				Blood transfusion			
Head or neck radiation treatments				Depression				Knee problems				Alcohol use			
Tumor or cancer (specify)				Excessive worry or anxiety or obsession				Recurrent back pain				Illegal Drug use			
Malaria				Ulcer (duodenal or stomach)				Neck injury				Eating disorder			
Thyroid trouble				Intestinal trouble				Back injury				Smoke			
Diabetes				Treatment for ADD or ADHD				Broken bone (specify)				Regularly exercise			
Serious skin disease				Frequent vomiting				Kidney infection				Wear seat belt			
Mononucleosis				Gall bladder trouble or gallstones				Bladder infection				Other (specify)			

Please list any drugs, medicines, birth control pills, vitamins, minerals, and any herbal/natural product (prescription and nonprescription) you use and how often you use them.

Name_______________________Use________________Dosage_______________Name_______________________Use__________________Dosage ____________

Name_______________________Use________________Dosage_______________Name_______________________Use__________________Dosage ____________

Name_______________________Use________________Dosage_______________Name_______________________Use__________________Dosage ____________

Name_______________________Use________________Dosage_______________Name_______________________Use__________________Dosage ____________

APPENDIX 4: INJURY DURATION

The mean (SD) duration of dance-related injury (in days) was 20.4(39.0), ranging from 1 to 443 days. Half (511/1014, 50.39%) lasted one week or less, and 44 (4.34%) lasted for 3 months or more (range= 93-443 days) (Figure 5.2). There were not significant differences in injury duration by gender or program, but ballet dancers had significantly longer injury durations than ballet dancers [23.4 (42.9) vs. 14.7 (29.6), p=0.0007]. In general, injuries to the lower extremity had the longest injury duration, with a mean ranging from 13-28 days (Table 5.4). Acute injuries and overuse injuries did not have a significantly different duration [20.1 (36.2) vs. 20.8(44.4)]. The three groups of injury diagnoses with longest mean (SD) duration were: fractures [70.4 (67.7)], stress injuries [51.1 (46.2)], and sprains [29.8 (61.0)] (Table 5.5). Mean injury duration by specific injury diagnoses can be found in Table 5.6.

APPENDIX 5: ADDITIVE AND MULTIPLICATIVE INTERACTION IN INJURY MODELS

The presence of additive and multiplicative interaction when investigating injury rates was explored for three pairs of variables: gender and program; gender and dance style; and program and dance style. Each set variable pair was recoded into a four-category variable, and the referent categories were high school males, female contemporary dancers, and high school contemporary dancers, respectively. Information evaluated included information suggested by Rothman[132] and Hosmer and Lemeshow[131]. An example of information used to evaluate presence of additive interaction for gender and program is shown below.

Theta1-Male college	0.179	RERI=	-0.23806
Theta2-Female high school	0.0455	Var(RERI)=	0.54132
Theta3- Female college	0.0045	SE(RERI)=	0.735744
Var(theta1)	0.1726	95% CI(L)=	-1.68012
Var(theta2)	0.1557	95% CI(U)=	1.203997
Var(theta3)	0.1653		
Cov(theta1,2)	0.02142	h1	-1.19602
Cov(theta1,3)	0.02143	h2	-1.04655
Cov(theta2,3)	0.02142	h3	1.00451

The observed IRRs when comparing college males, high school females, and college females to high school males were $e^{0.179}$=1.20, $e^{0.0455}$=1.06, and $e^{0.0045}$=1.00, respectively. The expected IRR under perfect additivity for college females is 1.20+1.06-1=1.26, and the expected IRR under perfect multiplicativity for college females is 1.20*1.06=1.27. Furthermore, the relative excess risk due to interaction (RERI) is -0.24, with a 95% CI from -1.68 to 1.20. When the RERI is equal to zero, this means there is no additive interaction. Based on the results, there was no evidence of additive interaction.

A multivariable NB GEE model with gender and program was compared to a multivariable NB GEE model with gender, program, and an interaction term for the two variables to evaluate presence of multiplicative interaction. The model without the interaction term had a smaller QICu score(182.5 vs. 180.8), indicating that model is a better fit to the data. Furthermore, the p-value for the interaction term was not statistically significant (p=0.26). Therefore, there was no evidence of multiplicative interaction.

There was no evidence of either additive or multiplicative interaction for gender and style. However, there was possible evidence of that the effects of program and style were not perfectly multiplicative (the QICu score for the model with the interaction term was lower than the model without the interaction term: 174.3 vs. 175.9, and the p-value for the interaction term was 0.02). The crude injury rates and 95% CIs for each program-style combination are shown below.

	Rate (per 1,000 person-days)	95% CI
High school ballet	5.02	4.60-5.48
High school contemporary	3.39	2.68-4.27
College ballet	4.68	3.98-5.49
College contemporary	5.25	4.68-5.90

Based on crude models with dance style alone and program alone, college dancers and ballet dancers have higher injury rates than high school dancers and contemporary dancers, respectively. However, in the present study, among college dancers, contemporary dancers have higher injury rates than ballet dancers.

APPENDIX 6: SCREENING-RELATED CALCULATIONS FOR POSSIBLE DISORDERED EATING

	Estimated Value	95% Confidence Interval	
		Lower Limit	Upper Limit
Prevalence	0.25	0.193871	0.315561
Sensitivity	0.057692	0.015019	0.169216
Specificity	0.955128	0.906165	0.980196
For any particular test result, the probability that it will be:			
Positive	0.048077	0.024616	0.08922
Negative	0.951923	0.91078	0.975384
For any particular positive test result, the probability that it is:			
True Positive (Positive Predictive Value)	0.3	0.080948	0.646329
False Positive	0.7	0.353671	0.919052
For any particular negative test result, the probability that it is:			
True Negative (Negative Predictive Value)	0.752525	0.685316	0.809724
False Negative	0.247475	0.190276	0.314684

The above numbers were generated from a publicly available online tool[189]. A cross-classification of having PDE (true outcome) and positive for PDE (presence of both low BMI and HIMP) used to calculate the numbers above are provided below.

		True outcome of PDE	
		Yes	No
Positive screen for PDE (BMI <18.5 and HIMP)	Yes	3	7
	No	49	149

Sensitivity= True Positive/(True Positive + False Negative) = 3/(3+49) = 0.057692

Specificity= True Negative/(True Negative+ False Positive) = 149/(149+7) = 0.0955128

Positive Predictive Value= True Positive/(True Positive + False Positive) = 3/(3+7) = 0.3

Negative Predictive Value= True Negative/(True Negative + False Negative) = 149/(149+49) = 0.752525

REFERENCES

1. Anderson, J. *Ballet & modern dance: a concise history*. Princeton Book Company, Princeton, NJ (1992).

2. Stretanski, M. F. & Weber, G. J. Medical and rehabilitation issues in classical ballet. *American Journal of Physical Medicine & Rehabilitation* **81,** 383–391 (2002).

3. Luke, A. C. *et al.* Determinants of injuries in young dancers. *Medical Problems of Performing Artists* **17,** 105–112 (2002).

4. Kraus, R., Chapman, S. & Dixon, B. *History of the Dance in Art and Education*. Prentice Hall, Englewood Cliffs, NJ (1991).

5. Cass, J. *Dancing through history*. Prentice Hall, Englewood Cliffs, NJ (1993).

6. Bureau of Labor Statistics. *Occupational Employment Statistics* (2015). http://www.bls.gov/oes/current/oes272031.htm. Accessed January 29, 2016.

7. Dance/USA — The national service organization for professional dance. https://www.danceusa.org/nationalcompanyroster. Accessed January 29, 2016.

8. Kinetz, E. *Practice, practice, practice. Go to college? Maybe.* New York Times**,** December 21, 2005.

9. Dance Magazine. 20*15/2016 Dance Magazine College Guide*. http://dancemagazine.com/dance-resources/college-guide/. Accessed January 29, 2016.

10. National Dance Education Organization. *Statistics: General US Education and Dance Education*. http://www.ndeo.org/content.aspx?page_id=22&club_id=893257&module_id=55774. Accessed January 29, 2016.

11. Hincapie, C. A. & Cassidy, J. D. Disordered eating, menstrual disturbances, and low bone mineral density in dancers: a systematic review. *Archives of Physical Medicine and Rehabilitation* **91,** 1777–1789.e1 (2010).

12. Hincapie, C. A., Morton, E. J. & Cassidy, J. D. Musculoskeletal injuries and pain in dancers: a systematic review. *Archives of Physical Medicine and Rehabilitation* **89,** 1819–29 (2008).

13. Conn, J., Annest, J. L. & Gilchrist, J. Sports and recreation related injury episodes in the US population, 1997–99. *Injury Prevention* **9,** 117–123 (2003).

14. Centers for Disease Control and Prevention. Nonfatal traumatic brain injuries from sports and recreation activities-United States, 2001-2005. MMWR **56,** 733–737 (2007).

15. Adirim, T. A. & Cheng, T. L. Overview of injuries in the young athlete. *Sports Medicine* **33,** 75–81 (2003).

16. Doherty, C. *et al.* The incidence and prevalence of ankle sprain injury: A systematic review and meta-analysis of prospective epidemiological studies. *Sports Medicine* **44,** 123–140 (2014).

17. Lopes, A. D., Hespanhol Jr, M. L. C., Yeung, S. S. & Costa, L. O. P. What are the Main Running-Related Musculoskeletal Injuries? *Sports Medicine* **42,** 891–905 (2012).

18. Centers for Disease Control and Prevention. Emergency Department Visits. http://www.cdc.gov/nchs/fastats/emergency-department.htm. Accessed January 29, 2016.

19. Simon, T. D., Bublitz, C. & Hambidge, S. J. External causes of pediatric injury-related emergency department visits in the United States. *Academic Emergency Medicine* **11,** 1042–1048 (2004).

20. Burt, C. W. & Overpeck, M. D. Emergency visits for sports-related injuries. *Annals of Emergency Medicine* **37,** 301–308 (2001).

21. American Cancer Society. Estimated New Cancer Cases by Sex and Age (years), 2013. http://www.cancer.org/acs/groups/content/@epidemiologysurveilance/documents/document/acspc-037114.pdf. Accessed January 29, 2016.

22. Centers for Disease Control and Prevention. Distribution of Age at Diagnosis of Diabetes Among Adult Incident Cases Aged 18-79 Years, United States, 2011. http://www.cdc.gov/diabetes/statistics/age/fig1.htm. Accessed January 29, 2016.

23. Premature Heart Disease. *Harvard Men's Health Watch* (2009). http://www.health.harvard.edu/newsletters/Harvard_Mens_Health_Watch/2009/November/premature-heart-disease. Accessed January 29, 2016.

24. Toft, A. M. H., Møller, H. & Laursen, B. The years after an injury: long-term consequences of injury on self-rated health. *Journal of Trauma-Injury, Infection, and Critical Care* **69,** 26–30 (2010).

25. Maffulli, N., Longo, U. G., Gougoulias, N., Loppini, M. & Denaro, V. Long-term health outcomes of youth sports injuries. *British Journal of Sports Medicine* **44,** 21–25 (2010).

26. Kujala, U. M., Orava, S., Parkkari, J., Kaprio, J. & Sarna, S. Sports Career-Related Musculoskeletal Injuries. *Sports Medicine* **33,** 869–875 (2003).

27. Sundgot-Borgen, J. & Torstveit, M. K. Prevalence of eating disorders in elite athletes is higher than in the general population. *Clinical Journal of Sport Medicine* **14,** 25–32 (2004).

28. Byrne, S. & McLean, N. Eating disorders in athletes: a review of the literature. *Journal of Science and Medicine in Sport* **4,** 145–159 (2001).

29. Johnson, C., Powers, P. S. & Dick, R. Athletes and eating disorders: the National Collegiate Athletic Association study. *International Journal of Eating Disorders* **26,** 179–188 (1999).

30. Powers, P. S. & Johnson, C. Small victories: Prevention of eating disorders among athletes. *Eating Disorders* **4,** 364–377 (1996).

31. Torstveit, M. K. & Sundgot-Borgen, J. The female athlete triad: are elite athletes at increased risk? *Medicine & Science in Sports & Exercise* **37,** 184–193 (2005).

32. Nattiv, A. *et al.* The female athlete triad special communications: position stand. *Medicine & Science in Sports & Exercise* **39,** 1867–82 (2007).

33. Gibbs, J. C., Williams, N. I. & De Souza, M. J. Prevalence of individual and combined components of the female athlete triad. *Medicine & Science in Sports & Exercise* **45,** 985–996 (2013).

34. Barrack, M. T. *et al.* Higher Incidence of Bone Stress Injuries With Increasing Female Athlete Triad–Related Risk Factors A Prospective Multisite Study of Exercising Girls and Women. *The American Journal of Sports Medicine* **42,** 949–958 (2014).

35. Mountjoy, M. *et al.* The IOC consensus statement: beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S). *British Journal of Sports Medicine* **48,** 491–497 (2014).

36. Shah, S., Weiss, D. S. & Burchette, R. J. Injuries in professional modern dancers: incidence, risk factors, and management. *Journal of Dance Medicine and Science* **16,** 17–25 (2012).

37. Chmelar, R. D., Fitt, S. S., Schultz, B. B., Ruhling, R. O. & Zupan, M. F. A survey of health, training, and injuries in different levels and styles of dancers. *Medical Problems of Performing Artists* **2,** 61–66 (1987).

38. Ramel, E. M., Moritz, U. & Jarnlo, G.-B. Validation of a pain questionnaire (SEFIP) for dancers with a specially created test battery. *Medical Problems of Performing Artists* **14,** 196–203 (1999).

39. Campoy, F. A. *et al.* Investigation of risk factors and characteristics of dance injuries. *Clinical Journal of Sport Medicine* **21,** 493–498 (2011).

40. Byhring, S. & Bø, K. Musculoskeletal injuries in the Norwegian National Ballet: a prospective cohort study. *Scandinavian Journal of Medicine and Science in Sports* **12,** 365–370 (2002).

41. Gamboa, J. M., Roberts, L. A., Maring, J. & Fergus, A. Injury patterns in elite preprofessional ballet dancers and the utility of screening programs to identify risk characteristics. *Journal of Orthopaedic & Sports Physical Therapy* **38,** 126–36 (2008).

42. Leanderson, C. *et al.* Musculoskeletal injuries in young ballet dancers. *Knee Surgery, Sports Traumatology, Arthroscopy* **19,** 1531–1535 (2011).

43. Allen, N., Nevill, A., Brooks, J., Koutedakis, Y. & Wyon, M. Ballet injuries: injury incidence and severity over 1 year. *Journal of Orthopaedic & Sports Physical Therapy* **42,** 781–90 (2012).

44. Ekegren, C. L., Quested, R. & Brodrick, A. Injuries in pre-professional ballet dancers: Incidence, characteristics and consequences. *Journal of Science and Medicine in Sport* **17,** 271–275 (2014).

45. Nilsson, C., Leanderson, J., Wykman, A. & Strender, L. E. The injury panorama in a Swedish professional ballet company. *Knee Surgery, Sports Traumatology, Arthroscopy* **9,** 242–6 (2001).

46. Bowerman, E., Whatman, C., Harris, N., Bradshaw, E. & Karin, J. Are maturation, growth and lower extremity alignment associated with overuse injury in elite adolescent ballet dancers? *Physical Therapy in Sport* **15,** 234–241 (2014).

47. Quirk, R. Injuries in classical ballet. *Australian Family Physician* **13,** 802–804 (1984).

48. Micheli, L. J., Gillespie, W. J. & Walaszek, A. Physiologic profiles of female professional ballerinas. *Clinics in Sports Medicine* **3,** 199–209 (1984).

49. Motta-Valencia, K. Dance-related injury. *Physical Medicine and Rehabilitation Clinics of North America* **17,** 697–723 (2006).

50. Liederbach, M., Dilgen, F. E. & Rose, D. J. Incidence of Anterior Cruciate Ligament Injuries Among Elite Ballet and Modern Dancers A 5-year Prospective Study. *The American Journal of Sports Medicine* **36,** 1779–1788 (2008).

51. Waller, A. E. Identification of risk factors for injury in adolescent dancers. Johns Hopkins University (1989).

52. Bowling, A. Injuries to dancers: prevalence, treatment, and perceptions of causes. *British Medical Journal* **298,** 731–734 (1989).

53. Garrick, J. G. & Requa, R. K. The relationship between age and sex and ballet injuries. *Medical Problems of Performing Artists* **33,** 17 (1997).

54. Murray, C. J. *et al.* Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet* **380,** 2197–2223 (2013).

55. Hudson, J. I., Hiripi, E., Pope Jr, H. G. & Kessler, R. C. The prevalence and correlates of eating disorders in the National Comorbidity Survey Replication. *Biological Psychiatry* **61,** 348–358 (2007).

56. Crow, S. The Economics of Eating Disorder Treatment. *Current Psychiatry Reports* **16,** 1–3 (2014).

57. Raenker, S. *et al.* Caregiving and coping in carers of people with anorexia nervosa admitted for intensive hospital care. *International Journal of Eating Disorders* **46,** 346–354 (2013).

58. American Psychiatric Association. History of the DSM. http://www.psychiatry.org/practice/dsm/dsm-history-of-the-manual. Accessed January 29, 2016.

59. Sunday, S. R. *et al.* Differences in DSM-III-R and DSM-IV diagnoses in eating disorder patients. *Comprehensive Psychiatry* **42,** 448–455 (2001).

60. Mintz, L. B. & O'Halloran, M. S. The Eating Attitudes Test: validation with DSM-IV eating disorder criteria. *Journal of Personality Assessment* **74,** 489–503 (2000).

61. Kupfer, D. & Reiger, D. DSM-5 Implementation and Support. http://www.dsm5.org/Pages/Default.aspx. Accessed December 4, 2014.

62. Call, C., Walsh, B. T. & Attia, E. From DSM-IV to DSM-5: changes to eating disorder diagnoses. *Current Opinion in Psychiatry* **26,** 532–536 (2013).

63. Thomas, J. J. *et al.* Do DSM-5 Eating Disorder Criteria Overpathologize Normative Eating Patterns among Individuals with Obesity? *Journal of Obesity* **2014,** (2014).

64. Smink, F. R., van Hoeken, D. & Hoek, H. W. Epidemiology, course, and outcome of eating disorders. *Current Opinion in Psychiatry* **26,** 543–548 (2013).

65. Arcelus, J., Witcomb, G. L. & Mitchell, A. Prevalence of eating disorders amongst dancers: a systemic review and meta-analysis. *European Eating Disorders Review* **22,** 92–101 (2014).

66. Holderness, C. C., Brooks-Gunn, J. & Warren, M. P. Eating disorders and substance use: a dancing vs a nondancing population. *Medicine and Science in Sports and Exercise* **26,** 297–302 (1994).

67. Ringham, R. *et al.* Eating disorder symptomatology among ballet dancers. *International Journal of Eating Disorders* **39,** 503–508 (2006).

68. Bulik, C. M. *et al.* Prevalence, heritability, and prospective risk factors for anorexia nervosa. *Archives of General Psychiatry* **63,** 305–312 (2006).

69. Hoek, H. W. & Van Hoeken, D. Review of the prevalence and incidence of eating disorders. *International Journal of Eating Disorders* **34,** 383–396 (2003).

70. Nordin-Bates, S. M., Walker, I. J. & Redding, E. Correlates of disordered eating attitudes among male and female young talented dancers: findings from the UK centres for advanced training. *Eating Disorders* **19,** 211–233 (2011).

71. Garner, D. M., Garfinkel, P. E., Rockert, W. & Olmsted, M. P. A prospective study of eating disturbances in the ballet. *Psychotherapy and Psychosomatics* **48,** 170–175 (1987).

72. Thomas, J. J., Keel, P. K. & Heatherton, T. F. Disordered eating attitudes and behaviors in ballet students: examination of environmental and individual risk factors. *International Journal of Eating Disorders* **38,** 263–268 (2005).

73. Calabrese, L. H. & Kirkendall, D. T. Nutritional and medical considerations in dancers. *Clinics in Sports Medicine* **2,** 539–548 (1983).

74. Kurtzman, F. D., Yager, J., Landsverk, J., Wiesmeier, E. & Bodurka, D. C. Eating disorders among selected female student populations at UCLA. *Journal of the American Dietetic Association* **89,** 45–53 (1989).

75. Braisted, J. R., Mellin, L., Gong, E. J. & Jr, C. E. I. The adolescent ballet dancer. Nutritional practices and characteristics associated with anorexia nervosa. *Journal of Adolescent Health Care* **6,** 365–371 (1985).

76. Hamilton, L. H., Hamilton, W. G., Meltzer, J. D., Marshall, P. & Molnar, M. Personality, stress, and injuries in professional ballet dancers. *The American Journal of Sports Medicine* **17,** 263–267 (1989).

77. McNulty, K. Y., Adams, C. H., Anderson, J. M. & Affenito, S. G. Development and validation of a screening tool to identify eating disorders in female athletes. *Journal of the American Dietetic Association* **101,** 886–892 (2001).

78. Morgan, J. F., Reid, F. & Lacey, J. H. The SCOFF questionnaire: assessment of a new screening tool for eating disorders. *British Medical Journal* **319,** 1467–1468 (1999).

79. Jacobi, C., Abascal, L. & Taylor, C. B. Screening for eating disorders and high-risk behavior: Caution. *International Journal of Eating Disorders* **36,** 280–295 (2004).

80. Feighner, J. P. *et al.* Diagnostic criteria for use in psychiatric research. *Archives of General Psychiatry* **26,** 57–63 (1972).

81. Garner, D. M. & Garfinkel, P. E. The Eating Attitudes Test: an index of the symptoms of anorexia nervosa. *Psychological Medicine* **9,** 273–279 (1979).

82. Garner, D. M., Olmsted, M. P., Bohr, Y. & Garfinkel, P. E. The eating attitudes test: psychometric features and clinical correlates. *Psychological Medicine* **12,** 871–878 (1982).

83. Carter, P. I. & Moss, R. A. Screening for anorexia and bulimia nervosa in a college population: problems and limitations. *Addictive Behaviors* **9,** 417–419 (1984).

84. Wells, J. E., Coope, P. A., Gabb, D. C. & Pears, R. K. The factor structure of the Eating Attitudes Test with adolescent schoolgirls. *Psychological Medicine* **15,** 141–146 (1985).

85. Ocker, L. B., Lam, E. T., Jensen, B. E. & Zhang, J. J. Psychometric properties of the eating attitudes test. *Measurement in Physical Education and Exercise Science* **11,** 25–48 (2007).

86. Belon, K. E. *et al.* Measurement invariance of the Eating Attitudes Test-26 in Caucasian and Hispanic women. *Eating Behaviors* **12,** 317–320 (2011).

87. Abraham, S. Characteristics of eating disorders among young ballet dancers. *Psychopathology* **29,** 223–229 (1996).

88. Evers, C. L. Dietary intake and symptoms of anorexia nervosa in female university dancers. *Journal of the American Dietetic Association* **87,** 66–68 (1987).

89. Garner, D. M. & Garfinkel, P. E. Socio-cultural factors in the development of anorexia nervosa. *Psychological Medicine* **10,** 647–656 (1980).

90. Neumarker, K. J., Bettle, N., Bettle, O., Dudeck, U. & Neumarker, U. The Eating Attitudes Test: comparative analysis of female and male students at the Public Ballet School of Berlin. *European Child & Adolescent Psychiatry* **7,** 19–23 (1998).

91. Henderson, M. & Freeman, C. P. A self-rating scale for bulimia. The 'BITE'. *The British journal of psychiatry : the journal of mental science* **150,** 18–24 (1987).

92. Ricciardelli, L. A., Williams, R. J. & Kiernan, M. J. Bulimic symptoms in adolescent girls and boys. *International Journal of Eating Disorders* **26,** 217–221 (1999).

93. Nascimento, A. L., Luna, J. V. & Fontenelle, L. F. Body dysmorphic disorder and eating disorders in elite professional female ballet dancers. *Annals of Clinical Psychiatry* **24,** 191–194 (2012).

94. Tseng, M. M. *et al.* Two-phase survey of eating disorders in gifted dance and non-dance high-school students in Taiwan. *Psychological Medicine* **37,** 1085–1096 (2007).

95. Tseng, M. C., Fang, D., Chang, C. H. & Lee, M. B. Identifying high-school dance students who will develop an eating disorder: a 1-year prospective study. *Psychiatry Research* **209,** 611–618 (2013).

96. Walter, S. D. & Hart, L. E. Application of Epidemiological Methodology to Sports ana Exercise Science Research. *Exercise and Sport Sciences Reviews* **18,** 417–448 (1990).

97. Caine, D., Goodwin, B. J., Caine, C. G. & Bergeron, G. Epidemiological Review of Injury in Pre-Professional Ballet Dancers. *Journal of Dance Medicine & Science* **19,** 140–148 (2015).

98. Rovere, G. D., Webb, L. X., Gristina, A. G. & Vogel, J. M. Musculoskeletal injuries in theatrical dance students. *The American Journal of Sports Medicine* **11,** 195–198 (1983).

99. Weigert, B. J. & Erickson, M. Incidence of injuries in female university-level modern dancers and the effectiveness of a screening program in altering injury patterns. *Medical Problems of Performing Artists* **22,** 52–57 (2007).

100. Neumarker, K., Bettle, N., Neumarker, U. & Bettle, O. Age- and gender-related psychological characteristics of adolescent ballet dancers. *Psychopathology* **33,** 137–142 (2000).

101. American College of Sports Medicine. The Female Athlete Triad. (2011). http://www.acsm.org/docs/brochures/the-female-athlete-triad.pdf. Accessed August 13, 2014.

102. Jones, B. H. *et al.* Epidemiology of injuries associated with physical training among young men in the army. *Medicine & Science in Sports & Exercise* **25,** 197–203 (1993).

103. Hagglund, M., Walden, M. & Ekstrand, J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *British Journal of Sports Medicine* **40,** 767–772 (2006).

104. Kucera, K., Marshall, S., Kirkendall, D., Marchak, P. & Garrett, W. Injury history as a risk factor for incident injury in youth soccer. *British Journal of Sports Medicine* **39,** 462 (2005).

105. Saragiotto, B. T. *et al.* What are the Main Risk Factors for Running-Related Injuries? *Sports Medicine* **44,** 1153–1163 (2014).

106. Reel, J. J., SooHoo, S., Jamieson, K. M. & Gill, D. L. Femininity to the Extreme: Body Image Concerns Among College Female Dancers. *Women in Sport & Physical Activity Journal* **14,** 39–51 (2005).

107. American Psychiatric Association. *DSM 5* (2013).

108. Klesges, R. C. & Klesges, L. M. Cigarette smoking as a dieting strategy in a university population. *International Journal of Eating Disorders* **7,** 413–419 (1988).

109. Resources for UNCSA Elite Artists. http://uncsa.edu/dance/health%20team.pdf. Accessed January 9, 2015.

110. Sundgot-Borgen, J. Prevalence of eating disorders in elite female athletes. *International Journal of Sport Nutrition* **3,** 29–40 (1993).

111. Sloan, A. W., Burt, J. J. & Blyth, C. S. Estimation of body fat in young women. *Journal of Applied Physiology* **17,** 967–970 (1962).

112. Sloan, A. W. Estimation of body fat in young men. *Journal of Applied Physiology* **23,** 311–315 (1967).

113. Freckleton, G. & Pizzari, T. Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis. *British Journal of Sports Medicine* (2012). doi:doi:10.1136/bjsports-2011-090664

114. van der Worp, H. *et al.* Risk factors for patellar tendinopathy: a systematic review of the literature. *British Journal of Sports Medicine* (2011). doi:doi:10.1136/bjsm.2011.084079

115. De Laet, C. *et al.* Body mass index as a predictor of fracture risk: a meta-analysis. *Osteoporosis International* **16,** 1330–1338 (2005).

116. Paulis, W. D., Silva, S., Koes, B. W. & Middelkoop, M. Overweight and obesity are associated with musculoskeletal complaints as early as childhood: a systematic review. *Obesity Reviews* **15,** 52–67 (2014).

117. Leddy, M. H., Lambert, M. J. & Ogles, B. M. Psychological consequences of athletic injury among high-level competitors. *Research Quarterly for Exercise and Sport* **65,** 347–354 (1994).

118. Guskiewicz, K. M. *et al.* Recurrent concussion and risk of depression in retired professional football players. *Medicine and Science in Sports and Exercise* **39,** 903–909 (2007).

119. Sullivan, P. F., Neale, M. C. & Kendler, K. S. Genetic epidemiology of major depression: review and meta-analysis. *American Journal of Psychiatry* (2014).

120. Runeson, B. & Åsberg, M. Family history of suicide among suicide victims. *American Journal of Psychiatry* (2014).

121. Milne, B. J. *et al.* Predictive value of family history on severity of illness: the case for depression, anxiety, alcohol dependence, and drug dependence. *Archives of General Psychiatry* **66,** 738–747 (2009).

122. Janssen, I., Dostaler, S., Boyce, W. F. & Pickett, W. Influence of multiple risk behaviors on physical activity–related injuries in adolescents. *Pediatrics* **119,** e672–e680 (2007).

123. Bovard, R. S. Risk behaviors in high school and college sport. *Current Sports Medicine Reports* **7,** 359–366 (2008).

124. Fisher, M., Schneider, M., Pegler, C. & Napolitano, B. Eating attitudes, health-risk behaviors, self-esteem, and anxiety among adolescent females in a suburban high school. *Journal of Adolescent Health* **12,** 377–384 (1991).

125. Neumark-Sztainer, D., Story, M., Dixon, L. B. & Murray, D. M. Adolescents engaging in unhealthy weight control behaviors: are they at risk for other health-compromising behaviors? *American Journal of Public Health* **88,** 952–955 (1998).

126. Thacker, S. B. *et al.* The prevention of ankle sprains in sports A systematic review of the literature. *American Journal of Sports Medicine* **27,** 753–760 (1999).

127. Emery, C. A. Risk factors for injury in child and adolescent sport: a systematic review of the literature. *Clinical Journal of Sport Medicine* **13,** 256–268 (2003).

128. Ryan, J., DeBurca, N. & Mc Creesh, K. Risk factors for groin/hip injuries in field-based sports: a systematic review. *British Journal of Sports Medicine* **48,** 1089–1096 (2014).

129. Opar, M. D. A., Williams, M. D. & Shield, A. J. Hamstring strain injuries. *Sports Medicine* **42,** 209–226 (2012).

130. University of North Carolina School of the Arts. http://uncs Why is it important to know my family medical historya.edu/. Accessed July 28, 2015.

131. Hosmer, D. W. & Lemeshow, S. Confidence interval estimation of interaction. *Epidemiology* **3,** 452–456 (1992).

132. Rothman, K. J., Greenland, S. & Lash, T. L. *Modern epidemiology*. Lippincott Williams & Wilkins, Philadelphia, PA (2008).

133. Dekker, R., Kingma, J., Groothoff, J. W., Eisma, W. H. & Ten Duis, H. J. Measurement of severity of sports injuries: an epidemiological study. *Clinical Rehabilitation* **14,** 651–656 (2000).

134. Schneider, S., Seither, B., Tönges, S. & Schmitt, H. Sports injuries: population based representative data on incidence, diagnosis, sequelae, and high risk groups. *British Journal of Sports Medicine* **40,** 334–339 (2006).

135. Centers for Disease Control and Prevention. WISQARS: Cost of Injury Reports. Updated September 18, 2014. https://wisqars.cdc.gov:8443/costT/. Accessed February 4, 2016

136. Steffen, K. & Engebretsen, L. More data needed on injury risk among young elite athletes. *British Journal of Sports Medicine* **44,** 485–489 (2010).

137. Shrout, P. E. & Fleiss, J. L. Intraclass correlations: uses in assessing rater reliability. *Psychological Bulletin* **86,** 420 (1979).

138. Owens, J., Adolescent Sleep Working Group & Committee on Adolescence. Insufficient sleep in adolescents and young adults: an update on causes and consequences. *Pediatrics* **134,** e921–e932 (2014).

139. Meerlo, P., Havekes, R. & Steiger, A. in *Sleep, Neuronal Plasticity and Brain Function* 459–481. Springer, Berlin (2015).

140. Urrila, A. S., Paunio, T., Palomäki, E. & Marttunen, M. Sleep in adolescent depression: physiological perspectives. *Acta Physiologica* **213,** 758–777 (2015).

141. Reilly, T. & Edwards, B. Altered sleep–wake cycles and physical performance in athletes. *Physiology & Behavior* **90,** 274–284 (2007).

142. Noh, Y., Morris, T. & Andersen, M. B. Psychosocial factors and ballet injuries. *International Journal of Sport and Exercise Psychology* **3,** 79–90 (2005).

143. Pecoraro, R. E., Inui, T. S., Chen, M. S., Plorde, D. K. & Heller, J. L. Validity and reliability of a self-administered health history questionnaire. *Public Health Reports* **94,** 231–238 (1979).

144. Why is it important to know my family medical history? *Genetics Home Reference* (2015). http://ghr.nlm.nih.gov/handbook/inheritance/familyhistory. Accessed September 1, 2015.

145. Smilkstein, G. School Health-History Forms—A Study of Those Used in California, with Suggestions for Changes. *California Medicine* **110,** 315–318 (1969).

146. Moser, B. R. 30,000 Kicks: Gaining Perspective in Dance Training Volume. *Current Sports Medicine Reports* **13,** 293–294 (2014).

147. Lyman, S., Fleisig, G. S., Andrews, J. R. & Osinski, E. D. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *American Journal of Sports Medicine* **30,** 463–468 (2002).

148. Hamilton, L. H., Hamilton, W. G., Warren, M. P., Keller, K. & Molnar, M. Factors contributing to the attrition rate in elite ballet students. *Journal of Dance Medicine and Science* **1,** 131–138 (1997).

149. Taimela, S., Kujala, U. M. & Osterman, K. Intrinsic risk factors and athletic injuries. *Sports Medicine* **9,** 205–215 (1990).

150. Taunton, J., McKenzie, D. & Clement, D. The role of biomechanics in the epidemiology of injuries. *Sports Medicine* **6,** 107–120 (1988).

151. Wanke, E. M. *et al.* Dance floors as injury risk: analysis and evaluation of acute injuries caused by dance floors in professional dance with regard to preventative aspects. *Medical Problems of Performing Artists* **27,** 137–142 (2012).

152. Wanke, E. M. *et al.* Dance partner or dance floor? Exogenous factors resulting in accidents in professional dancers. *Medical Problems of Performing Artists* **28,** 131–136 (2013).

153. Roos, K. G. & Marshall, S. W. Definition and usage of the term ‘overuse injury’ in the US high school and collegiate sport epidemiology literature: a systematic review. *Sports Medicine* **44,** 405–421 (2014).

154. Bennell, K., Matheson, G., Meeuwisse, W. & Brukner, P. Risk factors for stress fractures. *Sports Medicine* **28,** 91–122 (1999).

155. Parsons, L. C. Osteoporosis: incidence, prevention, and treatment of the silent killer. *Nursing Clinics of North America* **40,** 119–133 (2005).

156. National Institute of Arthritis and Musculoskeletal and Skin Diseases. Handout on Health: Osteoporosis. http://www.niams.nih.gov/Health_Info/Bone/Osteoporosis/osteoporosis_hoh.asp. Accessed September 23, 2015.

157. Brooks-Gunn, J., Warren, M. P. & Hamilton, L. H. The relation of eating problems and amenorrhea in ballet dancers. *Medicine and science in sports and exercise* **19,** 41–44 (1987).

158. Smith, P. G. & Day, N. E. The design of case-control studies: the influence of confounding and interaction effects. *International journal of epidemiology* **13,** 356–365 (1984).

159. Lubin, J. H. & Gail, M. H. On power and sample size for studying features of the relative odds of disease. *American journal of epidemiology* **131,** 552–566 (1990).

160. Stein, C. J. *et al.* Dance-related concussion: a case series. *Journal of Dance Medicine & Science* **18,** 53–61 (2014).

161. Rosenthal, J. A., Foraker, R. E., Collins, C. L. & Comstock, R. D. National high school athlete concussion rates from 2005-2006 to 2011-2012. *American Journal of Sports Medicine* (2014). doi: DOI: 10.1177/0363546514530091

162. Marshall, S. W., Guskiewicz, K. M., Shankar, V., McCrea, M. & Cantu, R. C. Epidemiology of sports-related concussion in seven US high school and collegiate sports. *Injury Epidemiology* **2,** (2015).

163. McCrea, M., Kelly, J. P., Randolph, C., Cisler, R. & Berger, L. Immediate neurocognitive effects of concussion. *Neurosurgery* **50,** 1032–1042 (2002).

164. Moser, R. S., Schatz, P. & Jordan, B. D. Prolonged effects of concussion in high school athletes. *Neurosurgery* **57,** 300–306 (2005).

165. Centers for Disease Control and Prevention. *HEADS UP*. http://www.cdc.gov/headsup/index.html. Accessed December 18, 2015.

166. McCrory, P. *et al.* Consensus statement on Concussion in Sport–the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *South African Journal of sports medicine* **21,** (2009).

167. Harmon, K. G. *et al.* American Medical Society for Sports Medicine position statement: concussion in sport. *British journal of sports medicine* **47,** 15–26 (2013).

168. Aschengrau, A. & Seage, G. *Essentials of epidemiology in public health*. Jones & Bartlett Learning, Burlington, MA (2008).

169. Cohen, J. A coefficient of agreement for nominal scales. *Educational and psychological measurement* **20,** 37–46 (1960).

170. Gwirtsman, H. E., Kaye, W. H., Curtis, S. R. & Lyter, L. M. Energy intake and dietary macronutrient content in women with anorexia nervosa and volunteers. *Journal of the American Dietetic Association* **89,** 54–57 (1989).

171. Stice, E. Interactive and Mediational Etiologic Models of Eating Disorder Onset: Evidence from Prospective Studies. *Clinical Psychology* **12,** 2016 (2015).

172. Bulik, C. M., Marcus, M. D., Zerwas, S., Levine, M. D. & La Via, M. The changing 'weightscape' of bulimia nervosa. *American Journal of Psychiatry* **169,** 1031-1036 (2012).

173. Yager, Z. & O'Dea, J. A. Prevention programs for body image and eating disorders on University campuses: a review of large, controlled interventions. *Health Promotion International* **23,** 173–189 (2008).

174. Yager, Z., Diedrichs, P. C., Ricciardelli, L. A. & Halliwell, E. What works in secondary schools? A systematic review of classroom-based body image programs. *Body Image* **10,** 271–281 (2013).

175. Piran, N. Eating disorders: A trial of prevention in a high risk school setting. *Journal of Primary Prevention* **20,** 75–90 (1999).

176. Liederbach, M., Hagins, M., Gamboa, J. M. & Welsh, T. M. Assessing and Reporting Dancer Capacities, Risk Factors, and Injuries: Recommendations from the IADMS Standard Measures Consensus Initiative. *Journal of Dance Medicine & Science* **16,** (2012).

177. Dotti, A. *et al.* Eating behavior of ballet dancers. *Eating and weight disorders : EWD* **7,** 60–67 (2002).

178. Frusztajer, N. T., Dhuper, S., Warren, M. P., Brooks-Gunn, J. & Fox, R. P. Nutrition and the incidence of stress fractures in ballet dancers. *The American Journal of Clinical Nutrition* **51,** 779–783 (1990).

179. Grange, D. le, Tibbs, J. & Noakes, T. D. Implications of a diagnosis of anorexia nervosa in a ballet school. *The International journal of eating disorders* **15,** 369–376 (1994).

180. Herbrich, L., Pfeiffer, E., Lehmkuhl, U. & Schneider, N. Anorexia athletica in pre-professional ballet dancers. *Journal of sports sciences* **29,** 1115–1123 (2011).

181. Ravaldi, C. *et al.* Eating disorders and body image disturbances among ballet dancers, gymnasium users and body builders. *Psychopathology* **36,** 247–254 (2003).

182. Szmukler, G. I., Eisler, I., Gillies, C. & Hayward, M. E. The implications of anorexia nervosa in a ballet school. *Journal of psychiatric research* **19,** 177–181 (1985).

183. Toro, J., Guerrero, M., Sentis, J., Castro, J. & Puertolas, C. Eating disorders in ballet dancing students: problems and risk factors. *European eating disorders review : the journal of the Eating Disorders Association* **17,** 40–49 (2009).

184. Garfinkel, P. E. & Newman, A. The eating attitudes test: twenty-five years later. *Eating and weight disorders : EWD* **6,** 1–24 (2001).

185. Williams, R. L. Use of the eating attitudes test and eating disorder inventory in adolescents. *Journal of Adolescent Health Care* **8,** 266–272 (1987).

186. University of North Carolina School of the Arts. *Academic Programs*. http://www.uncsa.edu/academicprograms/programs.htm#HighSchoolDiploma. Accessed January 9, 2015.

187. Wilson, J. M. G. & Jungner, G. Principles and practice of screening. *WHO: Geneva* (1968).

188. Andermann, A., Blancquaert, I., Beauchamp, S. & Déry V. *Revisiting Wilson and Jungner in the genomic age: a review of screening criteria over the past 40 years*. http://www.who.int/bulletin/volumes/86/4/07-050112/en/. Accessed November 20, 2015.

189. VassarStats. *Clinical Calculator 1*. http://vassarstats.net/clin1.html. Accessed January 14, 2016.