OVERUSE INJURIES IN COLLEGE AND HIGH SCHOOL POPULATIONS: OCCURRENCE AND METHODOLOGICAL ISSUES IN SURVEILLANCE

Karen Gayle Roos

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Approved by:

Stephen Marshall

Yvonne Golightly

Kristen Kucera

Joseph Myers

Wayne Rosamond

ABSTRACT

Karen Gayle Roos: Overuse injuries in college and high school populations: occurrence and methodological issues in surveillance
(Under the direction of Stephen Marshall)

Overuse injuries are difficult to define, can have long term effects and are underrepresented in the literature. This dissertation aimed to 1) compare the incidence of overuse injuries between college and high school athletes, 2) compare how overuse injuries are captured in injury surveillance to medical records, and 3) describe variation between clinicians in the assessment of the role of overuse and the assignment of an overuse mechanism of injury to hypothetical injury scenarios. Overuse injury rates and rate ratios calculated from data from the National Collegiate Athletic Association's (NCAA) Injury Surveillance System (ISS) and the High School RIO (Reporting Information Online) indicate that overuse injuries occurred three times more often in college than high school athletes (IRR: 3.28, 95% CI: 3.12, 3.44) and more often in female than male athletes (IRR: 1.55 95% CI: 1.43, 1.68) (Aim 1). A capture-recapture analysis of ISS and medical records for college mens and womens soccer injuries demonstrated that the ISS captured 63.7% (95% CI: 52.8%, 74.5%) of total overuse injuries (Aim 2). A survey which presented hypothetical injury scenarios was conducted among athletic trainers (ATs), the data collectors for injury surveillance (Aim 3). All but one scenario generated some degree of discordance among respondents regarding the role of overuse in the scenario and the probability of reporting an overuse mechanism of injury to surveillance. ATs also reported that nearly 50% of total

treated injuries were overuse, and of those, only 62% were reported to surveillance. In summary, the findings demonstrate that overuse injuries comprise a significant proportion of injuries, specifically to college and female athletes (Aim 1). However, overuse injuries can be difficult to assess, which likely contributes to underreporting (Aim 2) and variability (Aim 3) in the reporting of these injuries. Based on these results, it is recommended a consensus definition for overuse injuries be created and adopted, with the goal of improving the capture of overuse injuries in surveillance systems. Improved capture will result in a more complete understanding of the incidence of overuse injuries and may lead to effective and targeted interventions to prevent these debilitating injuries.

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Also heartfelt congratulations to anyone who has ever attempted such a thing. It is not for the faint of heart.

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LIST OF ABBREVIATIONS

AE	Athlete Exposure
AT	Athletic Trainer / Certified Athletic Trainer
CI	Confidence Interval
HS	High School
IRR	Injury Rate Ratio
ISP	Injury Surveillance Program
ISS	Injury Surveillance System
ISS/ISP	Injury Surveillance System/Program
MD	Medical Doctor
n/a	Not applicable
NCAA	National Collegiate Athletic Association
OIC	Overuse Injury Questionnaire
OOS	Occupational Overuse Syndrome
OSTRC	Oslo Sport Trauma Research Center
PT	Physical Therapist
RIO	High School RIO (Reporting Information Online)
RSI	Repetitive Stress Injury
UNC	University of North Carolina at Chapel Hill
US	United States
WRMSD	Work-Related Musculoskeletal Disorder

CHAPTER 1

INTRODUCTION

Injuries resulting from sport participation have can have profound immediate and long term effects. [1] The initial injury may result in pain and dysfunction which limits current athletic participation. The long term effects can result in symptoms beyond the resolution of the immediate injury, such as chronic pain and prolonged limitations in function that impedes maintenance of healthy physical activity in later life. [2-4] Thus, preventing sport related injury, particularly in youth can contribute to better health throughout the athlete's life. [5]

Overuse injuries have been reported to account for up to 30% of total athletic injuries in a college setting and 7.7% of high school sports injury. [6, 7] These injuries are classically characterized by a repetitive nature and gradual progression with the absence of a distinct injury event. [8, 9] Due to the gradual onset and accumulation of symptoms, athletes with overuse injuries may initially delay seeking care. When care is sought, it often does not result in time-loss from sport. [10, 11] Most sports injury surveillance systems are limited to time-loss injuries only, which often result in an underrepresentation of overuse injuries within surveillance data. [8, 12]

There are currently no standardized diagnostic tests to ascertain the presence of an overuse injury, so the assessment of overuse depends to some degree on the practices of the individual clinician or evaluator. [13-15] At this time, there is no consensus about the definition of an overuse injury in general practice or within injury surveillance systems. [8] The absence of

such a definition is widely suspected to contribute to variability between clinicians regarding the assessment and reporting of overuse injuries to injury surveillance systems, although this has not previously been formally investigated in the scientific peer-reviewed literature.

This dissertation is a comprehensive investigation of the incidence of overuse injuries using injury surveillance data combined with an exploration of some of the methodological factors associated with the reporting of overuse injuries within injury surveillance. Thus, this work summarizes our existing knowledge on the incidence of overuse injuries and explores the limitations of the current surveillance methods, and how these limitations may affect measures of incidence which surveillance systems produce.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Overuse injuries

Overuse injuries are generally defined as injuries which progress over time and result from repetitive stresses. [16, 17] They result from the accumulation of microtrauma on the cellular level in a variety of tissues (bone, muscle, tendon, ligament). [8, 18]

2.1.1 Biomechanics/nature of overuse injuries

Overuse injuries typically do not have a specific onset incident, but instead progress with continued activity, particularly if there is insufficient time for recovery between episodes of physical activity. [19-21] As these stresses are individually small, the injured person may not be aware of the presence or seriousness of the injury, until severe tissue damage has occurred. [16, 22] It is the repetitive nature of the stress, not the activity itself, which results in the injury. [14, 23] The repetitive stresses that contribute to the microtrauma of overuse injuries may be of any magnitude and can result from any repetitive activity, ranging from powerlifting to typing.

Sports participation, particularly in youth, can be significant source of repetitive activities. [24] Youth sports participation leans heavily on repetition as a means of learning specific sports skills. [25-27] As the athlete progresses and excels within a sport, the difficulty, intensity and duration of sports participation increases. This increases the potential for repetitive microtruama, as well as the risk of overuse injury among young athletes. [1, 3]

2.1.2 Clinical diagnosis of overuse injuries

There is a general understanding within the sports medicine community that an overuse injury has a gradual onset, progresses over time and results in pain and dysfunction. [28] However, there are no widely accepted diagnostic tests which are used to determine the presence of an overuse injury. [14, 15] There are specific diagnostic tests which are accepted for particular types of overuse injuries, such as bone scans for stress fractures. However, these do not exist for all overuse diagnoses and there is no universal diagnostic test for the larger category of "overuse injury". [13] The absence of diagnostic tests leaves the identification and determination of overuse to the individual evaluator. [29] Each evaluator is influenced by his or her education and experiences, as well as local practices for diagnosis. The lack of a gold standard test leaves much room for between-clinician variability in the individual diagnosis of overuse, and ultimately, the individual clinician as the arbiter of the presence or absence of overuse. [12, 29, 30]

2.2 Public health impact of overuse injuries

Overuse injuries, particularly in sports, are preventable. [18, 23]The biomechanical stress from repetitive activity is much less likely to result in injury if there is enough time for the tissue to recover. [31-33] However, young athletes are exposed to many factors which limit "down-time" from sports. [19] These include pressure for young athletes to excel, from parents, coaches, teammates or themselves, the opportunity for athletes to participate on multiple teams, in multiple leagues, and in multiple sports, and beginning sports at younger ages. [19, 24, 34] Sports specialization is also occurring at younger ages, leading to increased repetition of specific sports skills. [24] With increased participation, the athlete has less time to recover from the repetitive stress, thus leading to overuse injuries. [21, 35]

Overuse injuries include a variety of diagnoses and injury severity, and can result in a variety of outcomes. [36, 37] These diagnoses range from exercise related leg pain associated with running, to ACL tears associated with playing football. [38, 39] In the early stages of progression, overuse injuries often do not result in time-loss from sports. [7] Many athletes with these injuries can continue to participate on some level by compensating with alterations to the skills performed, body mechanics, or training volume to accommodate the injury. However, the outcomes of overuse injuries are not limited to the time period immediately following injury, but instead can last throughout the lifetime. This can result in chronic pain and limitations in activity in later life, even from injuries which did not result in immediate time-loss from sport. [2, 4]

As the US population lives longer and remains active longer, the impact of chronic injury on the population grows. This includes not merely the acute treatment of injury, but also the care for the long-term effects, such as musculoskeletal disorders (e.g. post-injury osteoarthritis). [40] This accumulating burden of injury and sequellae will increase demand on the health care system. [1, 40] Identifying the role of repetitive sports activity in injury will assist in the creation of appropriate interventions and guidelines to protect young athletes from the effects of injury, not only in youth, but from the sequella of injury later in life.

If untreated, overuse injuries can result in in prolonged withdrawal from sports due pain and dysfunction. [1, 41] Withdrawal from sports can lead to decreased activity and increased sedentary behavior which increase the risk of obesity, diabetes, cardiovascular disease, and metabolic syndrome. [42-47] A United Kingdom (UK) study found that 15 of 94 young elite athletes in the UK who withdrew from sports withdrew due to injury, and annually 8% of Australian youth athletes withdraw from sports due to injury. [20, 21] However, the number of athletes who withdraw from sports due to overuse injuries is currently unknown, and the long

term effects of withdrawal from sports on the individual athletes and the health care system will likely increase with time. [1, 2] Interventions implemented in high school and college athletic populations have the potential to decrease the burden of overuse injuries both in the individual athlete during sports participation and health care system as these athletes age.

2.3 Overuse injuries in the literature

The literature regarding overuse injuries is varied as to the nature of the study, injuries investigated, source populations and statistics (if any) reported. The majority of studies regarding overuse injuries are clinical in nature, describing the pathomechanics, diagnosis, treatment and interventions for specific injuries. Such studies often describe a distinct injury or injuries which occur in one sport, or to one body part. These studies may not include statistics regarding the incidence of these injuries, but instead focus on the description of the injury, mechanics, diagnosis, treatment or outcome related to that injury. [48]

2.3.1 Incidence of overuse injury from case series and prospective cohort studies

Certain studies of specific overuse injuries or interventions, including case series and prospective cohort studies, include measures of incidence. Within these studies, the reported incidence of overuse can be quite high, as these studies are specifically designed to capture these injures and use specialized case definitions or populations at high risk for overuse injury. Examples include studies of high school runners, where overuse injuries are reported to occur in 41% to 82% of all participants. [49, 50] A study of young tennis players in Sweden reported that “overuse type” injuries accounted for 54% of total injuries, while a study of elite young rowers reported that 74% of all injuries while rowing were due to overuse mechanisms. [51, 52] Other

studies, such as reviews of sports injury in youth, and various position statements regarding sports injuries to young athletes and overuse injuries have reported that overuse injuries account for 33% of total injuries to elite English adolescent athletes, and it has been suggested that overuse injuries could account for more than 50% of total childhood sports injuries.[18, 36, 53]

2.3.2 Incidence of overuse injury from injury surveillance studies

Surveillance studies of sports injury generally report a lower incidence of overuse injury as compared to cohort or case series studies. These studies use injury surveillance data, where a research hypothesis usually has not been identified prior to data collection. [48] Surveillance investigations which target overuse injuries are rare, specifically for young athletes. [18, 23] Currently the only surveillance studies of US athletes that focus on overuse injuries are Yang et al (2012) [7], in college athletes, and Schroeder et al (2014) [6] in high school athletes. These studies report that 30% of total injuries from one university over three academic years, and 7.7% of nationally representative high school injuries from 2006 through 2012, which had at least one day lost to sport after reporting the injury, were overuse injuries. College athletes reported overuse injuries at a rate of 63.1/10,000 athlete exposures, (AE, defined as one athlete participating in one sanctioned sports activity with the potential for injury), and high school athletes reported overuse injuries at a rate of 1.5/10,000 AEs. In both populations, female field hockey and female soccer had high rates of overuse injury (college: 70.5/10,000 AEs; high school: 2.9/10,000 AEs and college: 48.3/10,000 AEs; high school 2.0/10,000 AEs respectively). In high school athletes, female track and field had the highest rate of overuse injury (3.8/10,000 AEs), while in college athletes, it had one of the lowest rates of overuse injury (8.3/10,000 AEs).

Overall, male sports had lower rates of overuse injury than female, and overuse injuries occurred most often in the lower extremities (college: 49.0%, high school: 69.5%). [6, 7]

Aside from Yang et al (2012) [7], and Schroeder et al (2014) [6] the majority of sports injury publications, which include overuse injuries at all, only superficially discuss these injuries. [48] Surveillance studies of US school populations report that overuse injuries account for between 1% and 11% of total college sports practice injuries. [47, 48, 53-63] [54-65] In the high school setting, overuse injuries were reported to account for 5% to 10% of total soccer and baseball injuries, and 25% of lower extremity and knee injuries. [31, 66-68] Swenson et al (2013) [69] used US surveillance data regarding knee injuries in high school athletes, and provided the percentage of knee injuries with an overuse mechanism of injury. Of the 20 sports studied, 39% of 75 girls field hockey knee injuries, 56% of 68 boys track and field and 38% of 81 girls track and field knee injuries were due to overuse mechanisms. [69]

These studies which discuss overuse injuries present different analyses, data collection methods, and definitions of overuse. [48] The two studies which focus on the surveillance of overuse injuries also have different definitions for a reportable injury; one requiring a day lost to sport in order to be entered into surveillance and the other without this requirement. These differences limit both the interpretation and generalizability of the findings. Aside from Yang et al (2012) [7] and Schroeder et al (2014) [6] surveillance investigations provide overuse injury statistics within strata of injury type, body part injured or sport. This provides an estimation of the incidence of overuse only within a specific category, or strata and does not provide an overall estimate of overuse injury in a specific sport or sports in general. [41, 67, 70]

2.4 Injury surveillance and public health

Public health surveillance is traditionally defined as "the ongoing systemic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know." (Thacker et al, 1988) [71] The definition of surveillance is expanding in response to technological advances in data collection and analysis to include an a priori purpose of preventing or controlling disease or injury, in order to differentiate surveillance from data mining. [72] The data collected in traditional surveillance systems is usually minimal, and is collected to identify and control a health problem or improve a public health program or service. While surveillance is informed by an a priori purpose, it is not designed to test hypotheses, or apply its findings to a separate population. [71, 72] This is what differentiates surveillance from research, as the purpose of research is to generate generalizable knowledge, often through hypothesis testing. [73, 74] However, as the quality and quantity of surveillance data increases, similarities between the quality, utility and application of research and surveillance data within the literature increase as well.

2.5 Current sports injury surveillance systems

Sports injury epidemiology often uses data collected through injury surveillance systems. In general, these surveillance systems are used to identify trends in injury or health patterns and recognize areas for further research or intervention. [75] Effective injury surveillance should provide data to define the state of injury within the surveillance population in order to identify injury problems, design prevention programs, and evaluate these programs. [76] Sports injury surveillance programs collect data in regard to the specific injury incidents such as the

mechanism of injury, and activity at time of injury, injury outcome, if surgery was required, the amount of time lost to sports, the presence of protective equipment, and the position played by the athlete among others. [75]

Sports injury surveillance systems also collect data beyond what traditional surveillance systems require. An example of such data is information about the individual AEs. The major sports injury surveillance systems in use in the US collect data on the number of athletes participating in each athletic event, as well as the type, location, sport, seasonality and playing surface of each event among others, regardless of any injuries which may occur. [75, 77] This allows for the calculation of injury rates for the populations of total athlete exposures, as well as within specific sports exposures, game or practice exposures, or pre, in, or post season exposures.

There are several school based injury surveillance systems in the US collecting data on sports related injuries. The largest are the National Collegiate Athletic Association's (NCAA) Injury Surveillance System/Program (ISS/ISP) for college sports injuries and the High School RIO (Reporting Information Online) (RIO; Nationwide Children's Hospital, Columbus OH) for high school sports injuries. Both injury surveillance systems use ATs to collect data, and frequently publish reports of their findings. ATs are medical professionals who are specifically trained in the evaluation of sports injury, and have shown great reliability as data reporters in validation studies of both the RIO and ISS/ISP. [77-79]

2.5.1 National Collegiate Athletic Association's (NCAA) Injury Surveillance System/Program (ISS/ISP)

The ISS has been collecting data on college athletic injuries since 1982. This system was specifically developed to monitor injury patterns and trends in college sports. The ISS uses a

volunteer sample of NCAA institutions to collect injury and exposure data in a variety of sports. ATs collect data from all formal team activities for all college sports with a championship. There have been many changes to the ISS since its inception in 1982, such as advancing from a paper to online platform, and transferring the system to an external vendor, the Datalys Center for Sports Injury Research and Prevention, Inc. (Datalys Center) in 2008/2009. [75, 76, 80] These milestones are presented in Figure 2.1. In 2009, the Injury Surveillance System (ISS) was renamed the Injury Surveillance Program (ISP), coinciding with significant changes to the online platform, such as collecting data on non-time-loss injuries. [75] For the purposes of this dissertation, ISS refers to the system, or data from the system from 1982 through 2009, ISP refers to the system or data from the system from 2009 on. ISS/ISP refers to the system in general (regardless of timeframe).

The ISS/ISP is a voluntary system, where ATs at NCAA institutions volunteer to participate in data collection. [75] This can result in the underrepresentation of certain types of institutions within the data. The institution sampling scheme can also underreport rare, but important injuries and injury phenomena. For example, an individual catastrophic injury that receives widespread media attention and results in policy changes may not be present in the ISS/ISP data if the involved school does participate in data collection.

2.5.1.1 Impact and successes of the ISS/ISP

Collected data is shared annually with NCAA rules and medical committees such as the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports. This data has been used to support rule changes in multiple sports such as the 1995 rule changes to mens hockey to reduce hitting from behind and contact to the head, and the 1997 changes to the

allowable equipment, and level of contact in spring football. In 2003, rule changes required protective eye equipment in womens field hockey, and changes to allowable equipment and practice days in preseason fall football. In 2010 the NCAA legislated that all school must have a management plan for concussions, and in 2012, the rules regarding kickoffs in football were modified for injury prevention. [75] Data from the ISS/ISP have also been used for practical applications, such as identifying sports with increased injury risk for increased medical coverage and monitoring the results of rule changes and other injury prevention interventions. ISS/ISP data have also been used in numerous peer reviewed journal articles, including one entire issue of the Journal of Athletic Training in 2007. [75]

2.5.2 High School RIO (Reporting Information Online) (Nationwide Children's Hospital, Columbus OH)

The RIO is an online surveillance system developed in 2004 by Dr. R. Dawn Comstock as part of the National High School Sports-Related Injury Surveillance Study. This surveillance system was designed after the online ISS platform, with help from the National Federation of State High School Associations, National Collegiate Athletic Association, National Athletic Trainers' Association Secondary School Athletic Trainers Committee, US Consumer Product Safety Commission, and The Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. [81]

The RIO, as the ISS/ISP, is a voluntary system, and therefore has similar limitations in sampling and similar potential for bias due to the voluntary nature of the data collection. However, RIO obtains a nationally representative sample by randomly selecting schools which have been stratified by geographic region and size. [82] Also, the RIO does not represent schools which do not have access to athletic training services, as schools without ATs are ineligible to

participate in data collection. Not all high schools provide AT coverage for athletic events, and those with and without ATs may be fundamentally different, which may impact the generalizability of RIO results to schools without ATs.

2.5.2.1 Impact and successes of the RIO

The RIO began collecting data from a nationally representative sample of nine sports, in the 2005/2006 academic years. It continues to collect representative data on those sports, and has increased the number of sports it collects data on via convenience sampling. (Figure 2.2) The RIO system has established baselines and trends of high school sports injury, as well as identified emerging issues and evaluated interventions and policy changes. Twenty two manuscripts in peer reviewed journals have been published or accepted for publication. Specific reports on football blocking injuries, skin infections in wrestlers, dental injuries in soccer players and baseball injuries from being struck by a batted ball have been provided to the National Federation of State High school Association's Sports Medicine Advisory Committee and individual sport Rules Committees. [81]

2.6 Challenges in using the ISS/ISP and RIO for surveillance of overuse injuries

Sports injury surveillance has been successful in identifying targets for specific intervention and further research. Successes have been investigations into severe injuries to pole-vaulters and current research regarding concussions. [83, 84] A common factor for these successes is that all involve acute injuries. Using data from injury surveillance systems to describe the incidence of overuse injuries is challenging for several specific reasons associated with the cumulative nature of overuse injuries.

2.6.1 There is currently no consensus on a definition for overuse injuries within injury surveillance

As stated previously, there is no clinical consensus definition to determine the presence of an overuse injury. There is also no current consensus definition for overuse injuries within injury surveillance. In fact, overuse is defined differently between ISS/ISP and RIO (as "overuse/gradual onset" in the ISS/ISP, and as "overuse/chronic" within the RIO). While it has been suggested that a consensus definition should be used in injury surveillance, thus far, one has not been provided. [29]

In the absence of consensus definitions or precise diagnostic testing, the best option is likely the opinion of an expert clinician. [85] With this form of classification, clinicians use data from the history, including patient symptoms and dysfunction, physical examination and radiographic tests to assign a label of "overuse" based on guidelines set by an expert panel or Delphi committee. [85, 86] As of yet, no committee has addressed the operational definition of overuse injuries.

2.6.2 Use of a time-loss definition

The RIO, and the ISS (1982 through 2009), only collect data on time-loss injuries, defined as an injury which results in absence from sports for at least one additional day after injury. Orchard et al (2007) [87] support this methodology and argue that it provides the most consistent and clearest definition for a reportable injury, which results in the most accurate and reliable data. They argue that when the criteria for a reportable injury are symptom or diagnosis based, the differences in individual clinician's diagnostic practices lead to more error in the data, and a lack of generalizability between studies.[87]

Despite the strength of consistency, the time-loss only definition for a reportable injury is not comprehensive when specifically investigating overuse injuries, as many overuse injuries are not time-loss injuries. [7] In the ISS (1982 through 2009) and RIO system a severe muscle cramp which removes and athlete from participation for one additional day and requires minimal medical attention will be recorded in injury surveillance, but a tendonitis which requires daily attention from the medical staff for several weeks and results in altered participation for that whole time frame will not. Thus, a time-loss only criteria for sports injury surveillance will underrepresent the incidence and prevalence of overuse injuries. [12] It will also underrepresent the health care costs, in money and in attention from the medical staff, associated with overuse injuries. While the ISP (2010 through present) currently has the ability to record all treated injuries, it is expected that the history of a time-loss definition within the ISS continues to influence the data. Specifically, all non-time-loss injures may not be reported to the ISP, due to the AT's previous history with a time-loss definition. ATs also just may not report all treated injuries due to other priorities or duties in their jobs. [87]

Recently epidemiologists and clinicians in several sports have developed consensus statements for the standardization of injury surveillance methods within those sports. Consensus statements for soccer and rugby proposed an adapted model for the definition of injury within surveillance systems. This model separates "injury" into three different operational definitions: 1) events which result in any physical complaint, 2) events which required any medical attention, and 3) events which result in any time-loss. [12, 16, 20] Of those definitions, there is growing support for using the first definition, as it is the most inclusive. [88] A separate consensus statement for track and field recommends an injury definition of "A physical complaint or observable damage to body tissue produced by the transfer of energy experienced or sustained by

an athlete during participation in Athletics training or competition, regardless of whether it received medical attention or its consequences with respect to impairments in connection with competition or training." [11] Others argue that consistent injury definitions may not be the solution, and rather the definition should be specific to the research question being studied. [10] While this remains a contentious issue with increasingly divergent viewpoints, it is encouraging that these methodological challenges are receiving attention. [89]

2.6.3 Overuse as a mechanism of injury vs. injury diagnosis

A major methodologic issue in injury surveillance systems is the lack of consensus about the application of the term "overuse". Within the ISS (1982 through 2009) and currently with cross country injuries in the RIO, "overuse" can refer to a mechanism of injury, an injury diagnosis, and at times, both. When used as a mechanism of injury, "overuse" refers to the causation, the repetitive or cumulative activity which led to the injury. [35, 90, 91] When used as a diagnosis, "overuse" often refers to a family of injuries classified by slowly progressing inflammation, pain and loss of function. [17, 92, 93] Thus, as a mechanism of injury "overuse" is the cause, as a diagnosis "overuse" is the effect.

Our systematic literature review [48] of the use of the term "overuse" within US epidemiological studies found that of 35 articles of college and high school sports injury which also reported overuse injuries, 14 articles reported overuse as a mechanism of injury, seven reported overuse as a category of injury diagnoses, and eight reported overuse as both. The use of "overuse" as a mechanism of injury or injury diagnosis was also inconsistent within data sources. Of the articles which used data from the ISS, two reported overuse as a mechanism of injury, three reported overuse as a category of injuries, and four reported overuse as both.

Similarly, among articles which used data from the RIO, eight reported overuse as a mechanism of injury, two reported it as a category of injuries and three reported it as both. The multiple uses of the term "overuse" in the literature limits comparability between studies, even studies which use the same data source. This complicates interpretation of the data, and may impact the development of interventions from these studies.

2.6.4 Potential misclassification of overuse

The diagnosis of an overuse injury is often dependent on when and whether the athlete seeks care. [22] As these injuries may initially present as small, nagging pains which can be initially ignored, they may not be addressed until significant pain or deficit in function is present. [22] If the athlete presents only the current state of the injury, it may appear to be from acute, rather than overuse, mechanisms. This can affect the diagnosis the athlete receives and the mechanism assigned to the injury, which can result in misclassification when this injury is submitted to surveillance systems. [12, 60, 64] Misclassification may result in an underestimation of the incidence of overuse, and will affect the estimates that injury surveillance produces. [48] The athlete may also withdraw from sports rather than seek treatment thus avoiding diagnosis altogether, further underestimating the incidence of overuse. [1, 3]

2.7 Alternate methods for measuring overuse injuries

Alternate strategies specifically for studying overuse injuries that do not use injury surveillance models have been developed. The Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire (OIQ) has already been implemented in several studies. [20]

Additionally established methods of studying repetitive stress injury in occupational research, may be applicable to sport injury.

2.7.1 Oslo Sports Trauma Research Center Overuse Injury Questionnaire (OSTRC/OIQ)

The OSTRC/OIQ, [16, 20] relies on athletes to self-report levels of difficulty with participation, reduced training volume, affected performance and pain due to sports participation to capture overuse injuries. The OIQ is a questionnaire which asks four questions per body part included in the study, and is intended to be administered serially to athletes (e.g. weekly, biweekly or monthly). [20] The OIQ operationally defines overuse injury as a limit in function regardless of time-loss from sports. The outcome of these systems is prevalence of substantive overuse injury and average injury severity scores. [16, 20]

The nature of this method remains subjective, but the onus shifts from the clinician to the athlete, and, it has the advantage of capturing the burden of overuse injuries in a more thorough manner than the currently used surveillance systems. This data will not be limited to information on time-loss injuries, and is not subject to bias in injury definitions from injury evaluators, data reporters or analysts. However, it is difficult to compare the results of the OIQ to the traditional injury surveillance as they use different injury definitions and paradigms. Furthermore, the effect of varying thresholds for personal pain and variations in function remain a concern.

2.7.2 Occupational models

Additional operational definitions of overuse injuries and methods of measuring overuse injury are found in the occupational injury literature. In this research domain, overuse injuries are often referred to as repetitive stress injuries (RSI) or occupational overuse syndrome (OOS) and

are a subset of work-related musculoskeletal disorders (WRMSDs). [94-99] WRMSDs encompass a diverse range of diagnoses and musculoskeletal impairments, which results in a category of disorders rather than one specific operational definition. All WRMSDs involve an occupational component, indicating that the injurious incident is, in some way related to occupational exposure. [94, 95] For overuse-type WRMSDs, this occupational exposure is often repetitive tasks. [99, 100]

Occupational studies often define RSI or OOS much like the biomechanical definition of sports overuse injury: as injuries which develop progressively over time and do not have a specific onset incident. [98] These studies also have various methods of quantifying occupational exposure to overuse. Occupational exposure can be quantified by minutes of repetitive activity using both subjective and objective measures. [100, 101] While subjective surveys rely on participant recall regarding minutes of exposure, objective methods rely on direct observation and documentation of time spent at specific tasks.

One method of observation involves a multistep process that resembles a job exposure matrix: 1) workers are observed in order to identify tasks which are repetitive, 2) repetitive tasks with similar physical demands are categorized and placed into task groups , 3) a number of workers from each task group (1 – 10) are video-taped or observed for a period of time (10-15 minutes) and the number of repetitions of specific tasks are counted, 4) the count of repetitive tasks are weighted to produce a total repetitive task exposure for the work week. The weighted exposure is then applied to each member of that specific task group, which allows for comparisons between task groups in regard to cumulative exposure. [101, 102]

This objective measuring of exposure offers the potential to establish a dose-response relationship which is not yet available from sports injury surveillance. Although sports injury

surveillance can collect exposure data with covariates related to event type, location, field and weather conditions no sport injury researchers to date have sought to quantify the time that an individual athlete spends on repetitive skills or drills. [80, 103] The adoption of objective exposure methods in sports injury research would advance the field and address the role of cumulative sports participation as a causal factor in injury incidence, and the role of repetition of specific activities in specific injury outcomes. Data on recovery time (time between scheduled team activities) could also be captured and investigated for its role in the onset and prevention of overuse injuries.

2.7.3 Qualitative studies

Qualitative studies also have the potential to influence overuse injury assessment and intervention. van Wilgen and Verhagen (2011) [104] interviewed athletes and coaches about their beliefs on the etiology and risk factors for overuse injuries. Both athletes and coaches believed that overuse injuries were due to behaviors and activities rather than physiological causes. [104] This study suggests that there is the potential for effective behavioral interventions, and that athletes and coaches have similar beliefs about overuse injuries. While qualitative studies cannot measure injury incidence, they are effective for studying personal conceptual paradigms of overuse injuries in athletes, coaches and health care providers.

2.8 Summary

Prevention of overuse injuries in youth is important to continued participation in an active lifestyle, which can have a positive impact throughout the athlete's lifetime. Overuse injuries are challenging to identify, diagnose, report, and at times even discuss with real

consistency in the application of the term "overuse". This is likely due to their mechanism of repetitive stress and their slow, progressive nature. Recently there has been an increased awareness of, and investigation into, measuring overuse injuries in both surveillance and alternative systems. With this increased attention, there is opportunity to address the current state of injury surveillance for overuse injuries, including the role of the data collector in this process. Improved knowledge of the variation in how data collectors define and report overuse injuries will enhance the interpretation of the statistics regarding overuse injuries they produce, and can lead to improvements in the methods of these systems in regard to capturing overuse injuries.

This dissertation is a start towards improving our understanding of how overuse injuries are captured within injury surveillance. These results may aid the creation of a single operational definition for overuse that could be universally applied within injury surveillance systems in the future. This methodological advance would likely also inform and stimulate creation of future overuse interventions. While a consensus operational definition of overuse is not achievable within the scope of this dissertation, the work in this dissertation is an important step towards that goal.

The proposed dissertation examined the following general research questions:

RQ1: What is the current incidence and distribution of overuse injuries in college and high school athletes?

RQ2: How effective is the ISS at capturing overuse injuries, and what factors are associated with the reporting of overuse injuries?

RQ3: How do ATs determine if overuse contributes to an injury, and what strategies do they employ when reporting these injuries to surveillance systems?

This dissertation used de-identified surveillance data from the ISS and RIO, pre-existing data from a validity study (including data abstracted from medical records and data associated with the abstraction process) and survey data from ATs who participate in the ISP.

2.9 Figures

Figure 2.1. Timeline of NCAA ISS/ISP milestones

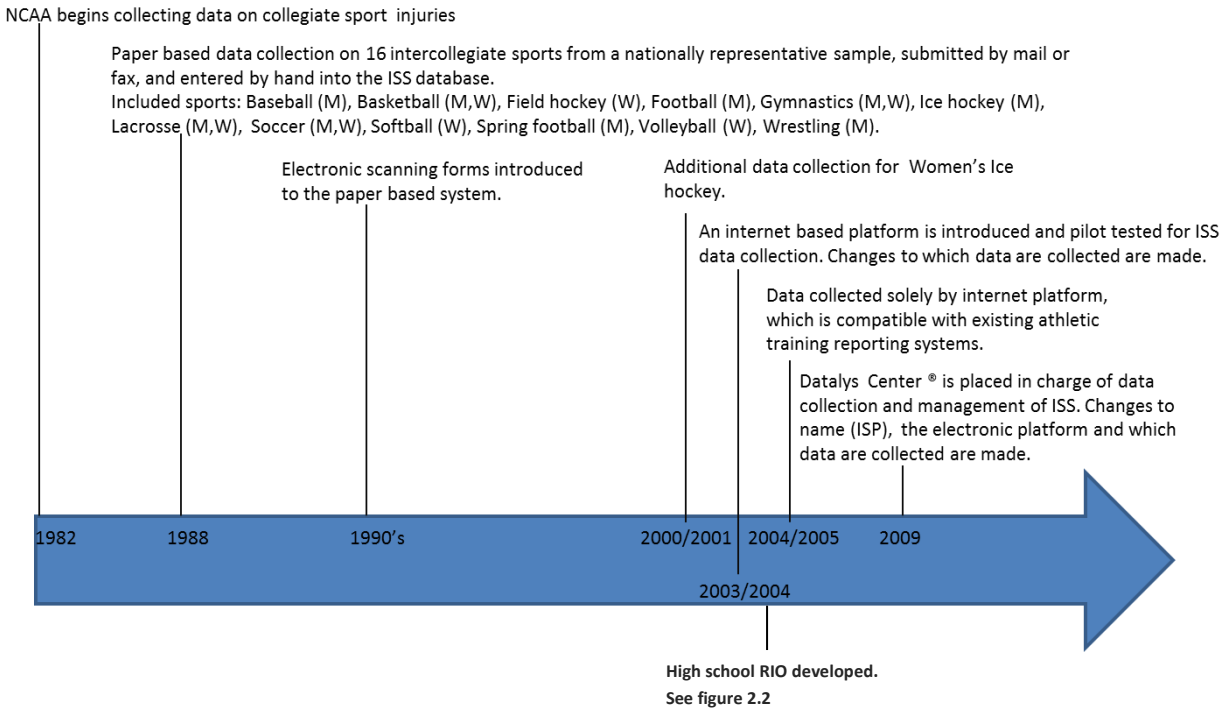
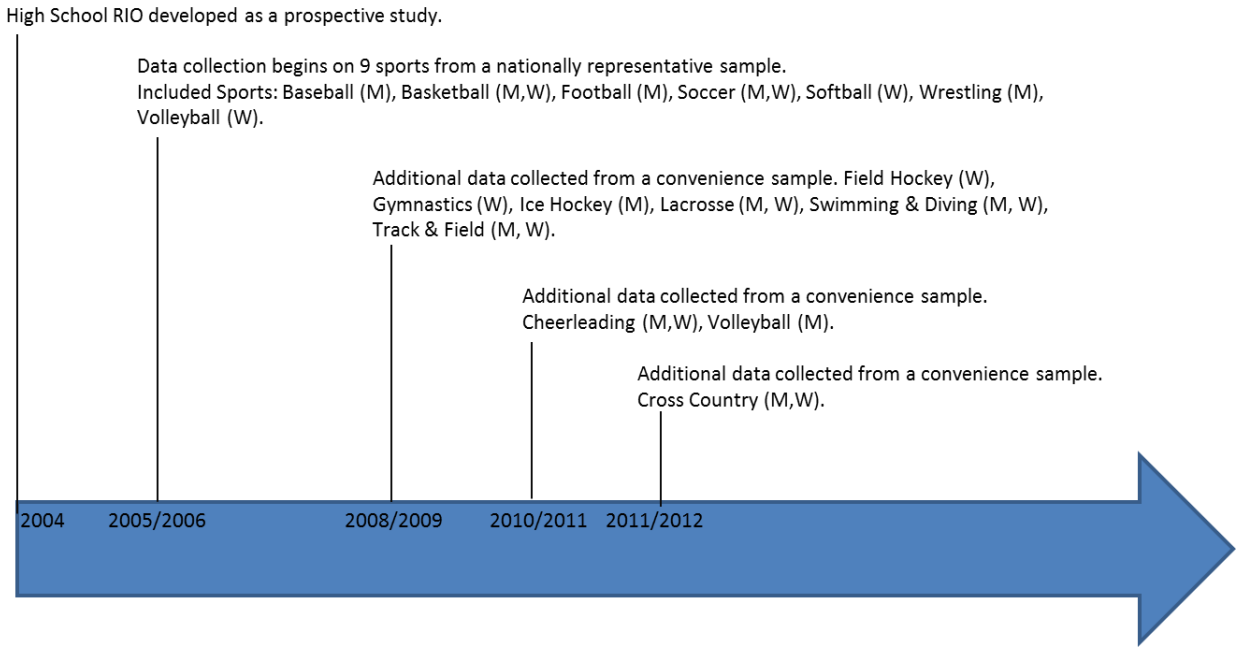


Figure 2.2. Timeline of RIO milestones



CHAPTER 3

STATEMENT OF SPECIFIC AIMS

This dissertation describes the incidence of college and high school overuse injuries determined from injury surveillance data, as well as the methodological implications of using surveillance data for these measures of incidence. The work has three specific aims. (Tables 3.1 – 3.3)

Aim 1: Describe and compare the distribution of time-loss overuse injuries in college and high school athlete populations using existing injury surveillance data. (Table 3.1)

Aim 1a: Estimate and compare the overall rate of overuse injury (defined as an overuse mechanism of injury) reported to college (ISS) and high school (RIO) injury surveillance systems.

Aim 1b: Describe the distribution of injury diagnosis, body part injured, time-loss to injury and injury severity in both college and high school overuse injuries.

Hypotheses:

H1: Overuse injury rates and patterns differ across college and high school populations, sport and gender.

H2: The distribution of injury diagnosis, body part injured, time-loss to injury and injury severity will differ between college and high school populations.

Rationale: As of yet, there is no published comparison of the incidence of overuse injuries in college and high school populations. In fact, there is currently only one published study of college overuse injuries, and only one study of high school overuse injuries. [6, 7, 48] The term "overuse" has been used in the literature in three ways: 1) to refer to a mechanism of injury; 2) to refer to injury diagnosis, and 3) in some studies, to refer to both mechanism and diagnosis. [8, 48]

"Overuse" was conceptually defined and analyzed as a *mechanism of injury* for the purposes of this aim. Therefore inclusion into these analyses required a mechanism of injury of "overuse/gradual onset" (ISS) or "overuse/chronic" (RIO). The use of a mechanism of injury definition is analogous to the published studies in college and high school populations, who also defined overuse as a mechanism of injury. [48] Injuries with a mechanism of injury of acute non-contact or a diagnosis of overuse (regardless of mechanism of injury) were also investigated as part of the Aim 1 analyses, to explore whether there was evidence that the mechanism of injury was overuse. Aside from the injuries with an overuse diagnosis that were already included due to their overuse mechanism of injury, no other injuries were determined to be appropriate for inclusion.

De-identified injury surveillance data from the ISS for 16 sports (2004/5 through 2008/9) and data from the RIO for 14 sports (2006/7 through 2012/13) was used to address Aim 1. The Aim 1 analyses are a necessary first step to compare the incidence of overuse injuries between these populations and determine potential factors associated with these injuries. The comparison of the incidence and severity of overuse injuries between college and high school athletes also demonstrates the nature of overuse as progressive injuries. [17] In general, college athletes have been performing their sport at high intensity for a significant amount of time, in fact, most played

that sport through their high school careers, and may have started their sport long before that. [3, 24] This fact likely underlies the hypothesized differences in rates and patterns of overuse injury between college and high school populations.

Table 3.1. Summary of Aim 1 for Dissertation

#	Aim	Data	Analysis
1	**Describe and compare the distribution of time-loss overuse injuries in college and high school athlete populations using existing injury surveillance data.**		
1a	Estimate and compare the overall rate of overuse injury (defined as an overuse mechanism of injury) reported to college (ISS) and high school (RIO) injury surveillance systems.	De-identified injury surveillance data from the ISS for 16 sports (n=3,569 injuries from 2004/5 through 2008/9) and data from the RIO for 14 sports (n=3,168 injuries from 2006/7 through 2012/13).	1) Calculate overuse injury rates for each system, each sport for each system and by gender for each system. 2) Calculate injury rate ratios comparing the rates of overuse injuries of the two systems in total, by sport and by gender.
1b	Describe the distribution of injury diagnosis, body part injured, time-loss to injury and injury severity in both college and high school overuse injuries.		1) Calculate the percentage of injury diagnosis, body part injured, time-loss to injury and injury severity by population.

Aim 2: Perform an analysis of college injury surveillance records, and data abstracted from clinical records on the same injuries, to determine how time-loss overuse injuries are captured in each system, and the agreement between systems. (Table 3.2)

Aim 2a: Estimate the capture-recapture rate for time-loss overuse injuries in the injury surveillance system.

Aim 2b: Estimate the agreement between the two systems for overuse as a mechanism of injury.

Aim 2c: Describe the factors associated with cases where the systems agree and disagree in regard to the assignment of overuse.

Rationale: Overuse injuries are assumed to be difficult to classify and underrepresented in surveillance data, but the extent of the underascertainment is unknown. [8] Knowledge about the practice of reporting overuse injuries to surveillance systems can be gained by comparing time-loss overuse injuries which appear in the ISS and/or the medical records. An understanding of the differences in reporting between clinical records and the ISS may assist in the interpretation of existing overuse injury data from the ISS. Identifying factors associated with cases where the two systems agree or disagree may be used to improve the ISS to better capture overuse injuries in the future.

This aim used data from a previous validation study that compared injury surveillance data from the ISS to information on the same injuries abstracted from clinical records. [78] Only injuries with a mechanism of injury of overuse in either system were included.

Table 3.2. Summary of Aim 2 for Dissertation

#	Aim	Data	Analysis
3	**Perform an analysis of college injury surveillance records, and data abstracted from clinical records on the same injuries, to determine how time-loss overuse injuries are captured in each system, and the agreement between systems.**		
3a	Estimate the capture-recapture rate for overuse injuries in the injury surveillance system.	De-identified data from a validation study that compared injury surveillance data from the ISS to information on the same injuries abstracted from clinical records, where the mechanism of injury was overuse in either system	1) Calculate the capture-recapture rate for overuse injuries.
3b	Estimate the agreement for overuse as a mechanism of injury between the systems.		1) Calculate the effective agreement and Kappa
3c	Describe the factors associated with cases where the systems agree and disagree in regard to the assignment of overuse.		1) Qualitative analysis of text responses, and identification of common responses in other variables where the systems agree and disagree in regard to the assignment of overuse.

Aim 3: Generate an instrument and conduct a survey among ATs to explore variation between clinicians in their assessment of overuse injuries and the assignment of overuse as the mechanism of injury within the ISP. (Table 3.3)

Aim 3a: Describe the variability among ATs in defining and reporting overuse injury to the ISP.

Aim 3b: Describe the variability among ATs in defining and reporting overuse injury within strata of age, gender, educational and work experience.

Aim 3c: Estimate the self-reported burden of overuse injuries as a percentage of the total treated injuries and the percentage of treated injuries which are reported to the ISP.

Aim 3d: Perform a qualitative analysis of AT responses regarding their processes for assigning overuse and reporting overuse as the mechanism of injury within the ISP.

Hypotheses:

H1: There is variability between ATs in determining the role of overuse and the probability of assigning an overuse mechanism of injury for each scenario.

H2: There is variability in the role and reporting of overuse injuries between strata of age, gender, level of education and years of experience.

Rationale: There is currently no consensus about the definition of overuse injuries in general and in the context of injury surveillance. [8] An understanding of how individual ATs diagnose and report overuse injuries to the ISP, and the strategies that they employ, may ultimately lead to the establishment of an operational definition of overuse within injury surveillance. Such a definition could decrease the variability among ATs who collect data for the ISP. [48]

The survey instrument was developed to describe the AT's opinion of the role of overuse in seven hypothetical injury scenarios, as well as, the probability of assigning overuse as the mechanism of injury to each scenario, followed by an open ended question about how the AT reached that decision. The survey instrument was developed by the candidate with guidance from the five committee members and five AT clinicians working in college settings. In-depth qualitative interviews were conducted with five AT graduate students to investigate how the scenarios were understood, and the processes these ATs used to complete the survey. Additional interviews were conducted with five other ATs regarding the understanding of the subject matter and facility with the survey. The survey was pilot tested by eight graduate students unaffiliated with the target population. The extent to which the cases presented in the instrument actually represent a typical case load in real clinical practice has not been assessed.

Data: Survey data from ATs who were currently participating in the ISP at the time of survey distribution. (n=74)

Table 3.3. Summary of Aim 3 for Dissertation

#	Aim	Data	Analysis
3	**Generate an instrument and conduct a survey among ATs to explore variation between clinicians in their assessment of overuse injuries and the assignment of overuse as the mechanism of injury within the ISP.**		
3a	Describe the variability among ATs in defining and reporting overuse injury to the ISP.	Survey data, quantitative and qualitative, from ATs who were currently participating in the ISP at the time of survey distribution. (n=74)	1) Describe distribution (by percentage) of responses regarding the role of overuse injury in each scenario. 2) Calculate the mean, median and range of responses regarding the probability of reporting and overuse mechanism of injury in each scenario.
3b	Describe the variability among ATs in defining and reporting overuse injury within strata of age, gender, educational and work experience.		Perform the same calculations as in 3a within strata of age, gender, educational and work experience.
3c	Estimate the self-reported burden of overuse injuries as a percentage of the total treated injuries and the percentage of treated injuries which are reported to the ISP.		1) Calculate the mean, median and range of responses regarding the percentage of total injuries treated and percentage of treated injuries which are reported to the ISP.

CHAPTER 4

METHODS

4.1 Data sources

This dissertation used four distinct data sources to address the incidence of overuse injuries and methodological issues related to surveillance of overuse injuries. Previously collected sports injury surveillance data from college and high school overuse injuries was used for Aim 1. Aim 2 used existing data previously collected as part of a validation study of the ISS. Primary data was collected from an online survey for Aim 3. All data sources and the use thereof in statistical and qualitative analyses were considered exempt by the Institutional Review Board at the University of North Carolina at Chapel Hill.

4.1.1 Data sources for Aim 1

Previously collected de-identified sports injury surveillance data from college and high school overuse injuries was used for this aim.

4.1.1.1 National Collegiate Athletic Association's (NCAA) Injury Surveillance System (ISS)

The ISS/ISP is the largest sports injury database for college athletics currently in use in the world. [76] The volunteer sample is not representative of all NCAA institutions, and injury counts are provided to estimate the national incidence. ISS/ISP data are collected by a volunteer group of ATs. Individual ATs request the sports on which they prefer to report. In the

2003/2004 academic year about 250 schools participated in ISS data collection, with a target enlistment sample of 10% of the number of schools that participate in an individual sport. [80] ISP participation from the 2009/10 through 2013/14 academic years was lower with <1% of the qualified teams participating for 10 sports. [75]

The Datalys Center, which currently runs the ISS/ISP, provided de-identified data from the 2003/4 through 2008/9 academic years for the analysis of Aim 1. In the 2004/5 through 2013/2014 academic years the ISS/ISP collected data on 29 injury variables, and 13 exposure variables. Injury data is collected as injuries occur and exposure information, including the number of athletes participating in each sport exposure, is collected weekly. [76] At the time of data collection for this analysis, the ISS employed a time-loss injury definition. Therefore in order for an injury to be reported, it must have resulted in one additional day lost from sport after the athlete seeks care.

Line item data, including all variables for all injuries with a "basic mechanism of injury" of "overuse/gradual" (from 16 selected sports) were included in the analysis of Aim 1. These sports represent a variety of contact and endurance levels (Table 4.1).

Data on injuries with a diagnosis of overuse, and injuries with a mechanism of acute non-contact for selected diagnoses, were assessed for potential inclusion in to the analyses for Aim 1. The mechanism of injury and injury diagnoses of the additional injuries which were considered for inclusion are presented in Table 4.2.

4.1.1.2 High School RIO (Reporting Information Online)

Starting in the 2006/7 academic year, the High School RIO surveillance system initially established contact with 425 schools, and 100 representative and randomly selected schools were

included in the data analysis for the annual report. These schools were sampled by geographic region and school size. In the 2013/2014 academic year, 260 ATs were invited to participate in data collection. [82, 105] Data is only collected by ATs, in high schools which provide medical coverage by ATs. While this facilitates reliable information, it limits the generalizability of these data as not all high schools have access to certified athletic trainers. [77, 78, 106]

High School RIO collects data on athlete demographics, injury information, injury event information, sport-specific information and medical notes. Within these categories, there are variables for the sport, body part injured, primary type of injury, factors relating to injury incidence (general and specific mechanism of injury), injury outcome (including return to sport, amount of time lost, and any surgery required). Exposure data reports the number of athletes participating in every individual sport exposure, the type of exposure (such as practice, game, or other sport activity), location of event (home, away) and season (pre, in, post). [82, 105] As with the ISS, injury information is collected as they occur and exposure information is collected weekly. The RIO uses a time-loss injury definition, as the ISS/ISP does, which facilitates comparisons between these systems.

Line item data, including all variables for all injuries with a "basic injury mechanism" of "overuse/chronic" (from 14 selected sports) were included in the analysis of Aim 1. Data from boys and girls tennis was not available from the RIO, and was therefore not included in this analysis. The sports as well as the academic years of available data for each sport are presented in Table 4.3.

4.1.2 Data source for Aim 2: NCAA Validation Study [5]

This aim used existing data, previously collected as part of a validation study of the ISS. [78] In this parent study, "A validation study of the ISS comparing data from the NCAA mens and womens soccer teams" data were collected from 15 institutions which participate in ISS surveillance, which also maintained separate injury tracking and medical records in the 2005/6 through 2007/8 academic years as part of a study to validate the ISS system for mens and womens soccer injury reports. The procedures for the parent study were approved by the Duke University Medical Center Institutional Review Board

Inclusion requirements necessitated each participating school have both mens and womens soccer teams, and have participated in the online ISS for a minimum of two years. All athletes whose medical records were included in the original data collection signed individual consent forms before their data could be included in the study. [78].

At the time of data collection, the ISS required that an injury result in one additional day lost to participation after reporting the injury. Therefore, for inclusion into the parent study, an injury had to occur during a school sanctioned event, require medical attention and result in a loss of participation for at least one day after the injury (time-loss, medical attention definition). All ISS and medical records were collected for the parent study. The various sources for the medical records and methods for data abstraction are discussed in Chapter 6.

This investigation of overuse injury used the previously abstracted data from the parent study. The majority of analyses were conducted with previously created data sets which identified information abstracted from the medical records, information from the ISS and original abstractor notes comparing the two. The hard copy data abstraction forms from the original study were also reviewed.

Covariate data included, but was not limited to: event type, event season, event location, basic and specific mechanism of injury, activity at time of injury, injury type, body part injured, injury assessor, and information regarding the injury outcome (including date of return to activity and total days lost to injury) were also analyzed. In the abstractors notes, there was an additional question of whether the data in the medical records agreed with the data in the ISS. If there was no agreement between sources for a specific question, the data abstractor was to provide an explanation why these did not agree.

4.1.3 Data sources for Aim 3: "Overuse injuries in collegiate populations" online survey

To ascertain the extent of personal practices among ISS data collectors in regard to overuse injuries, a survey containing injury scenarios with various levels of overuse involvement was created and implemented among ATs who were currently contributing to the ISP in October 2014. These injury scenarios were created with input from ATs with college athletic training experience, to represent a variety of injuries, body parts injured, and levels of overuse (scenario development is discussed in Chapter 7). These scenarios simulated real world injuries but were purposely vague, which are likely similar to events which have been encountered by participating ATs and surveillance participants. Each injury scenario was accompanied by three questions, 1) regarding the respondent's opinion of the role that overuse played in the injury scenario, 2) the probability of a respondent to assign an overuse mechanism of injury to that scenario within the ISP, and 3) an open ended question of how the subject arrived at those decisions. Demographic, educational and clinical experience data were also collected.

4.2 Statistical analyses

To address the distinct specific aims of this dissertation, each aim employed separate and individual statistical approaches. The statistical analyses for Aims 1, 2 and 3 are described in detail in their results chapters (Chapters 5, 6 and 7 respectively). Please refer to the methods sections of those chapters for full details.

4.2.1 Analysis for Aim 1

Descriptive statistics including, counts, percentages, and rates were calculated for overuse injuries in the ISS and RIO separately. These statistics were also calculated in strata of sport, gender, body part and injury diagnosis. Injury rate ratios (IRRs) were calculated to compare the rate of overuse injury in college to that in high school sports, and to compare the rate of overuse injury in female vs. male sports.

Injuries with a diagnosis of overuse (as opposed to a mechanism of overuse) were also available in the ISS data from the time frame of the study, and were considered for this investigation. Over 75% (200 of 266) of injuries with a diagnosis of overuse also had a mechanism of injury of overuse. The remaining 66 injuries had mechanisms of injury of acute non-contact, (n=59), contact with player (n=4) and contact with playing surface (n=3). There were 10,179 injuries with a mechanism of injury of acute non-contact considered for inclusion of this study. Data regarding the activity at time of injury, type of injury, and specific injury mechanism, and qualitative comments about the injury event were analyzed to determine if any injuries of these could be potentially misclassified as acute non-contact instead of overuse. Only six injuries (all with diagnoses of overuse and mechanisms of acute non-contact) demonstrated potential for inclusion as an overuse injury, however, the data was inconsistent, and a clear

designation of overuse was not possible. Therefore these injuries were not included in the analysis, and the operational definition of overuse as a mechanism of injury for this aim was used.

4.2.2 Analysis for Aim 2

4.2.2.1 Parent study

The parent study [78], used the formulas originally presented by Hook and Regal (1995) [107] to estimate the capture rate of the ISS, the capture rate of injuries within both sources, and the estimated number of injuries not captured by both sources. Effective agreement and Kappa were estimated as well.

4.2.2.2 Overuse study

The original study was focused on time-loss, medical attention injuries. The Aim 2 study was limited to the subset of injuries with a reported injury mechanism of overuse in either the ISS or other medical records. Therefore all injuries included in the Aim 2 analysis had a reported injury mechanism of overuse in at least one of the two data sources.

For the current investigation, the focus was on describing the capture rates of the ISS, medical records and both sources in regard to injuries with an overuse mechanism of injury. As the revised data source and purpose were fundamentally different than the parent study, the use of the capture-recapture methodology served a different purpose than that of the original study. The capture-recapture analysis was not used to estimate, but rather to describe the effectiveness of the ISS and medical records for capturing overuse injuries individually, rather than estimating

the total number of overuse injuries in this population. Thus, the Aim 2 analyses describe the variability between sources, rather than finding a true incidence estimate.

For example, the capture rate for overuse injury in the ISS can still be calculated by (a + b)/N (Appendix 4.1). However the interpretation is slightly changed. In Appendix 6.1, Cell A represents the events where the mechanism of injury was overuse in both the ISS and medical record sources, Cell B represents events where the mechanism of injury was overuse in the ISS, but not the medical records, Cell C represents events where the mechanism of injury was overuse in the medical records, but not the ISS, and Cell D are the hypothetical overuse mechanisms of injury which were missed, or misclassified by both the ISS and medical records. The formula for the capture-recapture estimations remains the same but the interpretation is subtly different. It is interpreted as the percentage of overuse injuries captured by the ISS, medical records and both, rather than the percentage of injuries alone. These capture rates were also calculated in strata of covariates (year, division, sport, electronic database, presence of undergraduate athletic training education program and AT supervised entry of surveillance data by an AT student).

Chi-square tests were conducted to determine differences in percentage of overuse mechanisms captured between strata of covariates (year, division, sport, electronic database, presence of undergraduate athletic training education program and AT supervised entry of surveillance data by an AT student), for the null hypothesis of the percentage of capture of overuse mechanisms is equal between strata. These chi-square tests were performed in strata of the covariates for the percentage capture in ISS, medical records and both the ISS and medical records (see Table 6.3).

Effective agreement [108] was estimated for the covariates, calculated as the percentage of ISS and medical records who agreed on the value for that covariate. The effective agreement

was calculated for these variables (injury date, activity, event type, event season, chronic, diagnosis code, incident/recurrent, body part, side, surgery, injury type, outcome and injury severity) for all injuries that appeared in both sources, and in strata of overuse mechanism. Injury events that appeared in both records were stratified into those where the mechanism of injury was overuse in both sources and those where the mechanism of injury was overuse in only one source. The effective agreement was calculated for each covariate within these strata.

Kappa analyses were performed to estimate agreement between the ISS and medical records for the above covariates, and also for the mechanism of injury. Kappa statistics were calculated for total records which appeared in both sources, records where there was an overuse mechanism in both sources, and where there was an overuse mechanism in only one source. The null hypothesis for the Kappa agreement is that the probability of each source (ISS and medical records) classifying a variable into any category is equal.

The distribution (n and %) of characteristics of injury events where the mechanism of injury agrees (overuse mechanism in both sources), and where the mechanism of injury disagrees (overuse mechanism in one source) was also calculated. These distributions were calculated for the ISS and medical records individually, in strata of overuse mechanism (overuse in both sources vs. overuse in one source). Data abstractor notes were reviewed by the primary investigator (KR) to provide context for the quantitative data, and to better understand the abstraction process. Quantitative analysis was not the purpose of this review, however some counts of variables associated with the abstractor forms were performed. The current study did not have access to the original ISS or medical files for comparison.

4.2.3 Analysis for Aim 3

Initially, descriptive statistics, including box and whiskers plots were used. The n and % was calculated for the responses to question regarding the role of overuse. The mean, median, range and distribution of responses for the question regarding the probability of reporting an overuse mechanism to injury surveillance were calculated.

The responses to the question regarding the role of overuse were then classified into three categories. The responses from the "overuse is not a major contributor" and "not overuse related" were combined into one category of "not overuse". The category of "overuse is the major contributor" remained intact, and was renamed "overuse" and the "not enough information" category remained the same for these analyses. The purpose of collapsing responses of "overuse was not a major contributor" and "not overuse related" was that ATs who chose these responses regarding the role of overuse in the injury would be unlikely to report an overuse mechanism of injury for that scenario. We were most interested in the differences in reporting between ATs who would report an overuse mechanism of injury to a scenario and those who would not, which was aided by collapsing these two categories.

The distribution of the responses regarding the role of overuse in each scenario was described by calculating the percentage of ATs for these new categories. The mean, median and interquartile ranges were calculated for the self-reported probability (0-100%) of assigning overuse as the mechanism of injury for each scenario. These two variables (role and reporting) were then combined to create a classification system to describe the level of discord between respondents in each scenario. This new classification system is fully discussed in Chapter 7.

Qualitative responses were analyzed as well. These analyses were used to inform the quantitative results. A directed content analysis approach was used, where the primary

investigator (KR) analyzed the qualitative data using previously identified themes, and iteratively added to and/or adapted those themes as the analysis progressed. [109]

4.3 Tables

Table 4.1. ISS data included in Aim 1 by sport and academic year

Sport	Academic years
Mens baseball	2004/5 through 2008/9
Womens softball	2004/5 through 2008/9
Mens basketball	2004/5 through 2008/9
Womens basketball	2004/5 through 2008/9
Mens cross country	2005/6 through 2008/9
Womens cross country	2005/6 through 2008/9
Mens football	2004/5 through 2008/9
Mens soccer	2004/5 through 2008/9
Womens soccer	2004/5 through 2008/9
Mens swimming & diving	2006/7 through 2008/9
Womens swimming &diving	2006/7 through 2008/9
Mens tennis	2005/6 through 2008/9
Womens tennis	2005/6 through 2008/9
Mens track & field, outdoor	2005/6 through 2008/9
Womens track & field, outdoor	2005/6 through 2008/9
Womens volleyball	2004/5 through 2008/9

Table 4.2. ISS injury mechanisms and injury diagnoses considered for inclusion to Aim 1

Mechanism of injury	Injury Diagnosis
All mechanisms	Overuse
Acute non-contact	Arthritis / chondromalacia
Acute non-contact	Bursitis
Acute non-contact	Capsulitis
Acute non-contact	Cartilage injury
Acute non-contact	Compartment syndrome
Acute non-contact	Disc injury
Acute non-contact	Effusion
Acute non-contact	Impingement
Acute non-contact	Inflammation
Acute non-contact	Miscellaneous
Acute non-contact	Plantar fasciitis
Acute non-contact	Osteochondritis
Acute non-contact	Sprain
Acute non-contact	Strain – muscle / tendon
Acute non-contact	Stress fracture
Acute non-contact	Synovitis
Acute non-contact	Tendinosis

Table 4.3. RIO data included in Aim 1 by sport and academic year

Sport	Academic years
Boys baseball	2006/7 through 2012/13
Girls softball	2006/7 through 2012/13
Boys basketball	2006/7 through 2012/13
Girls basketball	2006/7 through 2012/13
Boys cross country	2012/13
Girls cross country	2012/13
Boys football	2006/7 through 2012/13
Boys soccer	2006/7 through 2012/13
Girls soccer	2006/7 through 2012/13
Boys swimming & diving	2008/9 through 2012/13
Girls swimming &diving	2008/9 through 2012/13
Boys track & field, outdoor	2008/9 through 2012/13
Girls track & field, outdoor	2008/9 through 2012/13
Girls volleyball	2006/7 through 2012/13

CHAPTER 5

RESULTS FOR AIM 1: DESCRIPTIVE EPIDEMIOLOGY OF OVERUSE INJURIES IN US COLLEGE AND HIGH SCHOOL ATHLETES

5.1 Introduction

Overuse injuries are traditionally defined as injuries which present in a gradual manner and do not have a single definable event associated with their onset. [8, 18] They result from the accumulation of microtrauma on the cellular level in a variety of tissues (e.g., bone, muscle, tendon, ligament). [17, 23, 35, 110] This microtrauma results from repetitive activity that would not necessarily result in injury, if sufficient time was allowed for the affected tissue to recover between episodes of activity [31, 32]. Due to their progressive nature an injured person may not be aware of the presence or seriousness of the injury, or seek treatment, until severe tissue damage has occurred, which makes the identification and diagnosis of overuse injuries challenging. [23]

Organized sports are a sizeable source of repetitive activity for young athletes. Aside from the repetition often necessary for learning and perfecting sports skills, young athletes are exposed to many factors which limit recovery time. Athletes face pressure to excel and are offered many opportunities to participate on multiple teams, in multiple leagues, and in multiple sports, often at the same time [17, 19, 34]. Sports specialization is occurring at younger ages leading to increased practice of sport specific skills over a player's career. This in turn dramatically increases the cumulative load of microtrauma in particular tissues [24, 111]. These injuries can result in short-term pain and impairments (which sometimes prevent participation in

sports), as well as long-term musculoskeletal disorders (e.g. chronic tendonosis, arthritis)[1, 4]. Prevention and early intervention for overuse sports injuries will promote both healthy participation in athletics in youth, and participation in an active lifestyle beyond the athlete's competitive playing career.

Overuse injuries may account for more than 50% of total childhood sports injuries [31, 32]. Specifically, two studies of high school (HS) cross country runners indicated a self-reported lifetime prevalence of overuse injuries in 59-68% of runners (n=708) [50], and overuse leg pain in 48% of runners over one season (n=125) [49]. Furthermore a study of Swedish school age tennis players (n=55) reported 54% of total injuries were "overuse type" [51].

Although current injury surveillance systems in US college and HS institutions provide data on overuse injuries, these data are frequently reported in a cursory manner in the literature, listing specific diagnoses, or combining overuse injuries within the uninformative "other" category [48]. Little research is available on the overall incidence and characteristics of overuse injuries in college and HS populations [48]. There is only one published epidemiologic study of US college athletes that focused on overuse injuries which reported that they account for 30% of total college athletic injuries at one institution [7].

The purpose of this study was to analyze data from two large national injury surveillance systems to describe the epidemiology of overuse injuries in college and HS sports with the aim of comparing rates and patterns of injury across age groups between sports and by gender. These analyses capitalize on the wealth of data which injury surveillance systems provide to investigate the scope and burden of overuse injuries in college and HS athletes.

5.2 Materials and Methods

5.2.1 Data collection

Data were obtained from two sources: National Collegiate Athletic Association's Injury Surveillance System (ISS) operated by Datalys Center for Sports Injury Research and Prevention, and High School RIO (Reporting Information Online) operated by Nationwide Children's Hospital, Columbus, Ohio and the University of Colorado. These two large national sports injury surveillance systems provide data on athlete exposure and sports injury and illness information in college and HS populations respectively. The methods they employ have been previously described [75, 112].

Both systems utilize certified athletic trainers (ATs) who work in college or HS settings and volunteer to participate in data collection. These AT volunteers provide information, via online platforms, regarding details of the injury events and circumstances. Data on the number of athletes participating in each school sanctioned practice or competition are also collected by these ATs. The samples used in these systems are deterministic, as the number of participating schools is dependent on the number of AT volunteers. Participation in these systems is also dependent on the presence of an AT in the host institution, as those without AT services are ineligible.

For this study, ISS data were available from the 2004/2005 through 2008/2009 school years, and RIO data from the 2006/2007 through 2012/2013 school years. Data from 16 college and 14 HS sports were used in these analyses. However, data for all sports were not available for the entire study period (Table 5.1).

5.2.2 Injury and exposure definitions

In order to be included in the injury surveillance data release files for both systems, a reportable injury had to satisfy all three of the following criteria: 1) the injury occurred as a result of participation in an organized sports event, 2) the injury required medical attention, and 3) the injury resulted in absence from participation in practice or competition for at least one day beyond the initial day of the injury. Additionally any injuries with a diagnosis of concussion or fracture were entered into injury surveillance regardless of time-loss from sport. In this study, "overuse" was operationally defined and analyzed as a mechanism of injury. Therefore all injuries had a reported mechanism of injury of either "overuse/gradual onset" (ISS) or "overuse/chronic" (RIO). Injuries with acute mechanisms of injury were not included in this study. An athlete exposure (AE) was defined for both systems as one athlete participating in one school-sanctioned competition or practice. Gender comparable sports were considered to be mens/boys and womens/girls basketball, mens/boys and womens/girls cross country, mens/boys and womens/girls soccer, mens/boys and womens/girls swimming & diving, mens/boys and womens/girls tennis, mens/boys and womens/girls track and field, outdoor, and mens/boys baseball and womens/girls softball.

5.2.3 Data exclusions

The data were reviewed by the primary author for potentially erroneous and implausible entries which were excluded from descriptive analysis. Specifically three HS injuries with an event type of "performance" were excluded from the event type analysis, as "performance" is only related to cheer injuries (see Table 5.4). This investigation focused on musculoskeletal overuse injuries; therefore 15 college injuries (0.042%) with reported body parts of

cardiovascular, dermatologic, environmental/fluids, genitourinary and nervous system were excluded from that analysis (see Table 5.3). Injuries which were either systemic or acute in nature were excluded from analyses of overuse injury diagnosis (ex: diagnosis of cardiac event, dehydration, concussion, laceration; college: 5.9%; HS: 2.1%, Figure 5.1).

5.2.4 Statistical methods

Overuse injury rates per 10,000 AEs and percentages were calculated, using injury counts and AEs.

Overuse injury rate ratios were calculated to compare rates of overuse injury for college vs. HS and male vs. female among gender comparable sports. As an example, the ratio comparing the rate of overuse injuries in college to HS was computed as:

$$\text{Overuse Injury Rate Ratio} = \frac{\#\,\text{total college overuse injuries} / \#\,\text{total college AEs}}{\#\,\text{total HS overuse injuries} / \#\,\text{total HS AEs}}$$

Standard large-sample Poisson assumptions were used for this count data to compute 95% confidence intervals for all injury rates and rate ratios.

5.3 Results

5.3.1 Rates of overuse injury

There were 3,569 overuse injuries in college athletes and 3,168 in HS athletes during the study years (Table 5.1). The rate of overuse injury was 3.28 times higher in college athletes (5.36 per 10,000 AEs) than in HS athletes (1.64 per 10,000 AEs) (95% CI: 3.12-3.44; Table 5.2). The increased rate of overuse injury among college compared to HS athletes was consistent across all sports. Mens/boys outdoor track and field had the largest disparity between populations (RR:

6.36, 95% CI: 5.15-7.85). The rate ratios comparing overuse injury rates between college and HS populations were lowest for mens/boys football and womens/girls soccer, where rates of overuse injury were twice as high among college athletes.

In both populations, overuse injuries primarily were reported in non-contact, running sports with womens/girls cross country (college: 19.59 per 10,000 AEs; HS: 6.73 per 10,000 AEs), mens/boys cross country (college: 13.67 per 10,000 AEs; HS:4.02 per 10,000 AEs), womens/girls outdoor track & field (college: 15.76 per 10,000 AEs; HS: 3.82 per 10,000 AEs), and mens/boys outdoor track & field (college: 13.53 per 10,000 AEs; HS: 2.13 per 10,000 AEs) having the highest rates of overuse injury (Table 5.2). The sports with the lowest rates of overuse injury were all male sports: football (college: 2.85 per 10,000 AEs; HS: 1.35 per 10,000 AEs), basketball (college: 4.07 per 10,000 AEs; HS: 0.80 per 10,000 AEs), and swimming & diving (college: 3.81 per 10,000 AEs; HS: 1.21 per 10,000 AEs).

In each population, the rate of overuse injury was higher among females than males in gender-comparable sports. The sole exception was college soccer, in which men had a higher overuse injury rate than women (5.10 per 10,000 AEs vs. 4.19 per 10,000 AEs; Table 5.2). Among gender-comparable sports, the rate ratio for overuse injuries reported in females as compared to males was slightly higher in HS athletes (RR: 1.55, 95% CI: 1.43, 1.68) than college athletes (RR: 1.25, 95% CI: 1.16, 1.35). College women had the highest rate of overuse injury (7.32 per 10,000 AEs; Table 5.3), whereas HS boys the lowest rate of overuse injury (1.42 per 10,000 AEs).

5.3.2 Characteristics of overuse injury

Approximately 70% of overuse injuries were reported to the lower extremity in both college and HS athletes (69.4% and 70.4% respectively, Table 5.3). Specifically, 20.0% of college and 16.0% of HS overuse injuries reported were to the knee, and 18.6% of college and 22.5% of HS overuse injuries were to the lower leg. Other commonly injured body sites were the shoulder (college: 13.1%; HS: 12.0%), and lower back (including lumbar spine and pelvis; college: 8.6%; HS: 9.7%).

The distribution of injured body parts differed by individual sports, specifically in the college population. Among college athletes, the shoulder and elbow were the most commonly injured body part for mens baseball (43.2% and 20.1%), mens swimming & diving (58.6% and 13.8%), and mens tennis (35.3% and 11.8%), the shoulder was the most commonly injured body part for womens softball (33.9%) and womens swimming & diving (66.7%), while the forearm was the most commonly injured for womens tennis (31.4%) (Table 5.3). There were fewer exceptions among HS athletes; the shoulder and elbow were the most commonly injured body parts for boys baseball (45.1% and 24.8%) and girls softball (32.6% and 15.5%), the shoulder was the most common for boys swimming & diving (70.4%) and girls swimming & diving (63.8%), and the shoulder and lumbar spine were the most common for girls volleyball (27.8% and 16.5%) (Table 5.3).

Muscle/tendon strain and tendinosis (ISS)/tendinitis (RIO) were the most common overuse injury diagnoses (college: 18.9%; HS: 33.0% and college: 23.3%; HS: 24.5% respectively; Figure 5.1). Stress fractures accounted for 8.8% of college and 8.4% of HS overuse injuries, and, 6.0% of college and 4.5% of HS overuse injuries were shin splints (Figure 5.2). The majority of both college and HS individual sports followed this distribution of diagnoses,

with the exception of college womens basketball where stress fractures were the most common injury diagnosis (21.8%).

Knee tendinosis (ISS)/tendinitis (RIO) was the most common specific overuse injury among both college and HS athletes (6.1% and 7.9% respectively). College athletes commonly sustained tendinosis to the lower leg (6.0%) and shoulder (5.6%), as well as shin splints to the lower leg (5.4%), and inflammation/effusion of the knee (5.3%). HS athletes also commonly sustained muscle-tendon strains to the thigh (7.9%), lower leg (4.9%) and lumbar spine (4.9%).

5.3.3 Injury severity

The majority of injured athletes returned to sports activity within the same season (college: 89.6%; HS: 86.7%; Table 5.4). However, 20.4% of college athletes took longer than 21 days to return compared to 7.7% of HS athletes (Table 5.4). Additionally 5.9% of overuse injuries among college athletes and 4.6% among HS athletes were season ending (Table 5.4). Stress fractures were the most common diagnosis among these outcomes accounting for 20.8% of college and 34.6% of HS injuries which took longer than 21 days to return to sport and 26.5% of college and 32.6% of HS medical disqualifications for that season.

Very few overuse injuries resulted in surgery (college: 5.2%, HS 2.6%, Table 5.4). Of those injuries, the most common diagnoses were cartilage/disc injury (college: 27.2%, HS 23.0%), tendinosis (ISS)/ tendinitis (RIO) (college 9.2%, HS: 9.4%), and muscle/tendon strain (college: 4.4%, HS 13.7%). Mens/boys baseball (9.1% and 6.4%) and mens/boys basketball (6.8% and 5.6%) had the highest proportion of overuse injuries which required surgery.

5.4 Discussion

This study is the first to compare rates and patterns of overuse injuries in the athletes participating in a large number of sports across US college and HS populations. Previous studies of the incidence of overuse injuries have reported results from only singular sports, or from a single institution, without comparison to other sports or populations [48]. We found that overuse injuries were reported at a rate more than three times higher in college athletes than in HS athletes. Previous studies found higher proportions of injury at more elite levels of competition [3], but this is the first study to demonstrate this disparity using incidence rates. A comparison of rates is methodologically stronger than comparison of proportions because it accounts for differences in exposure-time.

The increased rate of overuse injury in college athletes may be due to an increased amount and intensity of competitive training in college sports [70]. Additionally, college athletes have been participating in their sports longer, accumulating more years of microtrauma as well as previously diagnosed injury incidents [17]. This microtrauma may accumulate and produce more damage as athletes age, thereby increasing their overuse injury rate [35]. It will be important to limit the incidence of these injuries to promote healthy participation in athletics throughout the lifetime [1]. Longitudinal research addressing the cumulative effects of sports participation, starting at sports initiation and through college career, would greatly assist in the identification of risk factors and inform the development of effective prevention strategies. Targeting interventions solely at college athletes may occur too late in the risk history of overuse injury to counteract the microtrauma accumulated over a lifetime of sports participation.

Our rate of overuse injury in college athletes (5.36 per 10,000 AEs), is considerably less than the rate of overuse injury previously published by Yang et al. [7] in 2012 (18.5 per 10,000

AEs). The difference in rates stems from different criteria for inclusion into each surveillance system. Yang et al. [7] used an injury definition where the athlete had to have clinical signs of tissue damage and an inability to return to practice on the same day in order to be included in injury surveillance. At the time of data collection, ISS and RIO required at least one additional day lost from sports after the initial injury. A standardized injury definition for use in injury surveillance would assist comparison across studies [12, 29, 87].

Another major finding of this study is that overuse injuries occur at a higher rate in female relative to male athletes. This was observed in both college and HS populations for all sports with the exception of college soccer. Similar gender disparities have been observed in other college and HS studies [7, 17]. Female athletes have differences in biomechanics, joint laxity, muscle strength, and hormone levels than male athletes which may also affect their physiological responses to microtrauma and training [110, 113]. Disparities in coaching and training may also affect the incidence of overuse injuries, and potentially training and conditioning programs for female athletes may need to be modified to reduce the incidence of overuse injury [114]. Additionally, female athletes may be more likely to seek health care resources. Thus, as overuse injuries progress to develop greater pain and functional limitations, female athletes may seek care sooner and more often than male athletes, leading to more overuse injuries being entered into injury surveillance [115]. All three factors likely contribute, at least in part, to the increased rate of overuse injuries in female athletes. Further research into the source of these differences will be helpful in developing appropriate interventions to minimize the gender gap as well as overall incidence of overuse injuries.

The majority of overuse injuries in both populations were to the lower extremities, accounting for 69.4% of college and 70.4% of HS overuse injuries. In both college and HS

populations, the highest rates of overuse injuries occurred in running sports. Lower extremity overuse injuries are common in running sports and runners in general, from the recreational jogger to the elite marathoner [15, 116, 117]. The repetition inherent to running itself, as well as the nature of training for the running sports, likely result in continuous microtrauma without sufficient time to heal, thus predisposing these athletes to overuse injuries [15, 118]. Prevention interventions designed for running sports have the potential to benefit athletes throughout their running careers, not only when they compete on school-based teams.

Overuse injuries were more severe (in terms of both time lost and percentage of overuse injuries which required surgery) in college athletes. Cumulative participation may contribute to more severe overuse injuries [3, 35]. The potential explanations for the increased severity in college athletes are the similar to those proposed for the increased incidence of overuse injuries in college athletes: more intensive training, longer history of cumulative sport participation, microtrauma and prior injury [23]. Injuries which result in increased time-loss from sport can have more severe repercussions on pain and general health throughout the athlete's lifetime [119]. Reducing the severity of overuse injuries would not only lessen the time-loss from sport, but also improve the long term ability to participate in an active and healthy lifestyle beyond competitive athletics.

5.4.1 Strengths and limitations

This is the first study published which compares college and HS overuse injuries. The extent of the two separate injury surveillance systems used, the breadth of the data across sports and variables, and that both systems used comparable definitions for a reportable injury are strengths of this study. However, in the RIO, overuse is categorized as "overuse/chronic" and

some chronic injuries may not arise from overuse, which may impact the reported incidence of high school overuse injuries. A potential weakness is that overuse is not defined within either system, indicating that variations in individual definitions of overuse may exist in those entering the data. However, the ATs who enter the data have specific training in injury evaluation, diagnosis and documentation, and the use of ATs to collect surveillance data may be more accurate than other studies which use self-reported data. As inclusion into injury surveillance is dependent on the presence of an AT in the high school institution, these results may not be generalizable to those schools without an AT. A weakness of this study is that overuse injuries may be underreported due to the use of a time-loss injury definition, which will not account for injuries which are evaluated and treated unless they result in the requisite time out of sport. Also, the progressive nature of overuse injuries makes them hard to diagnose, specifically if the athlete does not report the injury until significant limitations in function are present. This may contribute to underreporting as the injury may then be categorized as acute rather than overuse. Despite the underreporting these results show that overuse injuries are an extensive problem across sports and that prevention approaches should be developed and implemented.

5.5 Conclusion

Overuse injuries occur at higher rates, and have more severe outcomes in college athletes as compared to HS athletes. This is likely due to differences in training intensity and duration, accumulated microtrauma and injury history between the groups. Female athletes, and those involved in running sports may also be at a higher risk for overuse injury. Future research into the cumulative effects of sport participation throughout the lifetime may prompt the development of prevention and early intervention strategies. Interventions solely directed at college athletes

may not be enough to counteract the long history of cumulative microtrauma from life-long sport participation.

5.6 Tables and figures

Table 5.1. Overuse injury count and years of data collection by sport and data source

Sport	Total number of ISS overuse injuries	Academic years of ISS data collection	Total number of RIO overuse injuries	Academic years of RIO data collection
Total overuse injuries	3,569	2004/5 through 2008/9	3,168	2006/7 through 2012/13
Mens baseball	384	2004/5 through 2008/9	222	2006/7 through 2012/13
Womens softball	370	2004/5 through 2008/9	193	2006/7 through 2012/13
Mens basketball	266	2004/5 through 2008/9	165	2006/7 through 2012/13
Womens basketball	354	2004/5 through 2008/9	268	2006/7 through 2012/13
Mens cross country	123	2005/6 through 2008/9	52	2012/13
Womens cross country	187	2005/6 through 2008/9	76	2012/13
Mens football	634	2004/5 through 2008/9	620	2006/7 through 2012/13
Mens soccer	269	2004/5 through 2008/9	259	2006/7 through 2012/13
Womens soccer	233	2004/5 through 2008/9	288	2006/7 through 2012/13
Mens swimming & diving	29	2006/7 through 2008/9	54	2008/9 through 2012/13
Womens swimming & diving	51	2006/7 through 2008/9	83	2008/9 through 2012/13
Mens tennis	34	2005/6 through 2008/9	n/a[a]	n/a
Womens tennis	51	2005/6 through 2008/9	n/a	n/a
Men' track and field, outdoor	127	2005/6 through 2008/9	274	2008/9 through 2012/13
Womens track and field, outdoor	157	2005/6 through 2008/9	402	2008/9 through 2012/13
Womens volleyball	300	2004/5 through 2008/9	212	2006/7 through 2012/13

[a] n/a = not applicable

Table 5.2. Overuse injury rate and injury rate ratio (95% confidence interval) by sport and data source

Sport	Rate of ISS overuse injury rate per 10,000 AEs[a]	Rate of RIO overuse injury rate per 10,000 AEs[a]	Injury Rate Ratio[b] (95% confidence interval)
Total overuse injuries	5.36 (5.19, 5.54)	1.64 (1.58, 1.70)	3.28 (3.12, 3.44)
Mens baseball	6.13 (5.52, 6.77)	1.43 (1.25, 1.63)	4.29 (3.64, 5.07)
Womens softball	8.85 (7.97, 9.80)	1.66 (1.44, 1.92)	5.31 (4.47, 6.33)
Mens basketball	4.07 (3.60, 4.59)	0.80 (0.68, 0.93)	5.11 (4.21, 6.20)
Womens basketball	6.01 (5.40, 6.67)	1.61 (1.43, 1.82)	3.73 (2.18, 4.37)
Mens cross country	13.67 (11.36, 16.31)	4.02 (3.00, 5.28)	3.40 (2.46, 4.70)
Womens cross country	19.59 (16.88, 22.61)	6.73 (5.30, 8.41)	2.91 (2.23, 3.80)
Mens football	2.85 (2.64, 3.08)	1.35 (1.24, 1.46)	2.11 (1.90, 2.45)
Mens soccer	5.10 4.51, 5.75)	1.49 (1.31, 1.68)	3.43 (2.89, 4.07)
Womens soccer	4.19 (3.67, 4.76)	1.96 (1.74, 2.21)	2.13 (1.79, 2.53)
Mens swimming & diving	3.81 (2.55, 5.46)	1.21 (0.91, 1.58)	3.14 (2.00, 4.92)
Womens swimming & diving	4.30 (3.20, 5.65)	1.65 (1.31, 2.05)	2.61 (1.84, 3.69)
Mens tennis	8.39 (5.81, 11.72)	n/a[c]	n/a
Womens tennis	12.51 (9.32, 16.54)	n/a	n/a
Mens track and field, outdoor	13.53 (11.28, 16.10)	2.13 (1.88, 2.39)	6.36 (5.15, 7.85)
Womens track and field, outdoor	15.76 (13.39, 18.43)	3.82 (3.56, 4.22)	4.12 (3.43, 4.96)
Womens volleyball	7.37 (6.56, 8.25)	1.36 (1.18, 1.55)	5.44 (4.56, 6.48)

[a] AE =Athlete Exposure

[b] Rate of ISP overuse injury / rate of RIO overuse injury

[c] n/a = not applicable

Table 5.3. Distribution of overuse injuries by population, sport and body part

College Sport	Shoulder	Upper arm	Elbow	Forearm/ hand/wrist	Lower Back	Hip	Thigh	Knee	Lower leg	Foot/ankle	Other	Total
Mens baseball	166 (43.2%)	28 (7.3%)	77 (20.1%)	29 (7.6%)	24 (6.3%)	7 (1.8%)	4 (1.0%)	22 (5.7%)	13 (3.4%)	7 (1.8%)	7 (1.8%)	384 (100%)
Womens softball	79 (33.9%)	6 (2.6%)	20 (8.6%)	24 (10.3%)	18 (7.7%)	5 (2.1%)	10 (4.3%)	31 (13.3%)	22 (9.4%)	13 (5.6%)	5 (2.2%)	233 (100%)
Mens basketball	9 (3.4%)	1 (0.4%)	1 (0.4%)	0	32 (12.2%)	14 (5.3%)	9 (3.4%)	74 (28.1%)	42 (16.0%)	75 (28.5%)	6 (2.3%)	263 (100%)
Womens basketball	5 (1.4%)	0	1 (0.3%)	2 (0.6%)	37 (10.5%)	21 (6.0%)	25 (7.1%)	86 (24.4%)	81 (23.0%)	93 (26.4%)	1 (0.3%)	352 (100%)
Mens cross country	1 (0.8%)	0	0	0	7 (5.7%)	7 (5.7%)	7 (5.7%)	26 (21.1%)	54 (43.9%)	18 (14.7%)	3 (2.4%)	123 (100%)
Womens cross country	0	0	0	0	10 (5.3%)	14 (7.5%)	14 (7.5%)	33 (17.7%)	75 (40.1%)	41 (21.9%)	0	187 (100%)
Mens football	44 (7.0%)	4 (0.6%)	3 (0.5%)	7 (1.1%)	72 (11.4%)	70 (11.1%)	81 (12.9%)	157 (24.9%)	79 (12.6%)	94 (14.9%)	19 (3.0%)	630 (100%)
Mens soccer	3 (1.1%)	0	0	0	20 (7.5%)	47 (17.6%)	43 (16.1%)	47 (17.6%)	57 (21.4%)	42 (15.7%)	8 (3.0%)	267 (100%)
Womens soccer	4 (1.1%)	0	0	2 (0.5%)	20 (5.4%)	39 (10.6%)	60 (16.3%)	90 (24.5%)	89 (24.2%)	57 (15.5%)	7 (1.9%)	368 (100%)
Mens swimming & diving	17 (58.6)	0	4 (13.8%)	1 (3.4%)	0	1 (3.4%)	1 (3.4%)	4 (13.8%)	0	0	1 (3.4%)	29 (100%)
Womens swimming & diving	34 (66.7%)	1 (2.0%)	0	1 (2.0%)	2 (3.9%)	1 (2.0%)	0	8 (15.6%)	2 (3.9%)	2 (3.9%)	0	51 (100%)
Mens tennis	12 (35.3%)	1 (2.9%)	4 (11.8%)	3 (8.8%)	3 (8.8%)	0	0	2 (5.9%)	5 (14.7%)	4 (11.8%)	0	34 (100%)
Womens tennis	9 (17.7%)	2 (3.9%)	1 (2.0%)	16 (31.4%)	5 (9.8%)	2 (3.9%)	2 (3.9%)	2 (3.9%)	4 (7.8%)	8 (15.7%)	0	51 (100%)

Mens track and field, outdoor	4 (3.1%)	0	0	0	10 (7.9%)	6 (4.7%)	10 (7.9%)	28 (22.0%)	42 (33.1%)	24 (18.9%)	3 (2.4%)	127 (100%)
Womens track and field, outdoor	5 (3.2%)	2 (1.3%)	3 (1.9%)	2 (1.3%)	8 (5.1%)	10 (6.4%)	12 (7.7%)	23 (14.8%)	52 (33.3%)	39 (25.0%)	0	156 (100%)
Womens volleyball	72 (24.1%)	2 (0.7%)	2 (0.7%)	3 (1.0%)	39 (13.0%)	5 (1.7%)	15 (5.0%)	77 (25.8%)	44 (14.7%)	36 (12.0%)	4 (1.3%)	299 (100%)
College total	**464 (13.1%)**	**47 (1.3%)**	**116 (3.3%)**	**90 (2.5%)**	**307 (8.6%)**	**249 (7.0%)**	**293 (8.2%)**	**710 (20.0%)**	**661 (18.6%)**	**553 (15.6%)**	**64 (1.8%)**	**3554 (100%)**

High School Sport	Shoulder	Upper arm	Elbow	Forearm/ hand/wrist	Lower Back	Hip	Thigh	Knee	Lower leg	Foot/ankle	Other	Total
Boys baseball	100 (45.0%)	9 (4.0%)	55 (24.8%)	6 (2.7%)	19 (8.6%)	6 (2.7%)	4 (1.8%)	10 (4.5%)	3 (1.4%)	6 (2.7%)	4 (1.8%)	222 (100%)
Girls softball	63 (32.6%)	7 (3.6%)	30 (15.5%)	9 (4.7%)	10 (5.2%)	8 (4.2%)	14 (7.3%)	29 (15.0%)	12 (6.2%)	9 (4.7%)	2 (1.0%)	193 (100%)
Boys basketball	4 (2.4%)	0	0	2 (1.2%)	24 (14.6%)	5 (3.1%)	13 (7.9%)	41 (25.0%)	30 (18.3%)	44 (26.8%)	1 (0.6%)	164 (100%)
Girls basketball	9 (3.4%)	0	1 (0.4%)	2 (0.8%)	31 (11.6%)	9 (3.4%)	10 (3.7%)	66 (24.7%)	73 (27.3%)	55 (20.6%)	11 (4.1%)	267 (100%)
Boys cross country	0	0	0	0	1 (1.9%)	8 (15.4%)	2 (3.8%)	14 (26.9%)	24 (46.2%)	3 (5.8%)	0	52 (100%)
Girls cross country	0	0	0	0	2 (2.6%)	18 (23.7%)	5 (6.6%)	10 (13.2%)	32 (42.1%)	9 (11.8%)	0	76 (100%)
Boys football	35 (5.7%)	1 (0.2%)	5 (0.8%)	6 (1.0%)	94 (15.2%)	57 (9.2%)	83 (13.4%)	96 (15.5%)	94 (15.2%)	106 (17.1%)	42 (6.7%)	619 (100%)
Boys soccer	3 (1.2%)	0	0	0	33 (12.7%)	23 (8.9%)	44 (17.0%)	39 (15.1%)	54 (20.8%)	58 (22.4%)	5 (1.9%)	259 (100%)
Girls soccer	1 (0.4%)	0	0	0	21 (7.3%)	28 (9.7%)	41 (14.2%)	54 (18.8%)	85 (29.5%)	55 (19.1%)	3 (1.0%)	288 (100%)

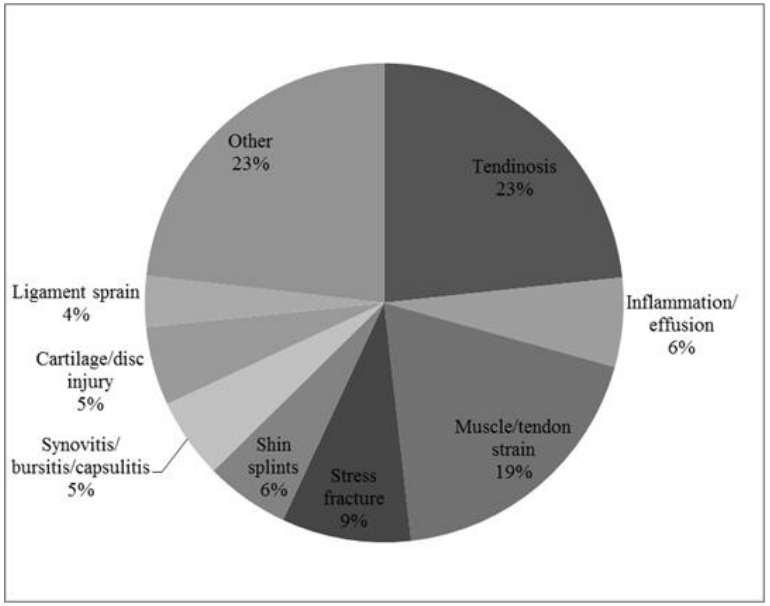
Boys swimming & diving	38 (70.4%)	0	2 (3.7%)	1 (1.8%)	4 (7.4%)	0	0	5 (9.3%)	2 (3.7%)	0	2 (3.7%)	54 (100%)
Girls swimming & diving	53 (63.9%)	2 (2.4%)	1 (1.2%)	3 (3.6%)	5 (6.0%)	1 (1.2%)	3 (3.6%)	5 (6.0%)	2 (2.4%)	3 (3.6%)	5 (6.0%)	83 (100%)
Boys track and field, outdoor	3 (1.1%)	0	1 (0.4%)	1 (0.4%)	17 (6.2%)	36 (13.1%)	31 (11.3%)	54 (19.7%)	92 (33.6%)	36 (13.1%)	3 (1.1%)	274 (100%)
Girls track and field, outdoor	11 (2.7%)	0	0	3 (0.7%)	12 (3.0%)	40 (10.0%)	33 (8.2%)	57 (14.2%)	183 (45.5%)	58 (14.4%)	5 (1.3%)	402 (100%)
Girls volleyball	59 (27.8%)	1 (0.5%)	2 (0.9%)	4 (1.9%)	35 (16.5%)	12 (5.7%)	5 (2.4%)	26 (12.3%)	25 (11.8%)	30 (14.1%)	13 (6.1%)	212 (100%)
High school total	**379 (12.0%)**	**20 (0.6%)**	**97 (3.1%)**	**37 (1.2%)**	**308 (9.7%)**	**251 (7.9%)**	**288 (9.1%)**	**506 (16.0%)**	**711 (22.5%)**	**472 (14.9%)**	**96 (3.0)**	**3165 (100%)**

Table 5.4. Circumstances and outcomes for overuse injuries (ISS total = 3,569; RIO total = 3,147)

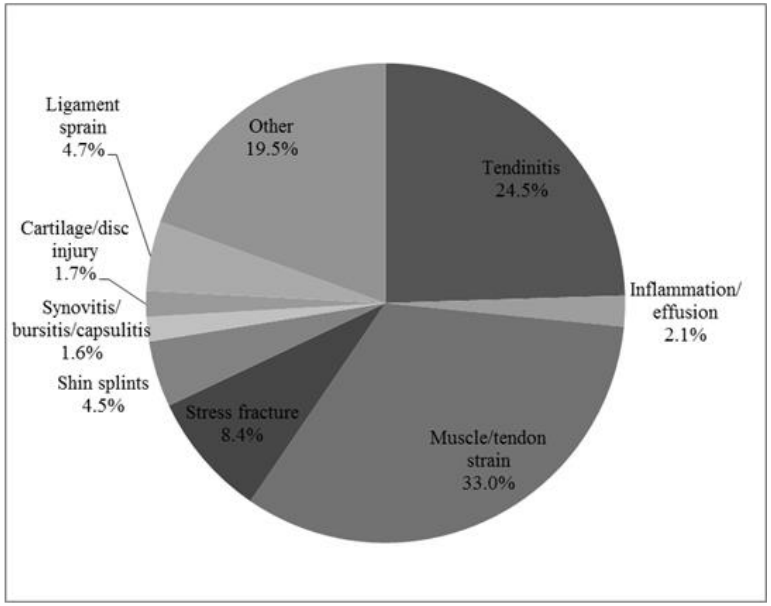
	ISS n (%)		RIO n (%)	
Event type				
Competition	624	(17.5)	520	(16.5)
Practice	2,945	(82.5)	2,507	(79.7)
Other training	n/a[a]		120	(3.8)
Outcome				
Athlete chooses to depart	40	(1.2)	60	(1.9)
Athlete released from team	11	(0.3)	6	(0.2)
MDQ Career ending	16	(0.4)	2	(0.1)
MDQ Season ending	211	(5.9)	145	(4.6)
Returned to activity in 1-6 days	1,513	(42.4)	1,513	(48.1)
Returned to activity in 7-21 days	893	(25.0)	962	(30.6)
Returned to activity in 22 days or more	727	(20.4)	241	(7.7)
Returned to competition time-loss unknown	64	(1.8)	n/a	
Returned to activity in less than 1 day, fracture only	n/a		15	(0.5)
Season ended before athlete returned	n/a		125	(4.0)
Other	11	(0.3)	38	(1.2)
Missing	83	(2.3)	40	(1.3)
Recurrence				
New	2,558	(71.7)	2,457	(78.1)
Recurrence previous academic year	403	(11.3)	392	(12.5)
Recurrence this academic year	334	(9.4)	270	(8.6)
Prior to college	270	(7.6)	n/a	
Other	4	(0.1)	23	(0.7)
Missing	n/a		5	(0.2)
Surgery				
No	3,364	(94.3)	3,027	(96.2)
Yes	184	(5.2)	20	(0.6)
Yes, surgery before return to play	n/a		39	(1.2)
Yes, surgery postponed to continue to play	n/a		23	(0.7)
Missing	21	(0.6)	38	(1.2)

[a] n/a= not applicable

Figure 5.1: Percentage of college and high school overuse injuries by diagnosis



College overuse injuries (n=3,554)



High school overuse injuries (n=3,165)

CHAPTER 6

RESULTS FOR AIM 2: A COMPARISON OF THE IDENTIFICATION AND REPORTING OF OVERUSE INJURIES BETWEEN THE NATIONAL COLLEGIATE ATHLETIC ASSOCIATION'S INJURY SURVEILLANCE SYSTEM AND MEDICAL RECORDS

6.1 Introduction

Injury surveillance systems record information about sports injuries to athletes. The National Collegiate Athletic Association's (NCAA) Injury Surveillance System (ISS) has been collecting injury information on college athletes since 1982. [75, 80] Certified athletic trainers (ATs) are specially trained medical professionals who provide assessment and treatment of sports related injuries. [79] The ISS is dependent on ATs to collect data regarding sports related injuries to college athletes. ATs report information regarding all injuries which occur as a direct result of sport participation, received medical attention and result in a loss of participation in sport for at least one day after the reporting of the injury, (hereafter considered a time-loss, medical attention injury). The reported injury information can include, but is not limited to: the injury type, body part affected, mechanism of injury, injury outcome, and days lost to sport.

A 2011 validation study of the ISS, determined that the ISS captured 88.3% of all injuries from mens and womens NCAA division I, II and III soccer teams. [78] This study compared the ISS to medical records and was limited to all injures which met the time-loss, medical attention definition. The agreement was over 90% between the ISS and medical records on many of the variables, including season, body part and injury type. However, there was less agreement between the sources for time-loss from sport and injury mechanism. The agreement between data

sources regarding mechanism of injury was among the lowest for the variables studied (effective agreement: 75.2%, 95% CI: 71.4%, 79.0%). [78] This reflects the difficulty that can be associated with the categorization and description of the mechanism of injury for individual injury events.

Injuries where overuse is a contributing factor can be particularly difficult to classify. [88] Overuse injuries are traditionally described as injuries which result from repetitive stresses and progress over time and without a distinct onset incident. [16, 17] Due to their gradual onset and repetitive nature, overuse injuries can be hard to identify, and there is still a lack of consensus regarding how to define and report overuse injuries. [8, 11, 20, 48]

The purpose of this investigation was to assess the variability in how overuse injuries are captured in injury surveillance and medical records. This study describes the similarities and differences in how the ISS and medical records capture overuse injuries as well as describes factors associated with the agreement and disagreement between events and sources regarding overuse as the mechanism of injury.

6.2 Methods

6.2.1 Parent Study

The data used in this study were from a parent study which compared data from the NCAA mens and womens soccer teams' medical records from the 2005/6 through 2007/8 seasons to the ISS injury records from that time frame [78]. Up to three years of injury records were used from each team. Fifteen schools were included in the study, and the recruitment methods were previously published [78]. All ISS data for all consenting soccer athletes during the time frame of the initial study were available for the parent study. Parallel medical records

maintained by the university ATs including hard copy injury assessments, rehabilitation and progress notes, coaches reports, clinical notes from other clinicians (e.g., MDs, PTs etc.) and records from electronic databases other than the ISS were considered the medical records source. The data was abstracted by five researchers all with prior experience as college ATs. Medical records were only abstracted for athletes who consented to participate. Effort was made to reconcile misspellings of names and other discrepancies in the medical records. At the time of data collection, the ISS employed the time-loss, medical attention definition. Extensive efforts were made to adhere to a time-loss, medical attention definition for injuries in the medical records. See Kucera et al [78] for further detail.

6.2.2 Overuse injury study

The current investigation was a secondary analysis of de-identified data from the parent study to examine the capture of overuse injuries within injury surveillance and medical records. This study used abstracted data from both the ISS and medical records regarding mechanism of injury, gender, year, division, presence of an undergraduate AT program, presence of a non-ISS electronic data base, event details (injury date, activity, event type, event season) and injury details (diagnosis, body part, side of body, incident or recurrent, chronic), as well as notes from the abstractor's data sheet about the abstraction process, missing data, and quality of data. The current investigation was considered exempt from review from the University of North Carolina at Chapel Hill Institutional Review Board.

In the absence of a gold standard, capture-recapture analyses have been successfully used to estimate the incidence of specific outcomes in populations from various reporting sources. [107] The purpose of capture-recapture analyses has been to estimate the total occurrence of an

outcome or condition, as well as to estimate the capture rates of individual sources. The current investigation was focused on describing the capture rates of the ISS, medical records and both sources in regard to injuries with an overuse mechanism of injury. Thus, an injury event required that overuse was assigned as the mechanism of injury in one or both sources in order to be included in these analyses. The capture-recapture analysis was used to describe the variability between the ISS and medical records for capturing overuse injuries individually rather than to predict the total number of overuse injuries in this population. The capture rate of the ISS, the capture rate of the medical records, the capture rate of overuse injuries within both sources were estimated, as well as the number of overuse injuries not captured by both sources. These estimates were also calculated within strata of covariates including gender, year, division, presence of an undergraduate AT program and use of a non ISS electronic medical record.

Hook and Regal [107] presented the formula for estimating the content of Cell X (potentially missed overuse mechanism of injury) from the overlap of coverage from the two sources, where x=bc / a (Appendix 6.1). With this estimation of x, the total reported overuse mechanisms of injury can be estimated by: N = a + b + c + x. From the estimation of the total N (total overuse mechanisms), the capture rate for the ISS, medical records, and ISS and medical records can be estimated. The capture rate for the ISS can be calculated by (a + b)/N. (Table 6.1) The theoretical model for these calculations is presented in Appendix 6.2 which presents the cross tabulation of the injury events with a reported mechanism of injury of overuse in the ISS and/or the medical records.

Effective agreement [108] was estimated as the percentage agreement for a the following covariates: injury date, activity at time of injury, event type, event season, chronic, diagnosis code, incident/recurrent, body part injured, side, injury required surgery, injury type, outcome

and injury severity. This was calculated as the percentage of ISS and medical records who agreed on the value for that covariate. Kappa agreement was also calculated to compare the level of agreement among covariates. These calculations were limited to records which appeared in both sources, and analyses were conducted in order to have an estimation of agreement that also takes agreement according to chance into consideration. Strength of agreement was adapted from Landis and Koch (1977) [120] where Kappa <0 = poor agreement, 0-20% = slight agreement, 21-40% = fair agreement, 41-60% = moderate agreement, 61-80% = substantial agreement and 81-100% = almost perfect agreement. Kappa agreement was not calculated for the injury date and diagnosis code variables due to the large number of possible combinations. Effective and Kappa agreement were calculated in three strata of injury events: number of events which appeared in both records, events where the mechanism was overuse in both sources and events where the mechanism was overuse in only one source.

The distribution of the characteristics of the injury events were calculated (n and %) for strata where the mechanism was overuse in both systems and where the mechanism was overuse in one system. The distributions were calculated for the ISS and medical records separately within each group (Appendix 6.3). Data abstractor notes were reviewed to add context to the results.

6.3 Results

6.3.1 Capture-recapture analysis

There were 64 records where the mechanism of injury was overuse in one or both sources, i.e., the ISS, the medical records, or both (Figure 6.1). Of those records, there were 48 events which had an overuse mechanism of injury in the ISS, and 44 events which had an

overuse mechanism of injury in the medical records. There were 28 overlapping events that were captured in both sources. Using capture-recapture analyses, an estimated that 11.4 events were missed by both sources. Total overuse injuries was 75.4, or 11% of all reported injuries (Table 6.1).

Overall, the ISS had a higher capture rate for injuries with an overuse mechanism than the medical records, 63.7% compared to 58.4%. There was a lower capture rate for overuse injury for womens soccer compared to mens soccer; this was consistent across all sources. These were the only statistically significant differences in the capture rates between covariates.

The capture rate for injuries with an overuse mechanism of injury was lower in 2006 as compared to 2005 and 2007. There were higher capture rates of injuries with an overuse mechanism of injury in schools which had an undergraduate AT program. This is most noted in the medical records alone. There was minimal difference in the capture of injuries with an overuse mechanism of injury between schools which used an electronic non-ISS database and those without. The differences in these strata were not statistically significant.

6.3.2 Agreement

There were ten events with a mechanism of overuse which were reported to the ISS, and were not found in the medical records. These ten events were not included in either effective agreement or Kappa calculations. This resulted in an altered sample size for the total records which appeared in both sources (n=54), and overuse mechanism in only one source (n=26).

Season, surgery, and incident/recurrent had the highest effective agreement overall (>90%, Table 6.2), while injury date, activity, and injury severity had the lowest effective agreement among the total records (<70%, Table 6.2). According to the Landis and Koch (1977)

[120] criteria, Kappa agreement was almost perfect for body part across all strata of overuse mechanism and substantial across all strata for incident/recurrent, injury type and injury severity. (Table 6.3) In some analyses (event season, chronic, and injury required surgery) cell counts were too low to reliably estimate Kappa.

6.3.3 Characteristics of time-loss overuse injury events and data abstraction records

Nearly all overuse injuries occurred to the lower extremity. The majority of the injuries where overuse was the mechanism in both systems were to the lower leg (ISS: 35.7%, medical records: 32.1%, Appendix 6.3). Among the records where overuse was the mechanism in only one source, the majority of the injuries were to the hip/thigh (ISS: 26.9%, medical records: 34.6%). Overall there was a larger percentage of missing data for the injury characteristics in the medical records than the ISS. For the majority of variables, the medical records had two to five times the "not specified" or "don't know" responses than the ISS.

Data abstraction records for events where the mechanism was overuse for both data sources were similar to data abstraction records for events where the mechanism was overuse in only one data source. (Table 6.4) Disagreements between the ISS and medical records, were often in either close proximity (ex: discrepancies between the sources regarding body part were anatomically close together such as hip vs. thigh) or temporality (ex: close to half of all discrepancies between the sources regarding number of days out were less than three days apart). Notable differences in abstraction notes demonstrated that records with overuse mechanisms in one source had more missing or "don't know" responses in general, than records with overuse mechanisms in both sources.

6.4 Discussion

6.4.1 Capture-recapture analysis

The capture rates found in this study demonstrate variability in reporting time-loss, medical attention overuse injuries. The goal of this investigation was not to estimate the total occurrence of overuse injuries in college soccer players, but rather to quantify the variability in assigning an overuse mechanism of injury between two data sources. The results indicate that the ISS captured 64% of time-loss, medical attention overuse injuries in this population. This capture rate is considerably less than the capture rate of the ISS for total injuries, which was found to be 88% in the parent study. [78] The capture rate for overuse injuries was lower for medical records (58%), and both sources combined (37%).

The higher capture rate in the ISS as compared to the medical records may be related to the format of electronic medical records. In the ISS, the AT chooses a mechanism of injury from a list of provided options. Although there is a write-in option for "other", if the AT reports a mechanism, it generally falls into one of the identified categories. [75, 80] In medical records, the AT does not necessarily have to commit to a specific mechanism of injury. This was seen in the parent study, as mechanism of injury was one of the variables with the largest amount of missing data; of the 664 original injuries, 57 records (8.6%) were missing a mechanism of injury in either the ISS or medical records. [78] Although the ISS had a slightly better capture rate, it is clear that time-loss overuse injuries are not well captured by either system, and are likely underreported to the ISS.

While the ISS and medical records captured approximately the same percentage of overuse mechanisms, they captured different events. The variability in these results regarding the reporting and classification of overuse injuries within both sources is likely related to several

factors, including the lack of consistency regarding the definition of overuse within injury surveillance systems specifically and the literature in general, as well as the nature and onset of overuse injuries. [48] Currently, there is no standardized definition for overuse within injury surveillance. [8] The nature of these injuries, which result from repetitive stress and progress over time, likely contributed to the variability in the records as well. [16, 17] As an athlete can seek medical attention at any point in the injury process, the injury may present with variable symptoms. This may result in an overuse injury being misidentified or misclassified due to the complexity of the injury assessment. [121] A consensus definition of overuse to be used in injury surveillance and medical records will likely improve the consistency in the reporting of overuse injuries in the future.

The difference in overuse injury capture rates between mens and womens soccer is likely related to the fewer time-loss, medical attention overuse injuries reported in female athletes. These results are inconsistent with the literature, as overuse injuries have been reported at higher rates in female than male sports in previous studies of college athletes [6, 7] The higher capture rates in mens soccer may be due to gender differences in reporting injuries to ATs. Female athletes often report injuries more quickly after onset than male athletes. [115] This may result in the injuries appearing to be from more acute than overuse mechanisms. Also if female athletes report an injury before it results in significant limitation from sport, she may receive treatment for an injury before it meets the time-loss requirement for entry into injury surveillance. [87] This would likely contribute to the fewer reported time-loss, medical attention overuse injuries. Continued research into gender differences in reporting of injuries as well as the reporting of overuse injuries in general may help distinguish differences in the processes for capturing overuse injuries.

6.4.2 Effective agreement and Kappa

The effective agreement between the medical records and ISS was the highest for the variables which required the least clinical judgment from the AT. For example, the variables season and surgery had the highest effective agreement and these variables are less ambiguous. Conversely, variables which had the most options for data entry, and required greater clinical judgment or accuracy from the ATs such as injury date and injury severity had the lowest effective agreement. In injury surveillance, the goal is to capture a broad array of details, such as time-loss from sport and activity at time of injury however, medical records are not designed for this purpose. The difference in the variables that are captured and differences in the recorded values reflect these diverse purposes. These results are also consistent with the effective agreement in the parent study. [78]

The variable "chronic" had a high level of effective agreement, which may be due to the nature of this investigation. The terms "overuse" and "chronic" have been used in conjunction with similar injuries and, on occasion, interchangeably regarding a mechanism of injury. [48] As this investigation includes only injuries with a reported mechanism of overuse in at least one source, it should not be unexpected that many of these injuries are also classified as chronic.

There were differences in effective agreement between strata of overuse mechanism in two vs. one source (Table 6.4). When both sources had overuse as the mechanism of injury, there was higher effective agreement regarding the body part injured, side and outcome, as compared to when the mechanism was overuse in only one source. This may indicate that when overuse is clearly the mechanism of injury specific details about the injury such as location (body part, side) and outcome (surgery) and nature (chronic) are clearer as well. Conversely, the effective agreement for diagnosis, injury type and severity were higher when the mechanism was overuse

in only one source, which indicates that agreeing on the mechanism of injury is a separate issue from agreeing on these variables.

6.4.3 Characteristics of overuse injury events and data abstraction records

Almost all injuries in this investigation of soccer injuries were to the lower extremity regardless of data source or overuse mechanisms. This is directly related to the inclusion criteria for this study, a time-loss, medical attention event with an overuse mechanism of injury in at least one source, as a prior study has reported that lower extremity injuries account for 80% of total overuse injuries. [6]

There was a large amount of missing data regarding the characteristics of the injury in the medical records as compared to the ISS (8.6% for mechanism, Appendix 7.3). This is likely due to differences in the purpose of the medical records and the ISS. In clinical care, documentation (medical records) is used to maintain a history of the injury for use in evaluation and treatment specific to individual athlete. The medical records function to monitor progress, inform treatment decisions and to have a method to relate that information to other clinicians. On the other hand, injury surveillance is used to collect data on select characteristics of an injury to monitor trends on a population level, not just the progression of one athlete. [122] Complete data on all variables may be less important in medical records, which can have a narrower focus than injury surveillance. This would result in medical records with data that would be missing by ISS standards, but this missing data was not clinically relevant to patient care.

The data abstractor notes supported this finding as well. Discrepancies between records were often due to missing data from the medical records. Abstractors also commented on the presence of extensive information regarding one variable (e.g. return to participation) or broad

information that did not fit into an ISS category, found in individual medical records. Although the accuracy of the ISS or the medical records could not be assessed, it was found that neither source was complete individually, and both sources should be used for complete capture of events in epidemiologic investigations. Further, a chart review may offer more contextual information that can also complement the epidemiologic findings.

6.4.4 Limitations

A limitation of this study is its small sample size. This is related to this investigation using data from a prior study that was designed to assess all injuries, not overuse injuries specifically. [78] It is also related to the injury inclusion criteria of a time-loss injury definition. Overuse injuries may be entered in the ISS or medical records as a variety of diagnoses (e.g. tendinitis, stress fracture) with either a missing or alternate mechanism of injury, rather than an overuse mechanism of injury. Therefore the inclusion criteria requiring an overuse mechanism of injury may not capture all overuse injuries. Another limitation, specific to overuse injuries, is that the parent study was performed in a population of soccer athletes only and may not be representative of other sports. Different sports, such as cross country or swimming, where the athletes are exposed to repetition of specific sport skills, would have provided a larger number of overuse injuries.

6.5 Conclusion

It was encouraging to learn that the ISS captures two-thirds of overuse injuries resulting in medical attention and time-loss. However, the overlap between medical records and the ISS for overuse injuries was surprisingly small (37%). Since neither source can be considered a gold

standard, and since the assessment and reporting of overuse injuries is a complex issue, it is recommended that future studies of overuse injury supplement injury surveillance data with a record review for complete capture in addition to exploring the context and complexity of these injuries.

6.6 Figures and Tables

Figure 6.1. Distribution of injuries with a mechanism of injury of overuse in one or more sources (Note: Diagram is not to scale).

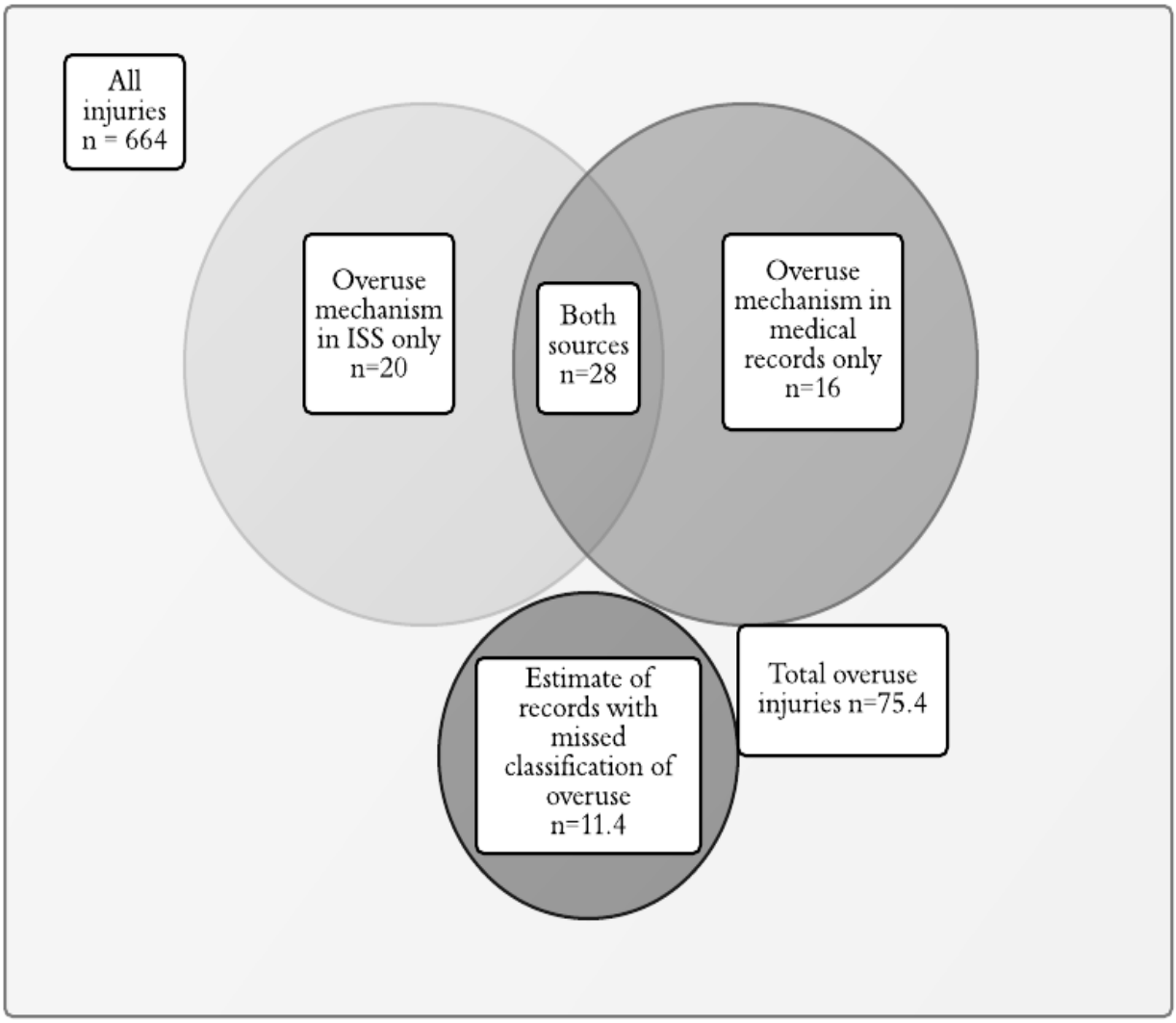


Table 6.1. Capture-recapture analysis for injuries with an overuse mechanism in one or both sources

	Injuries with an overuse mechanism of injury in both ISS and medical records	Injuries with an overuse mechanism of injury in ISS only	Injuries with an overuse mechanism of injury in medical records only	Estimated injuries missed by ISS and medical records	Total estimated injuries (x)	Percentage capture for ISS	Percentage capture for medical records	Percentage capture for both systems
Total	28	20	16	11.4	75.4	63.7 (52.8, 74.5)	58.4 (47.2, 69.5)	37.1 (26.2, 48.0)
Gender								
Mens Soccer	19	11	5	2.9	37.9	79.2 (66.2, 92.1)	63.3 (48.0, 78.7)	50.1 (34.2, 66.1)
Womens Soccer	9	9	11	11	40	45 (29.6, 60.4)	50 (34.5, 65.5)	22.5 (9.6, 35.4)
						X^2: 9.60, p=0.002	X^2: 1.41, p=0.236	X^2: 6.45, p=0.011
Year								
2005	3	4	2	1.3	10.3	68.0 (39.5, 96.4)	48.5 (18.0, 79.1)	29.1 (1.4, 56.9)
2006	11	8	8	5.8	32.8	57.9 (41.0, 74.8)	57.9 (41.0, 74.8)	33.5 (17.4, 49.7)
2007	14	8	6	3.4	31.4	70.1 (54.0, 86.1)	63.7 (46.9, 80.1)	44.6 (27.2, 62.0)
						X^2: 1.10, p=0.578	X^2: 0.77, p=0.681	X^2: 1.20, p=0.549
Division								
Division 1	12	11	6	5.5	34.5	66.7 (50.9, 82.4)	52.2 (35.5, 68.8)	34.8 (18.9, 50.7)
Division 2	4	2	1	0.5	7.5	80.0 (51.4, 1.00)	66.7 (32.9, 1.00)	53.3 (17.6, 89.0)
Division 3	12	7	9	5.3	33.3	57.1 (40.2, 73.9)	63.1 (46.7, 79.5)	36.0 (19.7, 52.3)
						X^2: 1.63, p=0.443	X^2: 1.06, p=0.589	X^2: 0.94, p=0.625
Undergraduate AT program								
Yes	13	5	6	2.7	26.7	67.4 (49.6, 85.2)	71.2 (54.0, 88.3)	48.7 (29.7, 67.7)
No	15	15	10	10	50	60.0 (46.4, 73.6)	50.0 (36.1, 63.9)	30.0 (17.3, 42.7)
						X^2: 0.41, p=0.532	X^2: 3.19, p=0.074	X^2: 2.62, p=0.105

Non-ISS electronic database								
Yes	13	8	7	4.3	32.3	65.0 (48.6, 81.5)	61.9 (45.2, 78.7)	40.2 (23.3, 57.2)
No	15	13	8	6.9	42.9	65.3 (51.0, 79.5)	54.6 (38.7, 68.5)	35.0 (20.7, 49.2)
						X^2: 0.0005, p=0.982	X^2: 0.52, p=0.471	X^2: 0.22, p=0.639

Table 6.2. Effective agreement between medical records and ISS for event, injury and return-to-play details

	Effective agreement, total records[a] (95% CI), n=54[b]	Effective agreement, overuse mechanism in both sources[a] (95% CI), n=28	Effective agreement, overuse mechanism one source[a] (95% CI), n=26[b]
Event details			
Injury date	61.1 (48.1, 74.1)	50.0 (31.5, 68.5)	73.1 (56.0, 90.1)
Activity	68.5 (56.1, 80.9)	64.3, (46.5, 82.0)	73.1 (56.0, 90.1)
Event type	87.0 (78.1, 96.0)	82.1 (68.0, 96.3)	92.3 (82.1, 100)
Event season	98.2 (94.6, 100)	100	96.2 (88.8, 100)
Injury details			
Chronic	90.7 (83.0, 98.5)	92.9 (83.3, 100)	88.5 (76.2, 100)
Diagnosis code	81.5 (71.1, 91.8)	78.6 (63.4, 93.8)	84.6 (70.8, 98.5)
Incident or recurrent	92.6 (85.6, 99.6)	89.3 (77.8, 100)	96.2 (88.8, 100)
Body part	90.7 (83.0, 98.5)	92.9 (83.3, 100)	88.5 (76.2, 100)
Side	87.0 (78.1, 96.0)	89.3 (77.8, 100)	84.6 (70.8, 98.5)
Injury required surgery	98.2 (94.6, 100)	100	96.2 (88.8, 100)
Injury type	81.5 (71.1, 91.8)	78.6 (63.4, 93.8)	84.6 (70.8, 98.5)
Return-to-play details			
Outcome	87.0 (78.1, 96.0)	89.3 (77.8, 100)	84.6 (70.8, 98.5)
Injury severity[c]	57.4 (44.2, 70.6)	50.0 (31.5, 68.5)	65.4 (47.1, 83.7)

[a] Number of categories per variable is two: agree vs. no.

[b] This analysis did not include ten records which only appeared in the medical records, but not the ISS. Therefore the number of records with an overuse mechanism in only one source was 26 (from 36), and the total number of records for this analysis was 54 (from 64)

[c] Severity derived from number of days lost, 0, 1-7, 8-14, 15-30 or 31+ days lost

Table 6.3. Kappa agreement between medical records and ISS for event, injury and return-to-play details

	Kappa percent agreement, total records (95% CI), N=54[a]	Kappa percent agreement, overuse mechanism in both sources (95% CI), N=28	Kappa percent agreement, overuse mechanism one source (95% CI), N=26[a]
Event details			
Activity	53.9 (38.6, 69.1)	50.7 (30.2, 71.2)	56.9 (33.8, 79.9)
Event type	73.6 (56.4, 90.9)	62.4 (34.3, 90.4)	84.7 (65.5, 100)
Injury details			
Incident or recurrent	83.9 (69.1, 98.8)	74.3 (48.6, 100)	92.4 (77.7, 100)
Body part	88.8 (79.5, 98.1)	91.0 (79.1, 100)	86.4 (72.1, 100)
Side	80.5 (67.1, 94.0)	83.4 (65.8, 100)	77.2 (56.6, 97.9)
Injury type	78.7 (67.0, 90.3)	73.5 (56.3, 90.8)	81.9 (65.7, 98.1)
Return-to-play details			
Outcome	60.7 (36.3, 85.2)	66.1 (34.6, 97.7)	55.6 (19.3, 91.8)
Injury severity[b]	76.8 (56.7, 96.9)	70.4 (33.4, 100)	79.6 (54.9, 100)

[a] This analysis did not include ten records which only appeared in the medical records, but not the ISS. Therefore the number of records with an overuse mechanism in only one source was 26, and the total number of records for this analysis was 54

[b] Severity derived from number of days lost, 0, 1-7, 8-14, 15-30 or 31+ days lost

Table 6.4. Characteristics of data abstraction records (n=52*)

Variable	Characteristics
Text description of injury	Included a history of the injury, primary symptoms, previous treatment and/or current symptoms with an identified assessment or diagnosis
	In cases where an assessment was missing (n=18), the text regarding the injury was either vague, described the treatment or progression of injury or the described a complex injury event
	Ten of 18 cases without an assessment were initialed by one abstractor
Body part	Disagreements between sources regarding the body part primarily concerned body parts in close proximity, ex: foot vs. lower leg, or involved missing information
Injury Type	There was a high amount of variability in the way the information for this section was presented. Complete information was included, but placed in different sections.
	Five of ten disagreements regarding injury type included sprains in one record. The remainder involved close types or diagnoses, such as stress reaction vs. stress fracture
Outcome	Six of 52 records agreed were close to agreement with discrepancies occurring from missing, rather than differing information as to all components of the outcome (return status, days out, date of return to participation).
	18 of 52 records had days out and date of return to participation differing by less than three days
	Six of 52 had days out and date of return that differed by over two weeks
	22 of 52 records had almost no information from one data source

* Two abstraction forms were missing.

CHAPTER 7

RESULTS FOR AIM 3: IDENTIFICATION AND REPORTING OF OVERUSE INJURES AMONG ATHELTIC TRAINERS WHO PARTICIPATE IN INJURY SURVEILLANCE

7.1 Introduction

Injuries are frequent among college athletes. Sport-related injuries have been reported to occur in competitions at rates of 1.5 - 39.9 per 1000 athlete exposures (AEs) and in practices at rates of 2.1 - 9.0 per1000 AEs depending on the sport. [123] Overuse injuries are a particular type of injury that are characterized by the accumulation of microtrauma as a result of repetitive activity. This trauma can affect many tissues, including but not limited to bone, muscle, tendon, ligament. [7, 17, 18, 124] These injuries typically do not have a single specifically identifiable incident associated with their onset. [6, 12] Their slow progression and insidious onset make them difficult to define. [12, 48] While overuse is generally characterized as resulting from repetitive stress or inadequate rest between activities, there does not appear to be a universally adopted definition of "overuse" at this time. [8, 121] This can result in variability regarding the mechanism of injury, injury onset date and diagnosis, as well as inconsistencies when documenting overuse injuries. [48, 87]

Athletic trainers (ATs) are medical professionals who have received training to diagnose, treat, and prevent sports injuries in settings such as high schools, colleges and universities. [77, 79] The National Collegiate Athletic Association's (NCAA) Injury Surveillance Program (ISP) depends on AT volunteers to collect data regarding all sport related injuries, including factors

related to the injury itself, the resolution of the injury, and specifics related to each sporting event. [60, 75] These data have been used to identify areas for intervention and to provide support for systemic changes in sport, including rule changes in men's hockey in 1995 to decrease impact to the head and hitting from behind, and the changes to spring football in 1997 that affected the permissible level of contact and allowable equipment. [80] Data from the ISP have also been used for practical applications, such as informing the allocation of certified athletic trainers to sports with higher incidence of injury, and monitoring the effectiveness of prevention interventions. [76, 125]

The ISP has been previously validated for NCAA divisions I, II and III mens and womens soccer, against electronic and non-electronic medical records and was found to capture 88% of time-loss injuries. [78] However, this previous study assessed a small number of overuse injuries in only one sport (soccer). Understanding how college ATs arrive at diagnostic, treatment and reporting decisions is important. The data recorded in injury surveillance systems reflects, to some extent, the injury assessment and clinical decision-making process of each contributing AT. Variations between clinicians will create ambiguity in the results obtained from the analysis of injury surveillance data. The effect of the individual clinician is of particular interest when considering injuries which are hard to identify or classify, such as overuse injuries. [29, 126]

The purpose of this investigation was to describe the variability in individual practices among college ATs who collect data for the ISP. This investigation was interested in both 1) how ATs determine if overuse played a role in the development of the specific injury, and 2) once the AT made that determination, how likely he or she would be to report an overuse mechanism of injury to the ISP. The first construct is referred to as "Role", and the latter construct as "Report".

It is important to investigate how injury surveillance data reflects the individual AT's practices specifically regarding overuse injuries, which are hard to define and categorize, to ensure that injury surveillance data and the literature is accurately representing this important injury topic.

7.2 Methods

This study examines the variability among ATs in their decision-making with respect to the designation of overuse in regard to its role in the injury event (Role construct) and the probability of reporting an overuse mechanism of injury in various injury scenarios (Report construct). The study used seven hypothetical injury scenarios to determine the range of variability and procedures that ATs use to arrive at their assessments. The seven scenarios (Appendix 7.1) represented situations in which an athlete presents with an injury that may have an overuse pathogenesis. Each scenario involved a mix of overuse and acute mechanisms, sometimes with incomplete details on the exact pathology of the injury. Scenarios were followed by a series of closed and open-ended questions. Question 1 addressed the AT's opinion of the contribution of overuse in each scenario (Role construct), Question 2 asked the likelihood of assigning an overuse mechanism of injury to that scenario (Report construct) and Question 3 asked how the AT reached those conclusions.

7.2.1 Research design and participants

This study used a cross-sectional design. Eligible participants were recruited from college ATs who were contributing to the ISP in October 2014. The Qualtrics online survey platform was used for the creation and distribution of the survey instrument. [127] This study was determined to be exempt from review by the IRB at the University of North Carolina at Chapel

Hill. Eligible participants were ATs who currently report injury data to the ISP as of October 2014.

7.2.2 Instrumentation – clinical scenarios

The seven clinical scenarios (A through G) covered a wide range with respect to level of involvement of overuse mechanisms. Each injury scenario presented the clinical history of an athlete presenting to the athletic training room, with variable amounts of information regarding subjective reports of symptoms and history of the injury, sport participation and previous injury history, clinical objective findings, results of clinical special and medical tests and rehabilitation outcomes. The scenarios were designed to approximate athletic training room clinical care, where total information is not always known, and athlete responses and clinical signs can sometimes be ambiguous. As mentioned above, these scenarios were constructed to represent a range of combinations of overuse and acute mechanisms. In some scenarios, the details of injury onset were intentionally ill-defined and vague, a situation that is not uncommon in college clinical settings. The scenarios were independent of each other, with the exception of two linked scenarios that involved the same athlete during the progression of one season. (Appendix 7.1)

The injury scenarios were developed by the primary investigator (KR) with input from the five committee members (SM, KK, YG, JM, WR), and five different AT clinicians. The injury scenarios were initially generated based on the primary investigator's personal clinical experience as a college AT. In-depth qualitative interviews were conducted with five AT graduate students which investigated 1) the appropriateness of the scenarios, 2) how the injury scenarios were understood, 3) the decision making processes which these ATs used to complete the survey, and 4) whether the survey accurately captured these factors. An additional 13 ATs

and graduate students were consulted regarding the content, ease, and comprehension of the survey.

7.2.3 Instrumentation – assessment of clinical decision-making

Clinical decision-making was assessed using two questions: one addressing the role of overuse in each scenario (Role construct) and one addressing the probability of reporting the mechanism of injury in each scenario as overuse to injury surveillance (Report construct).

7.2.3.1 Role construct

Following each scenario ATs were asked their opinion of the contribution of overuse in that injury scenario through a closed-response question with four response categories ("Overuse is the major contributor to this injury", "Overuse is a limited contributor to this injury", "This injury is not overuse related at all", and "Not enough information").

7.2.3.2 Report construct

Each AT was then asked to report the probability that he or she would assign overuse as the mechanism of injury for that scenario in the ISP. Numeric scores from 0 to 100% were implemented online using visual analog scale with a sliding pointer.

7.2.3.3 Open ended questions

ATs were asked an open ended question regarding their decision making process ("How did you reach these conclusions?"). If an AT responded "not enough information" to the role question or "n/a" to the report question he or she was presented with a follow up open ended

question asking what further information was needed to come to a conclusion about that scenario.

7.2.4 Recruitment and data collection

The Datalys Center for Sports Injury Research and Prevention (Datalys Center, Indianapolis, IN) conducts the ISP. The ISP uses ATs who volunteer to participate in data collection and consists of an online platform which can be used in conjunction with existing electronic documentation systems. [75] All 293 ATs who were currently participating in the ISP on October 1, 2014 were emailed an invitation to participate in this study by the ISP director on October 1, 2014. Two survey reminders were sent to ATs who had not completed the survey at one and two weeks. The survey closed on October 22, 2014. Only completed surveys were included for analysis. A total of 113 ATs (38.6%) began the survey, and 74 completed it (a 25.3% response rate). Incentives, ($25 gift cards), were mailed to all participants who provided contact information at the conclusion of the survey.

7.2.5 Assessment of discordance

The goal of these analyses was to describe the variability in clinical decision-making in each scenario, for both constructs of Role and Report. AT responses to scenarios were classified using two major axes, which were termed “Discordance” (three levels) and “Majority Opinion” (two levels). The criteria for classification of the scenarios into these groups were empirically-based and generated from the data in hand.

7.2.5.1 Discordance

The "Discordance" axis represented the level of concordance or discordance in the ATs responses to questions regarding both the Role and Reports construct. Criteria for the categorization into these three types are summarized in Table 7.1.

Type 1: those scenarios that generated *concordance* among ATs as to Question 1: the contributing role of overuse and Question 2: whether the injury should be classified as an overuse mechanism when reporting surveillance data. The criteria for Type 1 included 1) over 75% of responses to the role of overuse were in agreement, and 2) the interquartile range for the probability of reporting overuse as a mechanism of injury was either between 0% and 25% or 75% and 100%, and 3) less than 5% of data was missing from both contributing questions.

Type 2: those scenarios that generated *minor discordance* among ATs as to Question 1: the contributing role of overuse and Question 2: whether the injury should be classified as an overuse mechanism when reporting surveillance data. The criteria for Type 2 included 1) not classified as Type 1, and 2) over 50% of responses to the role of overuse were in agreement, and 3) the interquartile range for the probability of reporting overuse as a mechanism of injury was either between 0% and 50% or 50% and 100%, and 4) less than 10% of data was missing from one or both contributing questions.

Type 3: those scenarios that generated *major discordance* among ATs as to Question 1: the contributing role of overuse and Question 2: whether the injury should be classified as an overuse mechanism when reporting surveillance data. A scenario was classified as Type 3 if 1) it did not meet the criteria for Types 1 or 2, and 2) there was <75% agreement regarding role, and 3) the interquartile range for the probability of reporting overuse as a mechanism of injury

included 50%, and 4) more than 10% of data was missing from one or both contributing questions.

7.2.5.2 Majority opinion

In addition to the Discordance axis, the scenarios were also classified using an axis, which was termed "Majority Opinion" (Table 7.2). This represented the Report construct of whether or not the majority (>50%) of respondent ATs considered that overuse was a major contributing factor. Scenarios where the majority of ATs (>50%) considered the injury overuse related were labeled Type A, and scenarios where the majority of ATs considered the injury not overuse related were labeled Type B.

7.2.5.3 Global classification system

These two axes were combined to create a new classification system including a number (1, 2 or 3) and a letter (A or B, Table 7.3). Thus a classification of 1A would indicate that there was concordance in the AT responses regarding both the assignment and reporting of an overuse mechanism of injury. A classification of 3B would indicate major discordance between ATs in a scenario that overall was determined to be "not overuse". In addition to the development of these two classification axes (Discord and Majority Opinion), the overall level of variability in the responses to each scenario was assessed and presented through simple descriptive procedures, such as histograms, means, and box and whiskers plots. (Figure 7.1, Appendix 7.2)

7.2.6 Analysis of open ended responses

Qualitative responses were used to inform quantitative results. A directed content analysis, defined as analysis of qualitative data using previously identified variables of interest as preliminary categories for themes, adding new themes that did not arise from the original categories were conducted for all qualitative responses to the question "How did you reach these conclusions". [109] All text responses were read by the primary investigator and first coded according to themes regarding the ATs' 1) perceptions of the mechanism of injury in each scenario, 2) criteria for assigning overuse as a mechanism of injury, and 3) processes for reporting the mechanism of injury within injury surveillance systems. Additional themes were added throughout this process. A theme was defined as a theory or idea which was both present and clearly communicated in a text response. [109] Themes common to multiple ATs in response to multiple scenarios were noted for this analysis.

7.3 Results

7.3.1 Survey participants

Of the 74 ATs who completed the survey, the majority were male (n=46, 62.2%), and the mean age was 37.6 years old (SD: 9.4 years). A large proportion of participants had masters degrees (n=63, 85.1%), although only 27.0% of those degrees were in athletic training. A small percentage of participating ATs had doctoral degrees (n=4, 5.4%: 2 PhDs, 1 DPT, and 1 EdD). Respondents had been board-certified for an average of 4.9 years (SD: 4.6 years; range: <1 to 36 years), and 60.8% had been in their current job for five years or more (range: <1 to 20+ years).

7.3.2 Scenarios generating concordance

Scenario A was the only one to meet criteria for concordance among the ATs in assigning an overuse mechanism to the scenario. The majority of ATs (85.1%, Table 7.1) reported overuse as the major contributor to the injury (Role construct) and half of the ATs reported a probability of 92.5% or higher of reporting an overuse mechanism of injury (Report construct). Despite this concordance, there were four ATs who reported probabilities of reporting an overuse mechanism of injury of under 50% (Figure 7.1, Appendix 7.2)

There were two main themes from the qualitative responses to Scenario A. These were the progression of the injury presented in the scenario, and that the injury in the scenario had no specific mechanism of injury. The theme of progression of the injury included discussion of the information provided in the scenario specific to how the injury changed over time. An example of this was "Increase of pain as the season progresses." The theme of the absence of a specific mechanism of injury within the injury scenario discussed the lack of a specific injury incident, either missing from the injury scenario, but present in the injury itself, or missing from the injury event overall. An example of this theme was "There was no specific activity that started this injury."

7.3.3 Scenarios generating minor discordance

Four scenarios were classified as Type 2 (minor discordance). Scenario B was classified as 2A: minor discordance regarding an injury where overuse was the major contributor, and Scenarios C, D and E classified as 2B: minor discordance regarding and injury where overuse was not the major contributor.

Regarding the Role construct in each scenario, Scenario D had the highest percentage of ATs in one category (93%), and Scenario B the lowest (68.9%). Scenario B also had the highest percentage of missing data for this group (14.9% of the role of overuse and 8% of probability of reporting an overuse mechanism).

For the C, D and E scenarios, half of the ATs reported a probability of reporting an overuse mechanism of injury below 20% (Report construct). There were also one or two different ATs who reported a 100% probability of reporting an overuse mechanism of injury in each of these scenarios (rather than one individual AT who always reported a 100% probability and single handedly affected the distribution for each of these scenarios).

The variability of the distribution was also influenced by ATs who appeared undecided or neutral as represented by reporting a probability of reporting an overuse mechanism of injury between 45% and 55%. Scenarios C, D and E had eight, eight and ten ATs (respectively) reporting between 45% and 55% percent probability of reporting overuse as a mechanism of injury.

A major theme from Scenario B, a scenario determined to be from overuse mechanisms, was the duration of the injury. ATs whose qualitative responses included in this theme directly stated either the duration of the injury presented in the scenario, or a specific length of time that qualified the injury as overuse. An example of this was “the fact the pain has been going on for over one month.” In Scenario E, the primary theme among ATs was that the injury in the scenario was an acute event. These responses stated that the injury in the scenario was from an acute mechanism, or noted a specific incident that initiated the injury, such as “one specific mechanism that caused immediate symptoms that were not previously present.”

The text responses for Scenario C demonstrated the discordance that ATs had in response to that hypothetical injury. This is noted as the primary theme for Scenario C is that both overuse and acute components are present in this scenario. These ATs mentioned both overuse and acute mechanisms in their responses, for example "Has an acute mechanism, with overuse history that at that point was asymptomatic". This theme was also a dominant theme for Scenario D, for example "Although she was having back pain, she was being treated. There was also a specific incident that led to worsening pain. Overuse would be a moderate factor in the final injury because that muscle was already problematic."

7.3.4 Scenarios generating major discordance

Scenarios F and G were classified as Type 3B, major discordance (not overuse). These scenarios had the most variability in terms of the range of responses for reporting overuse as the mechanism of injury (Report construct, Figure 7.1). This variability was not affected by extreme values in one direction, but rather concentrations of extremely high and low values, as well as 10 and 13 values respectively between 45% and 55%. Scenario G had the highest percentage of missing data (27.0% for role of overuse and 9.5% for probability of an overuse mechanism) and Scenario F had the second highest percentage of missing data (12.2% for role of overuse and 9.5% for probability of an overuse mechanism).

The major theme in the Scenario F qualitative responses was that the injury in this scenario was from acute mechanisms. These responses did not always explain how they arrived at the assignment of an acute mechanism, but only that the injury was from acute causes. An example of this is "acute mechanism of kicking ball – would note tightness as contributor to injury." The primary theme for the Scenario G qualitative responses involved the activity at the

time of injury. Respondents stated that the activity presented in the injury scenario was the cause of the injury without assigning overuse or acute mechanisms to the injury, such as "She has been repetitively performing the same task with increased pain."

7.4 Discussion

The major finding of this study is that most of the scenarios generated at least some degree of discordance in responses among the participating ATs. This indicates that there is some degree of ambiguity in the assessment of the Role and Report constructs within this injury surveillance system (ISP). It was also found that, as a group, when ATs reported that overuse was a major contributor to the injury, ATs also reported a high probability of classifying overuse as the mechanism of injury within the ISP. The converse was also true. Where scenarios which the majority of ATs reported that overuse was not the major contributor, ATs had a low probability of reporting overuse as the mechanism of injury. This indicates content validity of the ISP for monitoring overuse injury among trained professionals.

Of particular significance were Scenarios F and G, where diverging opinions as to the Role construct led to a small majority of "overuse" or "not overuse" and an intermediate probability of reporting overuse as the mechanism of injury (Report construct). In Scenario F, which was considered not overuse by 63.5% of (Role construct), there was a 42.8% probability of reporting an overuse mechanism of injury (Report construct). Scenario G had a different response pattern and was considered not overuse as it did not meet the criteria set in Table 7.2, even though the largest percentage (45.9%) of respondents reported that the injury was due to overuse mechanisms. In this scenario, there was a mean probability of 59.2% of reporting an overuse mechanism, demonstrating the link between the majority opinion of the role of overuse

and the mean probability of reporting an overuse mechanism to injury surveillance. However, these mean probabilities of reporting a mechanism of injury for these scenarios disguise the polarization of AT respondents who had either an extremely high or low probability of reporting an overuse mechanism as a majority of ATs who have an intermediate probability of reporting an overuse mechanism. The lack of an overwhelming majority in regard to role of overuse, and the large percentage of missing data indicate substantial discordance with these scenarios.

The qualitative results demonstrate some of the reasons for this discordance. The most common themes for identifying overuse were the progression of the injury and the duration of the injury. This is likely related to the nature of overuse injuries, which are often defined by their progressive onset, and can be characterized as "chronic" or long lasting injuries. [111] These two themes were used to describe both "overuse" and "not overuse" injuries. This implies that the timeline of the injury and duration of symptoms are a key characteristic that ATs use to assign a mechanism of injury. However individual ATs use individual and different benchmarks for what qualifies as an overuse injury. At this time, no guidelines exist for the amount of time which results in an overuse injury, and such a guideline is likely impossible to formulate, as every injury and athlete is different.

Scenario G is an example of ATs trying to determine such a criteria, which would delineate an "overuse" injury from a "not overuse" injury. This scenario featured a female gymnast trying a new skill on the balance beam, which included a handspring, who complained of a wrist pain after three weeks of this new skill. There were ATs who thought that the repetition necessary to learn a new skill led to an overuse related injury; and others who thought that the three weeks of a new skill were unrelated to a single incident which occurred. It is clear that the ATs were trying to make sense the injury in their own terms. These ATs demonstrated

strong opinions regarding the probability of reporting an overuse mechanism, resulting in a polarization between extremely high and extremely low probability.

Among Scenario G responses, there were also eight ATs who were undecided and had a probability of reporting an overuse mechanism between 45% and 55%, and six of those fell within the "need more information" category regarding the role of overuse. These ATs may be trying to balance both the overuse and acute components of this injury. The theme of both overuse and acute mechanisms contributing to an injury demonstrates the difficulty associated with the assessment and definition of overuse. [8]

All injury scenarios were intended to be vague in regard to the mechanism of injury, with each scenario potentially having an aspect of both overuse and acute to the injury onset. The purpose of these scenarios was to learn how ATs assign overuse when the mechanism is unclear, as little can be learned from scenarios where agreement is already expected. That the participants identified that overuse was somewhat involved each scenario, even when they labeled them as "not overuse" indicates how these interrelated factors can impact an injury. It also shows that ATs believe that overuse can play a role in injuries which may present as acute. This illustrates the nature of the difficulty with assigning overuse as a mechanism of injury. In the absence of a specific injury event, there is no rubric or clear definition to determine when overuse is at fault, and it is up to the ATs to determine its role. [86] Future studies will have to delineate how overuse is defined, and providing specific criteria and examples of such injuries could improve the identification of these injuries.

A qualitative study by van Wilgan and Verhagen (2012) [104] asked athletes and coaches about their beliefs and found that the definitions for overuse injuries were either based on behavioral factors/ imbalance between strain and rest, or physiological factors.[104] It should

also be noted that there was no common theme within all their definitions. The themes in this analysis were greatly different from those found by van Wilgen and Verhagen. [104] Their definition for overuse focused on training load and the balance between training and rest.

7.4.1 Strengths and limitations

This is the first study to report the methods ATs employ to assign and classify overuse injuries within injury surveillance. All ATs who participated in the ISP were invited to complete the survey. However, only 25% completed the survey and this 25% may or may not be representative of all ATs who participate in the ISP. This is currently not possible to determine, as the Datalys Center does not collect data on the individual AT data collectors. It is important to note that there is currently no consensus definition of overuse injury that could be used as a gold standard for research or injury surveillance in general, much less for the intentionally vague contribution of overuse to the injury scenarios in this study. Therefore, it is not known whether ATs identified and reported overuse "correctly", however, that was not the purpose of this investigation.

Additionally, "Hawthorne effects" cannot be eliminated. The fact that these scenarios were followed by combined open and closed questions about their decisions and the process for making those may have affected ATs responses. Thus, it cannot be guaranteed that these results are independent of the ordering of the scenarios. Random shuffling of the scenarios was considered during survey administration, but it was decided not to introduce this additional source of variability into the study. Finally, because the scenarios were generated independently of clinical records, the extent to which scenarios such as those presented here occur in routine clinical practice cannot be quantified.

7.5 Implications for injury surveillance and clinical documentation

Our results demonstrate that in injury scenarios where the majority of ATs believe that overuse contributed to the injury, there is also a high probability of reporting overuse as the mechanism of injury within surveillance. This supports the ability of these systems for capturing overuse injuries once they have been identified. However, there is little to demonstrate that the assessment of the contribution of overuse is standardized between ATs. The discord between ATs in six of the seven scenarios demonstrates the lack of consensus regarding the definition for overuse and the variability in ATs interpretations of the criteria for classifying an injury as overuse, as well as the methods for assessing those criteria. Future investigations should address the sources of discord and provide clear operational definitions for overuse, including examples if possible.

A consensus definition would improve the consistency and generalizability of overuse injury results between studies. [48] Such a definition would also increase the consistency between ATs, specifically those with varying clinical assessments regarding overuse. Special instructions may be necessary for injury scenarios with dual or competing mechanisms, such as those where both overuse and acute mechanisms are present. Guidelines regarding the duration and progression of an overuse injury with or without specific time criteria may be helpful in creating a rubric for an overuse mechanism of injury in the future.

Operational definitions may assist in creating a rubric for the assessment of overuse as a mechanism of injury which could be implemented within injury surveillance. This may standardize how these injuries are identified, as once they are identified, this study found that they are categorized as such within the ISP. Standardization of methods for assessing and

reporting overuse injuries may improve consistency in the data and demonstrate a better picture of the burden of these injuries.

7.6 Conclusion

It is unlikely that the complex issues regarding the identification and reporting of overuse injuries will be easily resolved, but in order to progress towards clarity and consensus, continued research on overuse injuries with clearly identified operational definitions of overuse is necessary. This will help to ascertain the best way to define and classify overuse injuries, and hopefully pave the way for a readily employable operational definition in the future. Those advances may lead to a truer understanding of the burden of these injuries on athletes and ATs.

7.7 Acknowledgements

A doctoral grant from the Datalys Center for Sports Injury Research and Prevention provided for the incentives to participants.

7.8 Tables and Figures

Table 7.1. Criteria for categorizing individual injury scenarios into levels of discordance (Role and Report constructs)

Type of discordance	Type 1	Type 2	Type 3
General description	Concordance	Minor discordance	Major Discordance
General criteria		Is not categorized as Type 1	Is not categorized as Type 1 or Type 2
Question 1: Role construct	> 75% of responses were in agreement	> 50% of responses were in agreement	< 75% of responses were in agreement
Question 2: Report construct	The IQ[a] range for the probability of reporting an overuse mechanism of injury was either between 0%-25% or 75%-100%.	The IQ[a] range for the probability of reporting an overuse mechanism of injury was either between 0%-50% or 50%-100%.	The IQ[a] range for the probability of reporting an overuse mechanism of injury contains 50%.
Missing data	Less than 5% missing for each question	Less than 10% missing for one or both questions	More than 10% missing for one or both questions

[a] IQ: Interquartile

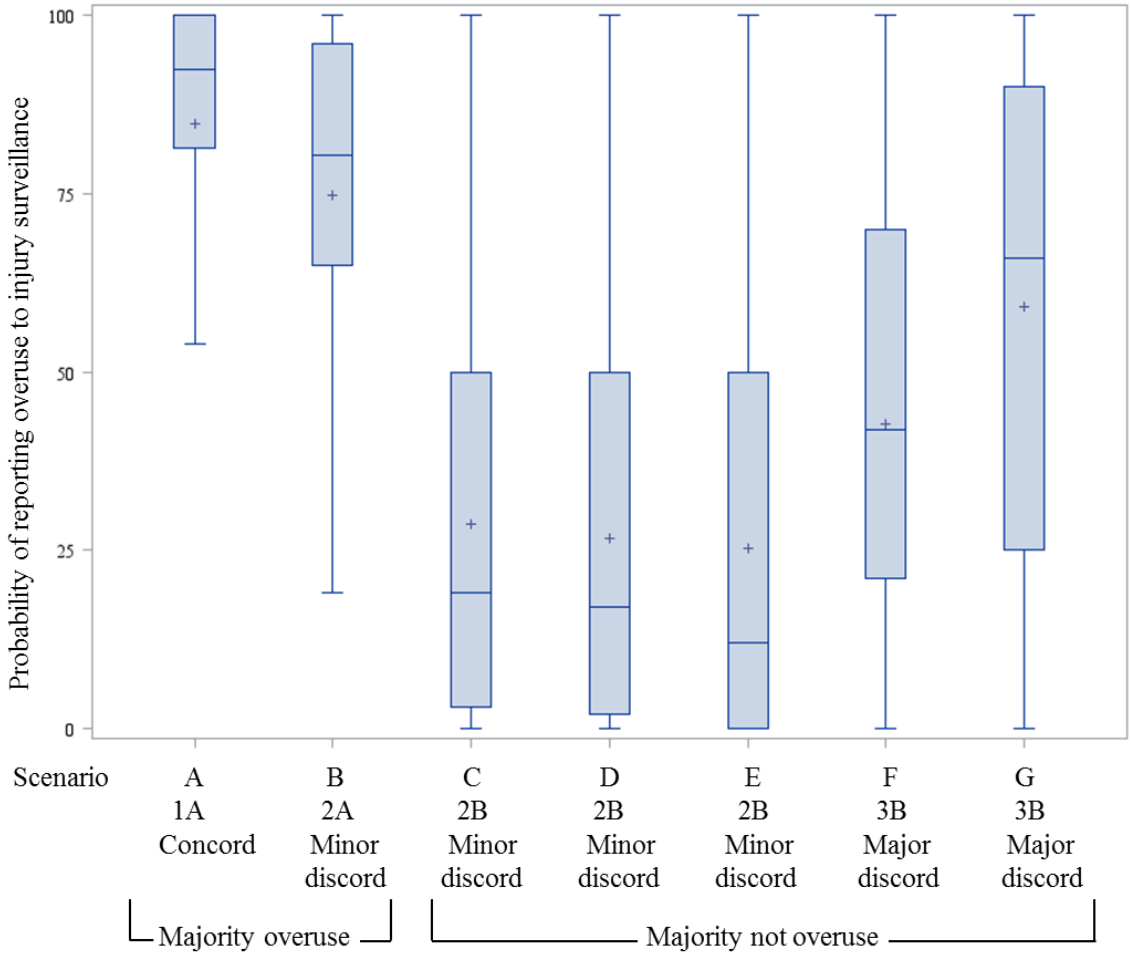
Table 7.2. Criteria for categorizing individual injury scenarios overuse or not overuse (Report construct)

Type	A	B
General description	Scenario is overuse	Scenario is not overuse
Question 1: Role construct[a]	≥ 50% of participants consider overuse the major contributor to the injury scenario	< 50% of participants consider overuse the major contributor to the injury scenario

Table 7.3. Responses to Question 1 (Role construct), regarding the role of overuse in each injury scenario (n=74)

Scenario	Overuse is the major contributor	Overuse is not a major contributor	Not enough information	Level of Discord	Majority opinion	Discordance classification
Scenario A: A softball athlete with a history of shoulder pathology two years ago reports similar symptoms mid-season.	63 (85.1%)	8 (10.8%)	3 (4.1%)	Concordance (Type 1)	Overuse related (Type A)	1A
Scenario B: A baseball pitcher with elbow pain for over one month, has been icing but not evaluated by AT, is mid-pitch when pain becomes "too much".	51 (68.9%)	12 (16.2%)	11 (14.9%)	Minor discord (Type 2)	Overuse related (Type A)	2A
Scenario C: The athlete from A completed rehab on her shoulder, returns to full participation, then falls on that outstretched arm resulting in a significant shoulder injury.	8 (10.8%)	64 (86.5%)	2 (2.7%)	Minor discord (Type 2)	Not overuse related (Type B)	2B
Scenario D: A new crew athlete has been having back pain prior to an episode of near dropping a boat, resulting in complaints of spasm and pain.	4 (5.4%)	69 (93.2%)	1 (1.4%)	Minor discord (Type 2)	Not overuse related (Type B)	2B
Scenario E: A swimmer with a history of significant sport involvement reports symptoms in his back after a rotation exercise in the weight room.	9 (12.2%)	63(85.1%)	2 (2.7%)	Minor discord (Type 2)	Not overuse related (Type B)	2B
Scenario F: A soccer goalkeeper with three week history of pain and treatment of thigh tightness collapses after punting the ball during a cold, uneventful game.	18 (24.3%)	47 (63.5%)	9 (12.2%)	Major discord (Type 3)	Not overuse related (Type B)	3B
Scenario G: A gymnast has been practicing a new skill on the balance beam for three weeks and presents with wrist pain and an inability to practice.	34 (45.9%)	20 (27.0%)	20 (27.0%)	Major discord (Type 3)	Overuse related (Type A)	3B

Figure 7.1. Distribution of the probability of reporting (Report construct) an overuse mechanism of injury by scenario, with designation of discordance classification



CHAPTER 8

DISCUSSION

8.1 Summary of findings

The major findings from the Aim 1 analyses were that overuse injuries are reported to injury surveillance over three times as often in college as high school athletes, and more than 50% as often in female than male athletes. These findings, that overuse injuries are more common in college and female athletes, are consistent with the published literature. [6, 7] These results have implications for future research, in that studies may need to investigate whether overuse injuries occur more often in, or are just more commonly reported by, female athletes. Given the gradual onset nature of overuse injuries, effective interventions may need to be targeted at younger athletes (even though their rates are lower) in order to prevent the cumulative effects of these injuries later in life.

In Aim 2, overuse injuries, as defined by the presence of an overuse mechanism of injury for that event, were found to be not well captured by either the ISS or parallel medical records. This is inconsistent with the parent study which demonstrated the ISS captured 88% of time-loss, medical attention injuries. [78] The current results demonstrate that, for overuse injuries, the ISS had a capture rate of 64%, and the medical records a capture rate of 58%. It is estimated that 37% of overuse injuries were captured in both systems, indicating that few injury events were assigned an overuse mechanism of injury in both systems. Effective agreement between ISS and medical records regarding covariates was highest for variables which involve less discretion in

judgment by data collectors, such as event season and whether the injury required surgery. Future investigations into overuse injuries should utilize ISS data in combination with medical records to ensure a more completion enumeration of cases, and to add depth and context to investigations of overuse injuries regarding the timeline and progression of each injury.

Responses to the hypothetical injury scenarios in Aim 3 generated some level of discord in all but one scenario regarding the role of overuse and the probability of reporting an overuse mechanism of injury to surveillance. Discord presented in two main ways: 1) some respondents were unsure of the role of overuse and their probable reporting of a mechanism of injury while others were certain about their decisions and, 2) the polarization of respondents, in which there was certainty among respondents, but in different directions. These findings indicate that there is heterogeneity in how ATs perceive the role of overuse in specific injury scenarios. This results in variability in how ATs report overuse mechanisms of injury to the ISS. The adoption of a consensus definition of overuse injury for use in injury surveillance may improve the capture and consistency of overuse injuries within the ISS, particularly if additional specific training and education of ISS AT data collectors is provided. This training and education should include specific examples and scenarios.

The Aim 2 analyses found that overuse injuries account for an estimated 11% of total time-loss medical attention injuries reported to the ISS in a sample of female and male soccer athletes. This is considerably lower than the subjectively reported burden of overuse injuries found in Aim 3, which was 49% of total treated injuries. This discrepancy between percentages may be a function of the population sampled in Aim 2, which only considered soccer athletes. The findings in Aim 1 indicate that among ISS injuries reported during the same time frame as the data collected for Aim 2, both mens and womens soccer had some of the lowest rates of

overuse injury. While the rates of overuse injury could not be compared to the rates of acute injury in this study, Yang et al 2012 [7], found 30% of total college sports injuries were overuse and just 20% (15/74) of womens soccer injuries were from overuse mechanisms. The sports which the ATs who took part in Aim 3 were responsible for is also unknown, and this could affect their perceptions of the treatment load of overuse injuries. ATs who worked with cross-country would experience a different injury load than ATs who worked with football. While the results cannot definitively state the percentage of total treated injuries in college settings which are overuse injuries, they demonstrate that overuse injuries can have a significant impact on athletes, as well as the perceptions of the ATs who treat them.

The results of Aim 2 also found that overuse injuries are likely underrepresented in injury surveillance data, as only 64% of potential total overuse mechanisms were reported to the ISS. This is consistent with Aim 3 results, from a survey of ATs, who reported that injury surveillance only captures 62% of their total treated overuse injuries. While these numbers are similar, there are some important distinctions between the cohorts that they come from. Data from Aim 2 was taken from the ISS and ISS era medical records, which required a medical attention, time-loss definition for an injury to be reported to injury surveillance, while Aim 3 was conducted among ATs who were participating in the ISP, which does not have a time-loss component to its injury definition. It should also be noted that the ISP data represents the ATs' perceptions of the percentage of overuse injuries that they treat. Regardless of the differences in definitions, it appears that a large percentage of overuse injuries are not entered into the ISS/ISP. This represents a group of injuries which are likely treated, but not accounted for in surveillance data. The impact of these unmeasured injuries on the athletes and sports medicine staff is not known at this time.

The likely underrepresentation of overuse injuries in injury surveillance was investigated in Aims 2 and 3. Aim 2 began to explore some of the sources for the underrepresentation and indicated that "overuse" was not consistently reported between injury surveillance and parallel medical records. In fact, from this sample, more cases disagreed regarding an overuse mechanism (overuse in only one source, n=36) than agreed (overuse in both sources, n=28). This demonstrates that a single injury incident can be assigned more than one mechanism of injury. The Aim 3 results further demonstrated this phenomenon, as only one of seven hypothetical injury scenarios generated consensus regarding the mechanism of injury.

The variability in the discord in Aim 3 regarding the role of overuse in an injury scenario and the probability of reporting an overuse mechanism to injury surveillance also demonstrate the complexity of defining "overuse". There were AT respondents who were unsure about the role of overuse, and unlikely to commit to a mechanism of injury. Additionally, there were clusters of AT respondents who were absolutely sure about the mechanism of injury in one scenario, but were split into groups of absolutely "overuse" and absolutely "not overuse" for that scenario. The breadth of AT opinions as to both the role and reporting of overuse would at times result in an intermediate aggregate response. This would inaccurately represent the polarized nature of results, disguising it instead as an "average" overall lack of commitment to a mechanism.

When these results are combined with the qualitative data from Aim 3, it is clear that there are many factors that go into determining the role of overuse in a scenario. Aim 3 identified the duration and progression of the hypothetical injury presented in the scenario as major contributors to AT decision making processes. Individual variables related to the injury (e.g. body part or diagnosis) that may have led to the differences in reporting between systems (ISS

vs. medical records in Aim 2), or factors related to the ATs (e.g. gender or experience) that may have led to differences in reporting tendencies (overuse vs. not overuse in Aim 3) were not found. It is unlikely that a single variable that is the major driver of AT opinion could be found, as overuse is a complex issue clinically. While the results demonstrate that often an AT has a strong opinion as to whether the injury was due to an overuse mechanism or not, the individual factors which lead the AT in such a direction still remain mostly unknown. Future studies should continue to explore this area.

Along with the duration and the progression of the injury, the presence of both acute and overuse elements are factors that were often taken into consideration in the assignment of overuse. It is also likely that factors related to how the individual ATs were trained were also involved. Although the survey instrument was unable to assess the definition which individual ATs were taught through the survey in Aim 3, such a definition is likely important in understanding how they diagnose overuse injuries, specifically in the absence of an overuse definition within injury surveillance. The creation of a standardized definition of overuse within injury surveillance which addresses both the duration and the progression of the injury would likely assist in bringing consistency to the results of injury surveillance regarding overuse injuries.

The continued use of these systems for surveillance of overuse injury is recommended, with the understanding that the true burden is likely underestimated. As these systems were initially designed to capture acute injuries, they likely misclassify, or do not capture a sizable percentage of overuse injuries. However, these systems can still be improved for the future use. The creation and implementation of a consensus definition for an overuse mechanism of injury to be implemented in injury surveillance may greatly assist in the classification and capture of these

injuries. Overuse injuries affect a large proportion of college and high school athletes, and the ramifications of these injuries throughout the lifetime is not entirely known. Further research into these injuries, aided by studies which provide a thorough and consistent definition of overuse, may further enumerate the burden of these injuries on both athletes and sports medicine staff.

8.2 Strengths

The main strength of this dissertation is the broad and various data sources that were utilized. In the pursuit of the goal of this dissertation ("to understand the incidence of overuse injuries through surveillance data") not only was the incidence estimated using existing surveillance data, but the validity of this data specific to overuse injuries was also investigated, which included the data abstracted from the medical records, notes on how that data differed from the ISS, and notes on the abstraction process itself. A survey was also conducted among ISP data collectors which investigated how they determine the role of overuse and their probability of reporting an injury as overuse.

This dissertation worked the topic of overuse using the existing injury surveillance systems. Injury surveillance has proven to be an invaluable tool in injury prevention for acute events. There is increasing research about new ways to measure overuse injuries which are more intensive on the athletes, ATs and researchers. If injury surveillance can be improved for overuse injuries with few modifications, such as an operational definition for overuse and additional training, then the additional resources needed for these different research methods may not be necessary. Instead, injury surveillance data may be sufficient and accessible enough to identify areas for intervention as well as monitor those interventions without a large influx of resources.

8.3 Limitations

A limitation of this study was the use of various time-loss requirements for injury inclusion between data sources. These changes are consistent with the changes in the ISS/ISP over time, but makes direct comparisons between aims and identification of trends over time difficult. The absence of a consensus definition for overuse was a limitation of Aim 3, in that the "correct" identification of overuse in the injury scenarios was not possible.

There were small sample sizes for Aims 2 and 3. This was a function of the number of overuse mechanism events in the parent study for Aim 2, and of the size of the target population for Aim 3 (N=293). This may have had some impact on power for some analyses, specifically when comparing between sub-strata, although the distribution of results remains informative. The data on clinical burden from Aim 3 was also self-reported. This limits the conclusions that can be made about the actual injury load that overuse injuries create.

The data from Aim 2 was previously abstracted data. Original data from the ISS or medical records was not available. The abstraction process was rigorous and the abstractors were all trained, however, there is still the potential for inconsistencies among abstracted data. Aim 2 data was also limited to one sport, soccer. This limits comparison between Aims 1 and 2, and as the sports which the participants in Aim 3 worked with was unknown, also limits the comparisons between Aims 2 and 3.

8.4 Alternate methods

Alternate methods were considered in the development of this dissertation. One method considered was the formation of a Delphi Committee to develop a consensus regarding the definition of overuse for use in either injury surveillance or research in general. This idea was

not pursued, although the work in this dissertation may be useful to such a committee in the future. To quantitatively assess the burden of overuse injuries on ATs and medical professionals, a formal chart review was also considered. This would have consisted of a medical record review from college or high school athletic training rooms to determine the percentage of treated injuries which were overuse. This would have provided definitive numbers about the burden of these injuries on the athletes and medical staff. However, this chart review would still have the potential to be incomplete, as not all treated injuries are recorded in any system, surveillance, medical records or otherwise. The perceived burden of overuse injuries from the ATs in Aim 3 gives an idea of the import and impact of these injuries. Future studies of these injuries may consider a chart review to determine a quantitative burden of overuse injuries.

8.5 Implications for injury surveillance methodology

Sports injury surveillance has proven successful for the identification of trends and patterns in acute injuries, and has resulted in effective injury prevention interventions. These systems are also evolving as new methods and new surveillance needs emerge. [75] Increased consistency in the definition and collection of overuse injury data may assist in the development of these systems to better capture overuse injuries, which will lead to a greater understanding of the incidence and impact of these injuries. [89, 121, 126] In the spirit of improving the quality of data for overuse injuries using current surveillance systems, the following recommendations are proposed.

8.5.1 Overuse injury as a mechanism of injury only, not as mechanism and diagnosis

In order to make injury surveillance more effective for identifying the incidence of overuse injuries, it is recommended to only use overuse as a mechanism of injury. This should be implemented by providing overuse as a mechanism of injury ONLY in all injury surveillance systems; it should NOT be included as a diagnosis AND as a mechanism. Maintaining overuse as a mechanism of injury only will avoid the multiple definitions, to better interpret the data, and also to create, implement and evaluate appropriate prevention strategies. This will also improve the comparability between studies, and may provide a foundation on which to build a consensus definition for overuse within injury surveillance. [121] The current platforms for the ISP and RIO work with these specifications, and this should be made permanent, regardless of changes to these platforms in the future

8.5.2 Adopt a consensus definition for overuse injury within injury surveillance systems

The term “overuse” has been used widely and for many different purposes. [48, 121] This has led to a diffuse application of the term in the literature. In order to decrease variability in the reporting of injuries and improve the data from injury surveillance systems, it is recommended that a consensus definition be created and adopted. This would standardize the meaning of the term, and hopefully improve consistency in diagnosis and assignment of overuse within injury surveillance. It would also improve the consistency and generalizability across studies which use various surveillance data. The process of consensus could be lengthy, and will require the collaboration of a variety of experts. The increased attention to overuse injuries and the methodology of reporting overuse injuries to injury surveillance indicates that there is both

interest in, and need for, the development of a consensus definition. This would greatly strengthen the use of injury surveillance systems for the study of overuse injuries.

8.5.3 Eliminate the time-loss requirement for a reportable injury

There is an ongoing debate over the time-loss requirement for a reportable injury.[10-12, 87, 128] There are those who recommend a time-loss only requirement, as it is the most consistent injury definition, and those who recommend neither time-loss nor the presence of objective findings be required in order to report an injury, as that definition is the broadest. [11, 87] Others recommend multiple definitions used at once, or a flexible definition that changes with the purpose of the study. [12, 20, 128] It may be that one definition for a reportable injury may not be feasible across multiple studies and systems. However, it is clear that there must be the option for a no time-loss definition in surveillance systems. This will greatly improve the systems' ability to comprehensively capture all overuse injuries. It may also result in a more accurate identification of the total burden of overuse injuries on both the athletes and health care professionals who treat them.

It should also be noted that eliminating the time-loss requirement for a reportable injury within injury surveillance will undoubtedly increase the burden of injury surveillance on the data collectors. This has been seen as the number of schools and ATs who have participated in the ISS/ISP has notably decreased in 2009/10 through 2013/14 academic years, from the 2004/5 through 2008/9 academic years, consistent with the move from a time-loss to non-time-loss definition. [75] The use of a non-time-loss definition may be more feasible for shorter term prospective studies, or injury surveillance that abstracts data from electronic medical records.

Although, the use of electronic medical records for injury surveillance has its own drawbacks, as medical records ultimately serve a different purpose than injury surveillance.

8.6 Public health implications

While the results of this study are primarily methodological, any methodological improvements in injury surveillance may also assist athletes by bringing greater recognition to these injuries in due course. Additionally, improved injury surveillance data on overuse injuries may identify specific populations at risk. While it is seen that female and college athletes have higher incidence of overuse injuries, these groups are quite broad. Future research may identify particular sport activities, seasons, or positions which are more prone to overuse injury and may result in more effective prevention interventions.

Providing a detailed definition for overuse injury within injury surveillance may also make injury surveillance less burdensome for the AT data collectors. Overuse injuries tend to be complicated and a clearer definition with provided examples may give ATs a clearer understanding of how a particular injury surveillance system defines overuse. These types of instructions may make it easier for the ATs by reducing the scope for interpretation, in addition to providing more consistent data for researchers.

There is growing concern about the impact of overuse injuries on young athletes. [8, 11] Improving injury surveillance will improve our ability to identify specific populations at higher risk, the appropriate manner to intervene, and the athlete age range (middle school vs. high school vs. college) and will bring the field of sports medicine closer to the possible objective of a comprehensive overuse injury prevention program.

8.7 Future research

There are many ways in which this research can and should be continued. In regard to ascertaining the burden of overuse injuries on both athletes and ATs, a chart review of athletic training room treatment logs and injury reports would be advantageous. Such a review could be performed at institutions which collect data for the ISP, so that comparisons between the AT perception of caseload to actual caseload can be made.

The Aim 3 survey can also be implemented among ATs who collect data for the RIO surveillance system. This would allow for comparisons across AT populations not only regarding their definitions of overuse, but the probability of reporting an injury scenario as overuse. Differences between AT populations regarding the probability of reporting an injury scenario as overuse can have implications of the findings in Aim 1. Systematic differences in how "overuse" is identified in younger athletes and reported to a different system may impact any future research regarding overuse, and conducted in high school settings.

As previously indicated, a consensus definition for overuse injury should be created and implemented in injury surveillance. Once such a definition is created, it should be field-tested and revised based on input from AT data collectors. Scenario-based methods similar to those used in Aim 3 may be helpful in the development and testing of a consensus definition for overuse.

Overuse injuries have been understudied relative to their burden on athletes and clinical staff. Part of this reluctance has been related to methodologic concerns about completeness of data capture. Future research into the factors associated with the incidence of these injuries will be important to the design of programs aimed at preventing overuse injuries. A detailed understanding of how these injuries are currently measured and defined is vital. This dissertation

is a step towards the understanding of how ATs consider and report overuse injuries. Based on these results, an implementable consensus definition for these injuries is important to developing a better understanding of the incidence and prevention of overuse injuries.

APPENDIX 2.1. DEFINITION AND USAGE OF THE TERM "OVERUSE INJURY" IN THE UNITED STATES HIGH SCHOOL AND COLLEGIATE SPORT EPIDEMIOLOGY LITERATURE: A SYSTEMATIC REVIEW

ABSTRACT:

Background: A number of epidemiologic and surveillance-based studies of sports injury provide statistics on, and sometimes discussion of, overuse injuries. However, there is no consensus on the definition of overuse. Some studies consider overuse as a mechanism of injury while others use a diagnosis-based definition.

Objective: To describe variation between studies in the definition and use of the term "overuse."

Methods: PubMed and SPORTDiscus databases were searched between May and November 2012 to find articles published or online ahead of printing pertaining to US high school or collegiate athletics, which were epidemiologic in nature. Inclusion criteria required that the article present data collected on athlete exposure and provided statistics pertaining to overuse injuries. PRISMA guidelines were adhered to, to the best ability of the authors.

Results: The initial search resulted in 5182 articles with potential for inclusion. After review of titles or abstracts where appropriate, 232 studies were read in entirety to determine if they were appropriate for inclusion. Of the 35 articles included, 13 used data from the National Collegiate Athletics Association's Injury Surveillance System, 12 used data from High School RIO (Reporting Injuries Online) injury surveillance system, and 1 used data from both of these systems. The remaining 9 articles used data from distinct surveillance systems or prospectively collected data. All of these articles included statistics of overuse injuries, although not all provided definitions for overuse. A major finding from the literature is that the term "overuse" has been used both as a mechanism of injury and as an injury diagnosis (or a category of diagnoses). Specifically, 14/35 articles used overuse as a mechanism of injury, 7/35 used it as a category of injury diagnoses, 8/35 used it as both a category of injury diagnoses and a mechanism of injury, and it was unclear in 1/35 how the term is used. Only one of the 35 articles provided a biomechanical definition for overuse injuries. 12/35 articles combined "overuse" with other terms such as chronic, gradual onset and repetitive stress. Use of the term "no contact" was investigated in relation to "overuse". Four of 35 articles define overuse in

This Appendix previously appeared as an article in Sports Medicine. The original citation is as follows: Roos KG, Marshall SW. Definition and usage of the term "overuse injury" in the US high school and collegiate sport epidemiology literature: a systematic review. Sports Med. 2014; 44(3): 405-21.

the context of no contact injuries. Only 1 of 35 articles define no contact as a specific acute mechanism of injury, while all other mentions of no contact do not specifically distinguish whether "no contact" limited to acute injuries only, or has potential to include overuse injuries.

Conclusion: There is a great deal of inconsistency in the use of the term "overuse" both within and between data sources. This is further complicated by the multiple uses of the term "no contact". We recommend that the term "overuse" only be used in regard to the mechanism of injury in order to enhance interpretation and understanding of the literature regarding overuse injuries and enhance the ability to compare results between studies.

1. INTRODUCTION:

Overuse injuries are traditionally defined as injuries which occur with gradual onset over time and result from a mechanism of repetitive stress and cumulative trauma. Such injuries typically do not have a specific onset incident, but instead progress with continued activity, particularly if there is insufficient time for recovery between episodes of physical activity.[14, 17, 23, 24, 129-132] These injuries may initially present as small, nagging pains which can be ignored at first and not addressed until significant pain or deficit in function is present. This lack of acute onset can delay diagnosis or treatment, as diagnosis may depend on when the patient seeks care.[7, 18, 104, 111, 116, 133-135]

These injuries are diagnosed at the level of the evaluator (Doctor of Medicine (MD), Physical Therapist (PT), Certified Athletic Trainer (AT) or other medical professional). There is a general understanding within the sports medicine community that an overuse injury has an insidious onset, progresses over time and results in pain and partial dysfunction. However, for many types of overuse injury, specific and sensitive diagnostic tests are lacking. [14, 30] Even in cases where valid and reliable tests do exist, they do not confirm the etiology or mechanism of the injury. [12, 23] Therefore, in a majority of cases the diagnosis and determination of overuse injury depends on the individual evaluator, who is influenced by their education and experience,

as well as local diagnostic practices and beliefs. This leads to minimal consistency in the diagnosis and reporting of overuse injuries.[12, 30, 136, 137]

To complicate matters, "overuse" can refer to a mechanism of injury, an injury diagnosis, and at times, both. When used as a mechanism of injury, "overuse" refers to the causation of the injury, the repetitive or cumulative activity which led to the injury.[35, 90, 91] When used as a diagnosis, "overuse" often refers to a family of injuries classified by slowly progressing inflammation, pain and loss of function.[14, 17, 92, 93] As a mechanism of injury "overuse" is the cause, as a diagnosis "overuse" is the effect.

1.1 "Overuse" in Clinical and Surveillance Settings

In the clinical setting, it is often not necessarily important to differentiate whether overuse is a mechanism of injury or an injury diagnosis. The individual treatment of these injuries does not depend on this distinction. Treatment of the injury should address the overuse component regardless of its label of mechanism of injury or injury diagnosis. However, in injury prevention and epidemiologic research, the distinction between overuse as a mechanism of injury or an injury diagnosis is important. A shoulder injury resulting from an overuse mechanism of injury may have a diagnosis of overuse. However, this injury might also have a diagnosis of muscle strain, tendinitis, inflammation, ligament strain, bursitis or shoulder pain.[29, 138] Each of these specific diagnoses may be due to an overuse mechanism; however this cannot be identified from diagnostic information alone. When overuse is used as a category of diagnoses, the mechanism of injury is implied, but not specified. If the mechanism of injury is not specified, it is up to the data analyst or the reader to make an informed opinion as to the origin of the injury. If overuse is only used as a diagnosis or category of diagnoses, then there can be some

misrepresentation, and injuries which occurred by acute mechanisms (such as cases of Trochanteric bursitis) are then classified as occurring from an overuse mechanism.[139-142] If overuse is only used as a mechanism of injury, not only is there less confusion, but more information can be communicated through the specific diagnosis.

1.2 "Overuse" and "No contact"

While the main interest of this review is the use and definition of the term "overuse", such an investigation would be incomplete without consideration of "no contact" injuries. "No contact" refers exclusively to a mechanism of injury, and it is sometimes used in combination with (or even interchangeably) with the term "overuse".[41, 66, 67, 70] However, while all overuse injuries (used as either mechanism of injury or injury diagnosis) can be classified as occurring from a no contact mechanism, not all no contact injuries can be classified as occurring from an overuse mechanism. No contact injuries can also occur from acute mechanisms.[17, 135, 142-145] Through this review, it will be seen that "overuse" is often used as a clarifier or descriptor for "no contact" when not all no contact injuries are also overuse injuries.[41, 66, 67, 145]

1.3 Objective

The purpose of this review was to investigate the use of the term "overuse" within the epidemiologic sports injury literature, as applied to US high school and collegiate athletic injuries. We sought to catalog and examine the various definitions of overuse. In particular, we sought to examine whether the term was used as a mechanism of injury or a category of injury diagnoses in the epidemiologic sports injury literature. Our overall hope is that an investigation

of overuse definitions that have been used in injury studies of US high school and collegiate athletes may lead to standardization of terminology in future research, resulting ultimately in a clearer understanding of the true burden of overuse injury in all sports populations.

2. METHODS:

The inclusion criteria for this review reflect the objectives of the study, and the intended population. For those reasons the articles had to: 1) be epidemiologic in nature, 2) involve either high school or collegiate athletes, 3) be of US origin and 4) published in English. (Table 1) An article was determined to be epidemiological in nature if data for athlete participation exposure was collected and rates of injury utilizing this exposure measure as a denominator data were present in the article. This criterion was established to create consistency in the statistics used in the reviewed articles. Exclusion criteria were also established prior to the literature search. These criteria eliminated any studies which were 1) biomechanical or anatomical, rather than epidemiologic, in nature 2) clinical in nature (either clinical evaluation or rehabilitation) or 3) assessed the effectiveness of an intervention. (Table 1)

Articles for this systematic review were primarily found through online database searches. Searches were conducted from May to November 2012 using PubMed and SPORTDiscus databases. The Boolean phrase (Athletics AND Injury) AND (Overuse OR Epidemiology) was searched from January 1st, 1996 to December 31st, 2012. All titles provided for published and online ahead of printing articles were read by one investigator (KR) for relevance to this systematic review. Titles which clearly did not meet inclusion criteria were eliminated. Abstracts for all remaining articles were read and evaluated according to the same criteria, and abstracts which did not fulfill the inclusion requirements were eliminated. All

articles remaining at this time were read by one investigator (KR). At this time an additional 16 studies, previously known to the investigator (KR), were read to assess appropriateness for inclusion into this review.

Each remaining study was read to determine if it included overuse statistics and rate statistics with an appropriate exposure denominator. If the appropriate denominator was present, the article was then searched for statistics and definitions of "overuse" injuries. If any statistic was found for "overuse", regardless of the presence of any definitions, that article was included in this systematic review.

Once an article was deemed appropriate for inclusion in this review, it was searched for all definitions, statistics and discussion of "overuse". If "no contact" was used as a descriptor, or in conjunction with "overuse", then the definition of "no contact" (if any) was extracted as well. All definitions and any applicable "overuse" statistics or discussion were extracted to determine not only the original authors' intended meaning of the terms, but how those definitions were applied to the statistical analysis of the paper.

There was no specific review protocol used, although this review aspired to comply with the PRISMA guidelines.[146, 147] We made every effort to be complete and comprehensive in our review, however, as with any systematic review, it is possible that articles were omitted or excluded, and this may present a source of bias in for this literature review.

3. RESULTS:

From these searches 4853 titles were found from the PubMed database and 329 were found from the SPORTDiscus database. Of these, 4800 titles were eliminated as the articles clearly did not fit the criteria for inclusion and 15 duplicates were deleted. Abstracts were found

and read for the 382 remaining titles and 166 were excluded for the same reasons as the eliminated titles. This left 216 studies which were read in entirety by one investigator (KR) to determine if they met the statistical requirement for being epidemiological in nature. Additionally, 16 studies previously known to the investigator were read and assessed for inclusion in this review. Of these 232 studies, 35 were found to fulfill the inclusion and exclusion criteria. (Figure 1)

Two injury surveillance programs were the data source for the majority of the included studies. There were 13 articles which used data from the National Collegiate Athletic Association's Injury Surveillance System (hereafter referred to as ISS), 12 which used data from the High School RIO (Reporting Injuries Online) surveillance system (hereafter referred to as RIO), and 1 article (Shankar et al, 2007) which used data from both surveillance systems. The remaining 9 articles use diverse data sources including surveillance and prospective study designs. Due to commonalities in the definition of overuse used in data collection within the ISS and RIO systems, all articles were placed into three groups according to data source. This was done to compare the definitions and usage of the term "overuse" both within and between data sources.

3.1 Group 1: Collegiate/High School studies using neither ISS nor RIO data

Nine articles used unique data sources for their analyses and are included in this group. The data sources included:

- data collected prospectively from one collegiate baseball team[148]
- data collected prospectively from 7 -8 collegiate hockey teams[149, 150]
- data collected prospectively from 14 high school wrestling teams[151]

- surveillance data from 23 high schools lacrosse teams [152]
- surveillance data collected from 87 high school football teams [153]
- surveillance data collected from high school athletes (an analysis focused on subsequent injuries)[25]
- data collected prospectively from 140 high school pole vaulters[154]
- collegiate surveillance data collected from the Big 10 injury surveillance system[7]

Table 2 presents the definitions and usage of overuse in these articles. Overuse is used as a mechanism of injury in 3 of the articles,[150, 151, 153] and "cause of injury" in another ("cause of injury" appears to be synonymous with mechanism of injury).[149] Overuse is a category of injury diagnoses in 2 articles,[25, 154] and is used as both a mechanism of injury and a category of injuries in 2 articles.[7, 152] The use of the term overuse is unclear in 1 article.[148]

Yang et al (2012) is the only paper located by our review in which the primary focus of the study was overuse injury. Yang et al (2012) defines overuse injuries as "a gradual-onset injury caused by repeated microtrauma without a single identifiable event responsible for the injury". This is the only definition of overuse presented within this group of articles, and the clearest definition provided among all articles reviewed. Among the remaining papers, overuse is variously labeled as "chronic / overuse" (2 articles),[148, 152] as "overuse / repetitive activity" (1 article),[151] and as "overexertion" (1 article).[153] The "overexertion" mechanism of injury included both overuse diagnoses and heat-related conditions (18 of 147 overexertion diagnoses are heat-related).[153] Overuse was completely undefined in three of these articles.[25, 149, 150] Hinton et al (2005) includes no contact injuries as a subset of "indirect force" which implies that these injuries are acute injuries. Of these articles in this group, Hinton et al (2005) is the only one

who delineates that no contact is an acute injury. Rebella et al (2008) defined "overuse –type" injuries as a category of diagnoses, and also provided a "general stress" as a mechanism of injury characterized as an injury, where there was no specific onset or event, which appears to be equivalent to an overuse mechanism of injury.

3.2 Group 2: Collegiate studies using ISS data

From 1988 to 2004, ISS data were collected on paper forms which did not specify overuse as an option for mechanism of injury or injury diagnosis (the so-called "paper data"). In the 2003 school year, the ISS migrated some sports to a web-based system and, in 2004, the ISS moved completely to an online data collection platform ("web-based system one"), where overuse was provided as both a mechanism of injury and an injury diagnosis. The online platform for the ISS was migrated to an external vendor (the Datalys Center, "web-based system two") in 2010, and at that time, overuse was provided as an option for mechanism of injury only.

There were 14 reviewed articles which used data from the ISS. Twelve of these articles were published in a special issue of the Journal of Athletic Training (JAT) in 2007; these articles all used data collected from 1988 to 2003 or 2004 ("paper data"). An article describing the general methods used by the ISS was included in this issue and provided a general description of the statistics and definitions intended to be used by all data collectors and research investigators.[80] Despite the publication of this "methods" article, the overall definition and use of "overuse" and "no contact" remained variable between the articles which use the ISS data.

Table 3 presents the definitions, usage and statistics regarding "overuse" in the articles using the ISS data. Overuse is categorized as a mechanism of injury twice, and as a category of injuries in 3 articles.[38, 58-60, 64] Four articles use overuse as both a mechanism of injury and

a category of injuries.[54, 61, 63, 65, 67] In Shankar et al (2007), overuse and no contact are not defined independently, but rather are interconnected as “noncontact, overuse injuries” and “no contact (overuse)”. These terms are used as mechanisms of injury, separate from statistics regarding overuse diagnoses. In the remaining 5 articles, only specific overuse diagnoses are presented (overuse as a category of injuries).[55-57, 62, 65]

Of the 12 articles in the 2007 issue of the Journal of Athletic Training, 7 provide statistics for injuries which are commonly diagnosed as overuse,[55-58, 62, 63, 65] but without a definition or discussion of overuse, and 2 discuss overuse without providing a definition.[61, 64] Two articles label overuse as “chronic / overuse”.[60, 65] Dick et al (2007) discuss overuse primarily in regard to the lower extremity and define overuse of the lower extremity as “any inflammation, stress fracture or tendinitis of the knee, patella, lower leg, ankle, heel or foot”.[59] This article provides the only definition of overuse from the 2007 ISS articles. Dragoo et al (2012) does not provide a definition for overuse, but labels it as “overuse / gradual”.

All of the articles which use data from the ISS used “no contact” as a mechanism of injury, although there are multiple definitions of this term. The articles on baseball and softball from 2007 JAT do not define no contact, but describe it as “no-contact mechanisms, such as throwing or pulling a muscle while running”, and also provide separate categories of no contact, “no apparent contact (non-throwing)”, “throwing (pitching)” and “throwing (non-pitching)”.[63, 65] The throwing mechanisms are likely mainly overuse injuries, and the non-throwing mechanism is likely mainly acute injuries, but likely includes overuse mechanisms of injury as well (although this is not specified). Dragoo et al (2012) is very specific and defines no contact as “acute noncontact”.

3.3 Group 3: High School Studies using RIO data

The 13 articles included in this literature review which use data from the RIO data source were all published independently of each other. Five articles were analyses of injuries to different specific body parts,[31, 65, 66, 69, 70, 155] 2 articles focused on broad categories of injuries,[156, 157] and 4 were analyses of all injuries within specific sports.[41, 67, 68, 158] Additionally, 1 article focused on injuries to 1 body part within 2 sports,[159] and 1 article which investigated injuries by BMI (body mass index).[160]

Table 4 presents how overuse is used and defined in the articles using the RIO data. Eight of these articles use overuse as a mechanism of injury.[31, 41, 68-70, 156, 158, 160] Nelson et al (2007) included overuse diagnoses which implied overuse as diagnoses. Swenson et al (2009) also implied overuse as diagnoses in an investigation of recurrent injuries; where overuse injuries were included as individual overuse diagnoses only, separate from the recurrent injuries. Three articles used overuse as both a mechanism of injury and injury diagnosis.[41, 66, 67] The definitions "noncontact, overuse injuries" and "no contact (overuse)" which Shankar et al, applied to collegiate football injuries are also applied to high school football injuries, resulting in the same lack of distinction between overuse and no contact.

None of the articles which used RIO data provided clear or distinct definitions of overuse. Four articles label overuse as "overuse / chronic",[68, 69, 159, 160] and 1 article labels overuse as "overuse, conditioning and so forth."[158] Four articles do not provide a specific definition of overuse, but use it as a descriptor of a no contact mechanism of injury,[41, 66, 67, 70] and 4 discuss overuse, but without any specific definition, or description.[31, 155-157]

All articles which used the RIO data used "no contact" as a mechanism of injury. Five did not provide a definition of no contact,[68, 69, 156, 157, 159] and 3 define no contact acutely

(rotation about a planted foot or hand).[155, 158, 160] Two articles provide a combined category of "no contact / overuse" for a mechanism of injury, without a specific definition or disambiguation for the term.[67, 70] Two separate articles defined no contact as "no contact (pulled muscle or overuse)", implying that overuse is a subset or descriptor of no contact.[41, 66] One article did not provide a definition for no contact, but described it as "improper shoulder rotation".[31]

4. DISCUSSION:

From the above results, it is clear that there is no consensus regarding the definition or use of the term overuse, irrespective of the source of the data or the authors. In fact, of all 35 included articles, only Yang et al (2012) provides a comprehensive, biomechanical definition of overuse: "a gradual-onset injury caused by repeated microtrauma without a single identifiable event responsible for that injury." This article is also the only one where overuse injuries are the main outcome of interest. Among the remainder, Dick et al (mbk) is notable for providing an informative definition of lower extremity overuse injury: "any inflammation, stress fracture or tendinitis of the knee, patella, lower leg, ankle, heel or foot". However, this is a list of injury diagnoses, rather than a causational definition. This lack of consensus, or more specifically, lack of definitions, is particularly apparent within the studies which use the RIO and ISS data. Among the 13 articles which use the RIO data, overuse is labeled in 4 different ways, overuse, overuse / chronic, overuse, conditioning and so forth and overuse / no contact. Among the 14 articles which use the ISS data, overuse is also labeled as either overuse, overuse / chronic, and overuse / gradual and overuse / no contact, without any consistency.

In total, 14/35 articles used overuse as a mechanism of injury,[31, 38, 41, 58, 68-70, 149-151, 153, 156, 158, 160] 7/35 used overuse as a category of diagnoses,[25, 59, 60, 64, 154, 155, 157] 8/35 used it as both a mechanism of injury and a category of diagnoses,[7, 61, 63, 65-67, 152, 159] and 1/35 were unclear of the usage of overuse.[148] In 12/35 articles overuse is combined with other terms such as chronic, gradual onset and repetitive stress.[7, 38, 60, 65, 68, 69, 148, 151, 152, 158-160]

When overuse is also used in conjunction with no contact (4 of 35 articles), it adds another layer of confusion. It is unlikely that all no contact injuries in these studies are due to overuse mechanisms, however, by definition, all overuse injuries are no contact in nature.[41, 66, 67, 70] In only one of these articles is no contact clearly defined as an acute mechanism of injury.[38] No contact is implied as acute mechanism in additional four articles.[152, 155, 158, 160] In 3 articles, no contact is subdivided into multiple categories with potentially both acute and overuse attributes.[58, 63, 65]

The conflicting nature of no contact appears to derive in large part from the methods of data collection used by the ISS. In the 2007 special issue of JAT, Dick et al presented an introduction and methods article which described the methods of data collection and analysis, as well as the functional definitions used in the JAT publications, but did not include any definition or discussion of overuse.[80] However, there were multiple categories of no contact injuries, many of which had the potential to include overuse injuries.[80] Notably, the RIO system was modeled after the ISS which perpetuated similar methods.

An important finding of this literature review is that the term overuse is used as both a mechanism of injury and a class of injury diagnoses. In injury epidemiology there is no ambiguity when overuse is used as a mechanism of injury. However, when overuse is used as a

category of diagnoses, there is the potential for misclassification, since such diagnoses could arise by either acute or overuse means. To illustrate this concept, consider some examples of common overuse diagnoses: rotator cuff tendonitis and labral tears such as a superior labral tear from anterior to posterior (SLAP tear) are classically caused by an overuse mechanism (repetitive throwing), but can also be caused by an acute mechanism (falling onto an outstretched arm).[15, 17, 116, 135, 139-143, 161-164] Injuries which classically occur from acute mechanisms can also occur from overuse mechanisms. Plantar fasciitis can be caused by overuse mechanisms (running), and acute mechanisms (stepping on a solid object with a bare foot).[35, 144, 164-166] Trochanteric bursitis may be caused by either an acute mechanism, (falling and landing on the hip), or an overuse mechanism (Iliotibial band tightness from repetitive running).[140, 142, 162, 163, 167] To avoid ambiguity, we recommend that the term "overuse" only be used in regard to the mechanism of injury in epidemiologic and surveillance-based sports injury studies. This will avoid the confusion that currently makes it difficult, not only to correctly interpret the data, but also to create, implement and evaluate appropriate prevention strategies.[12, 29, 30, 136, 137]

The "overuse" injuries captured by injury surveillance system are typically considered to represent only a small fraction of injuries which result from an overuse mechanism of injury. This is because most athletic injury surveillance focuses on time loss injuries, defined as injuries which result in restriction in participation for one or more days subsequent to the injury day.[12, 29, 30, 87, 92] Overuse injuries, which by nature are progressive over time, may result in significant limitation and alteration of activity without resulting in actual time loss. Twenty nine of 30 surveillance studies defined a reportable injury as an injury which resulted in one or more days lost from sport.[7, 25, 31, 38, 41, 55-70, 153, 155-160] Although overuse injuries often

receive continuous treatment from athletic medical staff and may result in altered participation, they often do not result in absence from participation.

As there are many working definitions and uses of the term “overuse”, the role of the data collector is highly important in regard to the capture of overuse injuries within injury surveillance.[137] In the current surveillance systems (ISS, RIO) the data collector may report an injury as overuse at the level of mechanism of injury which will assist with data analysis in the future. This literature review highlighted the regrettable ambiguity associated with the use of multiple definitions of the term “overuse” in sports injury epidemiology. When reading the current epidemiologic literature, one must keep in mind not only the definition of overuse which the authors provide, but also the definitions of overuse which individual data collectors may have used. As there is no consensus definition of overuse in the current literature, interpretation must be informed by the specifics of the article.[7, 29] We therefore highly recommend that a standardized working definition of overuse should be agreed upon and implemented by all data collectors.

However, recommendations can be made to influence future data collection for overuse injuries. As indicated above, our first recommendation is to only assign overuse at the level of mechanism of injury, in all surveillance and prospective cohort studies. Overuse should NOT be provided as a diagnostic category. This will simplify the interpretation of future studies; however it will not mitigate the effect of limiting surveillance to time loss injuries.[87]

4.1 Patient-Orientated Method

While the focus of this literature review is on the need for consensus on the definition and usage of “overuse” in the epidemiologic literature, there is also a need for this consensus among

the general literature.[29] It is not uncommon for articles about overuse injuries to lack a definition of overuse, even when the article is specific to "overuse injuries".[32, 50, 168] In cases where definitions do exist, there may not be a distinction of whether it is used as a mechanism of injury or a category of diagnoses.[18] These articles also use "overuse" in combination with other related terms such as gradual onset, recurrent injuries, chronic injuries etc.[90, 136] Creating guidelines for the use of overuse among the epidemiologic literature can have beneficial effects on the literature in general.[29, 137]

Alternative models of injury surveillance, specific to overuse injuries, have been proposed and are now being used. These models use questionnaires and rely on the athletes to self-report levels of difficulty with participation, reduced training volume, affected performance and pain due to sport participation. The concept underlying such methodology is to capture overuse injuries as a limitation in function, regardless of time loss from sport. The outcome is prevalence of substantive overuse and average injury severity score.[20] Studies also propose different models of injury definition, and separate overuse injuries into three different categories: 1) events which result in any physical complaint, 2) events which require any medical attention, 3) events which result in any time loss.[12, 16, 20] Overuse is also categorized separate to acute injuries. These terms are mutually exclusive, but only report that there is a specific injury incident. While this implies mechanism of injury it does not provide any biomechanical or physiological aspect to the definitions.[16, 20]

Although there is a subjective element to athlete-reported outcomes, such measures capture the true burden of overuse injuries in a more thorough manner than the current surveillance systems. These systems are not limited to information on time loss injuries, and are not subject to systemic bias in injury definitions from data reporter or analysts. However, it is

difficult to compare these new systems to the traditional surveillance as they use different injury definitions and paradigms. Recommendations from these studies for future development of studies to capture overuse injuries are 1) studies should be prospective, 2) studies should use valid and sensitive self-report instruments to be used by the athletes, 3) studies should measure prevalence not incidence, 4) measurements should be based on function, not time loss from sport.[85] While this literature review did not include any studies using the new method for data collection, this method may be revolutionary for capturing injuries which are not associated with time loss.

4.2 Limitations:

There were several limitations in conducting this literature review. The first is that the review was limited to US studies. There was a cohesive group of US studies from the ISS and RIO databases which provided a large number of studies to include. We included other US studies in order to broaden the data sources; however we limited the review to US studies in the interest of brevity. Inclusion in this also review required that an article present statistics on overuse and collected data on athlete exposure. The search also did not include studies which provided cross sectional or self-reported data on overuse injuries. While the search procedure was thorough, and rigorously followed, it cannot account for articles which are not indexed in the PubMed and SPORTDiscus databases.

5. CONCLUSION:

This literature review is only the first step in delineating the use and definition of overuse in regard to collegiate and high school athletic injuries. It is the opinion of the authors that

confusion and misclassification of diagnoses would be decreased by universally using overuse as mechanism of injury only. This will limit the misclassification between overuse injuries and acute mechanisms of injury. Furthermore to facilitate accurate and thorough investigations of overuse injuries among high school and collegiate athlete, a working definition of overuse should be agreed upon and implemented at the level of the surveillance data collector. This will not only improve the quality of surveillance and research data, but hopefully will stimulate development of appropriate prevention interventions and strategies which can be focused on overuse injuries. Finally, there is a need for prospective studies addressing athlete-based methods for overuse data collection and comparing the results to the overuse injuries detected by surveillance systems.

For these reasons, we recommend that the term "overuse" only be used in regard to the mechanism of injury in epidemiologic and surveillance-based sports injury studies. This will enhance interpretation and understanding of the literature regarding overuse injuries and will also enhance the ability to compare results between studies.

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Tables and Figures:

Figure A.1. PRISMA diagram of articles for inclusion

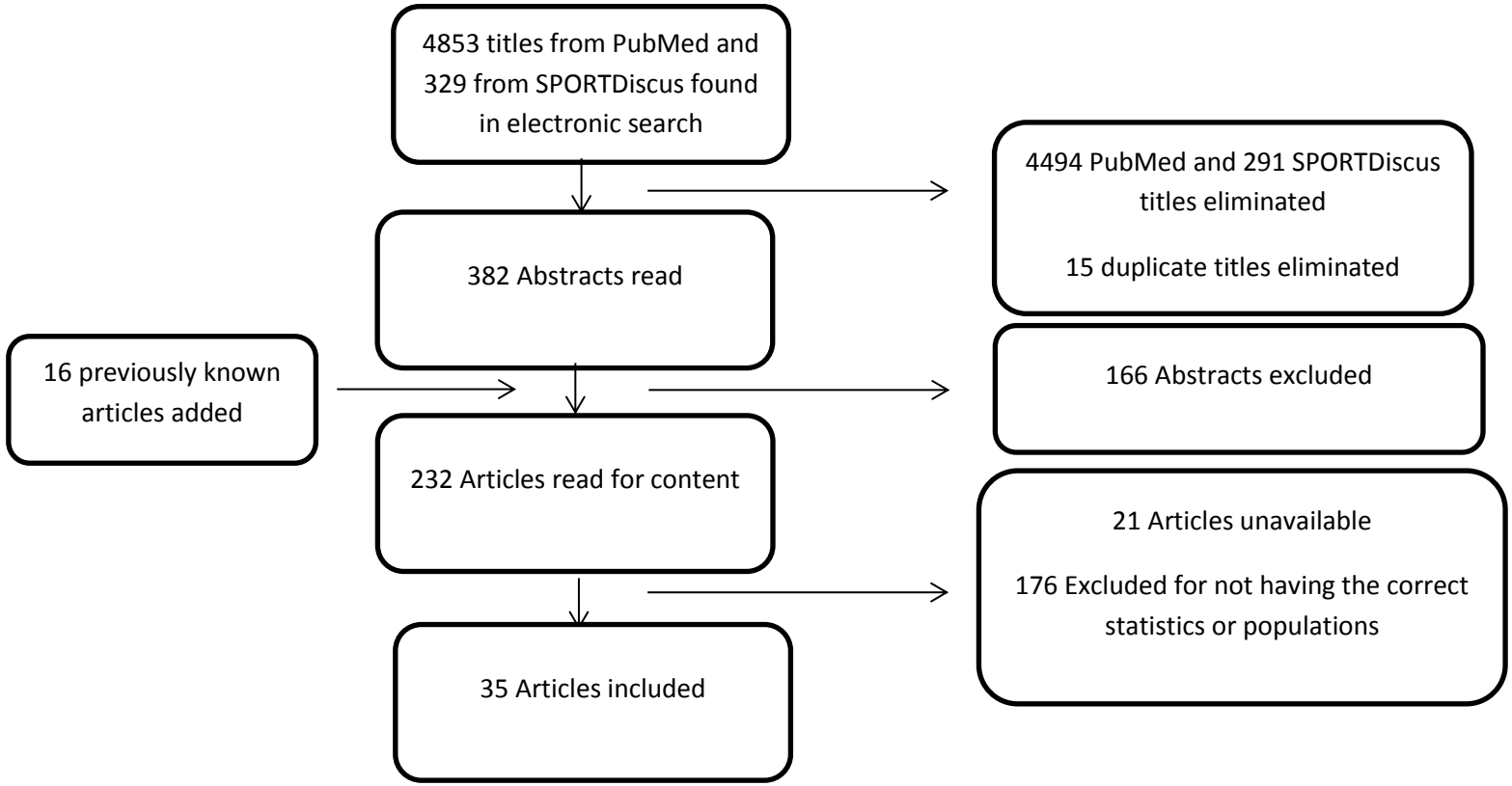


Table A.1. Inclusion and exclusion criteria

Inclusion Criteria	**Exclusion Criteria**
Article is epidemiologic in nature. It has data collected on athlete exposure for the purpose of rates	Research question and related statistics were biomechanical or anatomical in nature
Analysis of High school or Collegiate Athletes. Other populations could be included in the article, as long as the high school or collegiate populations had separate statistics	Article is clinical in nature, (for example, investigations of specific diagnoses, case studies, clinical evaluations or rehabilitation techniques)
United States based population	Article assessed the effectiveness of an intervention
Article is in English	Article based on extreme sport, or a sport uncommon to most high school or collegiate athletic programs, such as snowboarding, and rodeo

Table A.2. U.S. studies reporting results on overuse injuries, using data sources other than NCAA ISS and High School RIO

Study	Population & Study design	Period and Location of Data Collection	Exposure Definition	Outcome Definition	Definition provided for overuse injuries	Overuse as a mechanism or diagnosis (results section)	Comments
McFarland et al, 1998 [148]	Collegiate baseball injuries; prospective cohort study with 54 diagnoses of rotator cuff tendonitis and 1 diagnosis of acromioclavicular joint arthritis from 329 total injury events	Data collected from 1 team at one college from 1991-1993	One athlete participating in one practice or competition	Complaint is defined as any evaluation or treatment by medical staff; injury is defined as any complaint that resulted in an injury diagnosis AND any altered participation or time loss event	No formal definition provided for overuse; overuse injuries are referred to as "chronic-overuse injuries"	Unclear	Limited information provided on overuse injuries, but overuse was not the main focus of this article
Ferrera et al, 1999 [150]	Collegiate ice hockey injuries; prospective cohort study with 45 injuries from an overuse mechanism of injury of 280 total injuries	Data collected from 7 colleges in 2 conferences in 3 consecutive hockey seasons (years not specified)	Participation in one hockey event	Injury defined as any event that resulted in 1) loss of participation time, 2) required sutures OR 3) any fracture or dislocation	No definition provided for overuse	Mechanism of injury	Limited information provided on overuse injuries, but overuse was not the main focus of this article

Pasque et al, 2000 [151]	High school wrestling injuries; prospective cohort study with 13 of 219 injuries with an overuse mechanism of injury	Data collected from 14 high schools in 1 region, in 1 wrestling season, (year not specified)	One athlete participating in one practice or competition	Injury defined as any "significant condition limiting function that caused an athlete to seek care" AND resulted in time loss of one or more days	No formal definition provided for overuse; overuse injuries are referred to as "overuse or repetitive activity" within the article	Mechanism of injury	Limited information provided on overuse injuries; good example of how to present data on overuse injuries, even when they are not the main focus of the article
Flik et al, 2005 [149]	Collegiate men's ice hockey injuries; prospective cohort study with 8% of 113 total injuries due to an overuse "cause of injury"	Data collected from 8 colleges in one division in the 2001-2002 hockey season	One athlete participating in one practice or competition	Injury defined as any event that resulted in missing the immediately subsequent event	No definition provided for overuse	Mechanism of injury (overuse is presented as a "cause of injury")	Limited overuse injury information, but overuse was not the main focus of this article; information on overuse injury is clearly presented and easy to find
Hinton et al, 2005 [152]	High school lacrosse injuries; surveillance data with 104 overuse injury diagnoses from 986 total injuries	Data collected from 23 high schools in Fairfax County Virginia from 1999-2001	One athlete participating in one practice or competition	Injury defined as any incident which required any medical attention from the Athletic Trainer AND resulted in modified participation for one or more days	No formal definition provided for overuse; overuse injuries referred to as "chronic / overuse" in places	Both; overuse as is presented as both a mechanism of injury ("primary mechanism"), and a diagnosis ("nature of injury")	Extensive information about overuse injuries

Ramirez et al, 2007 [153]	High school football injuries in California; surveillance data with 147 injuries with an overexertion mechanism of injury (of which only 18 are diagnoses of heat exhaustion) from 2008 total injuries	Data collected from 87 high schools in California (with specific sampling of Los Angeles and San Diego counties) from the 2001 and 2002 football seasons	Athlete exposure not specifically defined; exposure data collected by player, player hour and session hour	Injury defined as any physical trauma which resulted in a player leaving the session or missing next session, OR any concussion, fracture, or dislocation	No definition provided for overexertion	Overexertion as a mechanism of injury	Overuse injuries not specifically mentioned, however 129 of 147 overexertion injuries are from causes other than heat exhaustion indicating that some of these injuries are likely the result of overuse
Rauh et al, 2007 [25]	Re-injuries in high school girls; surveillance data with 5640 total injuries; no overall overuse statistic provided	Surveillance data from 235 schools to represent 10 geographic regions from 1995 to 1997	Exposure not specifically defined; rates were determined using player-seasons	Injury defined as any event that removed athlete from current or future participation, OR any fracture, concussion or dental injury	No definition provided for overuse	Overuse used as a specific diagnosis	Limited information about overuse, but overuse is not the focus of this article; overuse data is included through specific diagnoses (stress fracture and musculoskeletal conditions), as a clearly separate phenomenon than subsequent injuries

Rebella et al, 2008 [154]	High school pole vaulters in Wisconsin; prospective cohort study with 3 overuse diagnoses from 38 total injuries	Data collected from 140 high school pole vaulters from 1 region in Wisconsin in the 2005 and 2006 track and field seasons	One athlete participating in one practice or competition	Injury defined as any incident that limited participation in any current or subsequent event OR any head or neck injury OR any injury which received medical attention	Overuse defined as "overuse-type injuries, including shin splints and rotator cuff tear"; general stress defined as injuries where the athlete "was not able to specifically determine an exact timing or mechanism of the injury event"	Overuse used as a diagnosis ("type of injury"); general stress used as a mechanism of injury	Presents data on "general stress" that appears to be consistent with an overuse mechanism of injury; 6 of 38 (15.8%) injuries occur from a mechanism of general stress, and the overuse data regarding specific diagnoses is detailed, given that this article is not focused on overuse
Yang et al, 2012 [7]	Overuse injuries in collegiate athletes; surveillance data with 386 overuse diagnoses of 1317 total injuries	Data collected from all intercollegiate teams in 1 college from 2005-2008	One athlete participating in one practice or competition	Injury defined as any event that 1) had clinical signs of tissue damage as determined by an Athletic Trainer or Doctor of Medicine AND 2) resulted in the inability to return to participation on same day	Overuse defined as "a gradual-onset injury caused by repeated microtrauma without a single identifiable event responsible for the injury"; overuse injuries are also called "chronic injuries"	Both; overuse used as a class of diagnoses including weakness, deformity, inflammation, tendonitis, stress fracture etc.; overuse used as an indirect mechanism of injury when compared against acute injuries	Overuse injuries are the main focus of this article; presents rates and rate ratios of overuse injury in strata of covariates and injury outcomes

Table A.3. U.S. studies reporting results on overuse injuries using data from the NCAA ISS

Study	Population / Impact of Overuse	Definition provided for overuse	Overuse as a mechanism or diagnosis (results section)	Comments
Articles from the 2007 Journal of Athletic Training				
Dick et al, 2007 [169]	NCAA women's lacrosse; overuse diagnoses account for 10% of practice injuries	No definition provided for overuse	Overuse used as specific diagnoses	Limited information about overuse, but overuse is not the main focus of this article; presents incidence of typical overuse diagnoses (tendonitis, stress fracture and inflammation)
Dick et al, 2007 [62]	NCAA men's lacrosse; overuse diagnoses account for 1.1% of practice injuries	No definition provided for overuse	Overuse used as a specific diagnosis	Limited information about overuse, but overuse is not the main focus of this article; presents incidence for tendonitis only
Dick et al, 2007 [61]	NCAA women's soccer; overuse diagnoses account for 5.4% of practice injuries	No definition provided for overuse	Overuse appears to be used as both mechanism and category of injury in the discussions	Limited information about overuse, but overuse is not the main focus of this article; presents incidence of typical overuse diagnoses (tendonitis, stress fracture and inflammation)
Agel et al, 2007 [55]	NCAA men's soccer; overuse diagnoses account for 1.1% of practice injuries	No definition provided for overuse	Overuse used as a specific diagnosis	Very limited information about overuse, but overuse is not the main focus of this article; presents incidence of tendonitis only
Agel et al, 2007 [57]	NCAA women's volleyball; overuse diagnoses account for 8.9% of practice injuries and 2.3% of game injuries	No definition provided for overuse	Overuse used as specific diagnoses	Limited information about overuse, but overuse is not the main focus of this article; presents incidence of typical overuse diagnoses (tendonitis and stress fracture)

Dick et al, 2007 [58]	NCAA men's football; 54 of 4818 knee injuries to the ACL, PCL, and meniscus occurred from an overuse mechanism of injury	No definition provided for overuse	Overuse presented as a mechanism of injury separate from no contact mechanisms of injury	Specific statistics regarding knee injuries which result from an overuse mechanism of injury, although such injuries represent a small proportion of collegiate football knee injuries overall
Agel et al, 2007 [56]	NCAA women's basketball; overuse diagnoses account for 4.3% of practice injuries and 1.2% of game injuries	No definition provided for overuse	Overuse used as specific diagnoses	Limited information about overuse, but overuse is not the main focus of this article; presents incidence for typical overuse diagnoses (tendonitis and stress fracture)
Marshall et al, 2007 [64]	NCAA women's gymnastics; overuse diagnoses account for 3.7% of practice injuries	No definition provided for overuse	Overuse used as specific diagnoses	Presents incidence for typical overuse diagnoses (tendonitis and stress fracture); discussion states the ISS does not capture non-timeloss injuries such as chronic low back pain
Dick et al, 2007 [59]	NCAA men's basketball; overuse diagnoses account for 1.2% of practice injuries and 531 lower extremity injuries in 1988-2004	No definition provided for general overuse; overuse injuries to the lower extremities defined as "any inflammation, stress fracture, or tendinitis of the knee, patella, lower leg, ankle, heel or foot"	Overuse used as specific diagnoses and a category of lower extremity diagnoses	Presents incidence for typical overuse diagnoses (tendonitis and stress fracture) and lower extremity overuse injury; discussion of how the incidence of overuse injuries has changed as the nature of basketball participation changed over time
Dick et al, 2007 [60]	NCAA women's field hockey; overuse diagnoses account for 9.4% of practice injuries	No formal definition of overuse ; overuse injuries referred to as both "chronic/overuse injuries" and "chronic overuse injuries"	Overuse used as specific diagnoses	Presents incidence for typical overuse diagnoses (stress fracture, tendinitis and inflammation) and states these diagnoses account for nearly 10% of practice injuries; discussion states NCAA ISS may not be sensitive enough to capture overuse injuries such as low back syndrome and medial tibial stress syndrome

Dick et al, 2007 [63]	NCAA men's baseball; overuse diagnoses account for 10.9% of practice injuries and 2.7% of game injuries	No definition provided for overuse or no contact; no contact is referred to as "no-contact mechanisms, such as throwing or pulling a muscle while running"	Overuse appears to be used as both mechanism and category of injury in the discussions	Presents incidence for typical overuse diagnoses (tendinitis and inflammation); also includes statistics on non-contact throwing injuries, which are likely overuse; discussion of the role of training in overuse injuries which states: "Two thirds of preseason injuries were noncontact in mechanism, suggesting acute strains or overuse injuries"; however there are no statistics or discussion of how many of those no contact injuries were overuse injuries vs. acute strains
Marshall et al, 2007 [65]	NCAA women's softball; overuse diagnoses account for 6.0% of practice injuries and 1.5% of game injuries	No formal definition of overuse; overuse injuries referred to as "chronic / overuse" in the discussion	Overuse appears to be used as both mechanism and category of injury in the discussions	Presents incidence for typical overuse diagnoses (tendinitis); discussion of overuse statistics from other studies (shoulder strains and tendonitis were discussed as "chronic / overuse" injuries); includes statistics on non-contact throwing injuries, which are likely overuse, the authors conclude that overuse is a main contributor to injury in softball.
Other ISS papers				
Shankar et al, 2007 [70]	NCAA men's football; injuries occurring from a "no contact, overuse" mechanism of injury account for 34.9% (743 of 2129) of practice injuries and 16.3% (217 of 1330) of game injuries (national estimates)	No formal definition provided for overuse; overuse is referred to as "…noncontact, overuse injuries", and "no contact (overuse)"; it is unclear if these are considered interchangeable, or if overuse is used as a descriptor of no contact	Both; overuse both as specific diagnoses and descriptor of the "no contact" mechanism of injury	Detailed statistics provided for overuse injuries, including counts, percentages and injury proportion ratios for game and practice injuries and high school and NCAA injuries, even though it is not the main focus of the article; discussion of increased overuse injuries in collegiate football as compared to high school football

Dragoo et al, 2012 [38]	ACL injuries in NCAA men's football; overuse is the mechanism of injury for .4% of 318 ACL injuries	No formal definition provided for overuse; overuse is referred to as "overuse / gradual"	Overuse/ gradual and acute noncontact as separate mechanisms of injury	One statistic presented for ACL injuries occurring from an overuse mechanism

NCAA = National Collegiate Athletics Association; ACL = Anterior Cruciate Ligament; PCL = Posterior Cruciate Ligament; ISS = Injury Surveillance System

Table A.4. U.S. studies reporting data on overuse injuries using data from the High School RIO

Study	Population / Impact of Overuse	Definition provided for overuse	Overuse as a mechanism or diagnosis (results section)	Comments
Fernandez et al, 2007 [66]	High school lower extremity injuries; no contact (overuse) mechanism of injury accounts for 24.7% high school lower extremity injuries	No contact defined as "no contact (eg, pulled muscle or overuse)"	Both; overuse both as specific diagnoses and descriptor of the “no contact” mechanism of injury	Numerous useful statistics for overuse lower extremity diagnoses (tendinitis and stress fracture)
Nelson et al, 2007 [155]	High school ankle injuries; <5% of high school ankle injuries have an “other” diagnoses which included tendinitis, stress fracture and muscle strain	No definition provided for overuse	Overuse used as a specific diagnoses	Minimal statistics provided for overuse injuries but this was not the main focus of the paper; specific overuse diagnoses are presented for ankle diagnoses under the "other" category (includes tendinitis, stress fracture and muscle strain)
Shankar et al, 2007 [70]	High school men's football; injuries occurring from a "no contact, overuse" mechanism account for 17.6% of practice injuries and 4.9% of game injuries (national estimates)	No formal definition provided for overuse; overuse is referred to as "…noncontact, overuse injuries", and "no contact (overuse)"; it is unclear if these are considered interchangeable, or if overuse is used as a descriptor of no contact	Both; overuse both as specific diagnoses and descriptor of the “no contact” mechanism of injury	Substantial statistics provided for overuse injuries, including counts, percentages and injury proportion ratios for game and practice injuries and high school and NCAA injuries, even though overuse it is not the focus of the article; discussion of increased overuse injuries in collegiate football as compared to high school football

Borowski et al, 2008 [158]	High school basketball injuries; overuse / conditioning injuries account for 29.5% of muscle - tendon strains in basketball	No formal definition provided for overuse; overuse referred to as "overuse, conditioning and so forth"	Overuse used as a mechanism of injury	Minimal statistics on overuse and overuse is always combined with either conditioning or acute injuries; however, overuse was not the focus of this article; discussion of muscle tendon strains includes "complete and incomplete muscle tears, tendon strain tendinitis and torn cartilage", combining acute and overuse injuries included in same category
Collins et al, 2008 [41]	High school baseball injuries; a no contact mechanism of injury including pulled muscles and overuse accounts for 30.4% of high school baseball injuries	No formal definition provided for overuse; overuse defined in relation to no contact as "no contact (eg, pulled muscle or overuse)" and "no-contact (eg, overuse or chronic use)"	Mechanism of injury; overuse used as a qualifier of the “no contact” mechanism of injury	Numerous statistics, including the percentage of "no contact (overuse or chronic use)" injuries to baseball players at certain positions, ranging from 12.6% – 60.3%; a large amount of useful statistics given that overuse is not the main focus of this study, however minimal discussion of overuse
Ingram et al, 2008 [67]	High school knee injuries; a no contact / overuse mechanism of injury accounts for 25.4% of high school knee injuries	No formal definition provided for overuse; overuse is defined in relation to no contact as "no contact / overuse"	"No contact / overuse" as a mechanism of injury	Presents statistics for "no contact / overuse" as a mechanism of injury and separate statistics for the individual overuse diagnoses (tendinitis and inflammation); overuse diagnoses are also included in the “other” category of injury diagnoses, which includes overuse and non-overuse injuries

Yard et al, 2008 [68]	High school soccer injuries ; an overuse / chronic mechanism of injury accounts for 9.9% of practice injuries (17,526 of 176,809), and 1.2% of competition injuries (2622 of 211,983) in boys and 10.5% of practice injuries (15,149 of 144,505) and 3.7% of competition injuries (9979 of 270,996) in girls	No formal definition provided for overuse; overuse referred to as "overuse / chronic"	Overuse as a mechanism of injury separate from the “no contact” mechanism of injury	Detailed and useful statistics for "overuse / chronic" injuries are presented with separate categories of mechanism of injury for "overuse / chronic" and "no contact", even though overuse is not the main focus of this article; the overuse results are presented clearly and in useful format
Bonza et al, 2009 [31]	High school shoulder injuries; an overuse / chronic mechanism of injury accounts for 4.6% of high school shoulder injuries	No formal definition provided for overuse	Overuse / chronic as a mechanism of injury separate from the “no contact” mechanism of injury	Detailed and useful statistics for "overuse / chronic" injuries are presented with separate categories of mechanism of injury for "overuse / chronic" and "no contact", even though overuse is not the main focus of this article; the overuse results are presented clearly and in useful format
Swenson et al, 2009 [157]	High school recurrent injuries; no overall overuse statistics are provided	No formal definition provided for overuse	Overuse used as specific diagnoses; recurrent injuries as a category of diagnoses	While the article focuses on recurrent injuries, statistics for specific overuse diagnoses (tendinitis and inflammation) for individual sports are provided and presented, distinct from the recurrent injury

Krajnik et al, 2010 [159]	High school shoulder injuries in baseball and softball athletes; an overuse / chronic mechanism of injury accounts for 21 of 91 total high school baseball injuries and 14 of 40 total high school softball injuries	No formal definition provided for overuse; overuse referred to as "overuse / chronic"	Both; overuse / chronic used as a mechanism of injury separate from “no contact mechanism of injury”; overuse also given as a subset of no contact injuries in the discussion	Extensive information on overuse injuries; overuse presented as both a mechanism of injury and a diagnosis; diagnoses presented include contact and no contact mechanisms such as "fracture (including stress fracture)"; presents statistics for individual overuse diagnoses (tendinitis and inflammation)
Yard et al, 2011 [160]	High school injury patterns by body mass index; an overuse / chronic mechanism of injury accounts for 2.5% to 6.5% total injuries depending on BMI category	No formal definition provided for overuse; overuse referred to as "overuse / chronic"	Overuse / chronic used as a mechanism of injury separate from “no contact” mechanism of injury	Overuse presented as percentages of athletes with injuries from an overuse mechanism of injury within strata of BMI categories
Swenson et al, 2012 [69]	High school knee injuries; an overuse / chronic mechanism of injury accounts for 4.9% of high school knee injuries	No formal definition provided for overuse; overuse referred to as "overuse / chronic"	Overuse / chronic used as a mechanism of injury and separate from the “no contact” mechanism of injury; a separate mechanism of injury is "other", which includes "contact with out of bound objects and overuse/chronic injuries"	Percentage of injuries due to "overuse / chronic" and "other" mechanisms of injury with strata for gender and sport; the “other” mechanism of injury category also includes “overuse / chronic” injuries resulting in overuse being represented in two columns of the same table; also provides statistics for individual overuse diagnoses
Swenson et al, 2012 [156]	High school fracture injuries; no overall overuse statistics are provided	No formal definition provided for overuse	Overuse used as a mechanism of injury	There are 2 statistics presenting overuse a common mechanism of injury for some teams

NCAA = National Collegiate Athletics Association; BMI = Body Mass Index

APPENDIX 6.1. THEORETICAL MODEL AND FORMULAS FOR CAPTURE-RECAPTURE ANALYSIS IN CURRENT INVESTIGATION*

		Mechanism is overuse in medical records: Yes	Mechanism is overuse in medical records: No	
Mechanism is overuse in ISS	Yes	a	b	Total number of records in the ISS with a mechanism of injury of overuse
	No	c	x	
		Total number of records in the medical records with a mechanism of injury of overuse		

$x = bc / a$

Total population (N) = a + b + c + x

Capture rate of ISS = (a+b) / N

Capture rate of medical records (a+c) / N

Capture rate of ISS and medical records (a+b+c) / N

* Model and formulas from Hook and Regal (1995) [107]

APPENDIX 6.2. JOINT DISTRIBUTION OF ABSTRACTED INJURIES WHERE THE MECHANISM OFF INJURY IS OVERUSE IN EITHER THE ISS OR MEDICAL RECORDS

		Mechanism of overuse in medical records		
		Yes	No	
Mechanism of overuse in ISS	Yes	28	20	48
	No	16	X	16
		44	20	64+x

APPENDIX 6.3. CHARACTERISTICS OF INJURIES WHERE THE MECHANISM OF INJURY IS OVERUSE IN EITHER BOTH SOURCES OR ONE SOURCE

		Mechanism is overuse in one record n=28				Mechanism is overuse in both records n=26			
		ISS		Other		ISS		Other	
Variable	Categories	n	%	n	%	n	%	n	%
Mechanism	Overuse	28	100	28	100	20	76.9	6	23.1
	Acute non-contact					4	15.4	4	15.4
	Contact with playing surface					2	7.7		
	Illness							1	3.9
	Other							1	3.9
	Don't know							14	53.9
Event Activity	Conditioning	8	28.6	8	28.6	6	23.1	4	15.4
	General play	15	53.6	10	35.7	17	65.4	13	50.0
	Other	4	14.3	2	7.2	2	7.7	2	7.7
	Not specified/missing	1	3.6	8	28.6	1	3.9	7	26.9
Chronic	No	26	92.9	27	96.4	24	92.3	25	96.2
	Yes	1	3.6	1	3.6	1	3.9	1	3.9
	Not specified/missing	1	3.6			1	3.9		
Incident / Recurrent	New	21	75.0	21	75.0	18	69.2	17	65.4
	Recurrent	7	25.0	7	25.0	8	30.8	9	34.6
Days out	1 to 7	14	50.0	7	25.0	8	30.8	6	23.1
	8 to 14	3	10.7	1	3.6	5	19.2	5	19.2
	15 to 30	3	10.7	4	14.3	4	15.4	2	7.7
	Over 30	3	10.7	1	3.6	4	15.4	1	3.9
	Missing	5	17.9	15	53.6	5	19.2	12	46.2
Outcome	Return to play	23	82.1	23	82.1	23	88.5	19	73.1
	Did not return same season	3	10.7	2	7.1	2	7.7	2	7.7
	Did not return to team	1	3.6	1	3.6	1	3.9	1	3.9
	Not specified/missing	1	3.6						
	Don't know			2	7.1			4	15.4
Body part	Ankle / Foot	4	14.3	5	17.9	7	26.9	7	26.9
	Hip / Thigh	7	25.0	7	25.0	7	26.9	9	34.6
	Knee	4	14.3	4	14.3	3	11.5	1	3.9
	Lumbar spine	3	10.7	3	10.7	1	3.9	1	3.9
	Lower leg	10	35.7	9	32.1	6	23.1	6	23.1
	Environmental / other					2	7.7	2	7.7
Injury type	Muscle / tendon strain	4	14.3	6	21.4	7	26.9	10	38.5
	Tendinosis	10	35.7	10	35.7	1	3.9	1	3.9
	Spasm / cramp	4	14.3	1	3.6	3	11.5	2	7.7
	Ligament sprain	1	3.6	2	7.1	1	3.9	2	7.7

	Compartment syndrome					3	11.5	3	11.5
	Overuse					2	7.7	2	7.7
	Fracture / avulsion					2	7.7	1	3.9
	Inflammation					2	7.7	1	3.9
	Stress fracture	1	3.6	1	3.6	1	3.9		
	Other*	7	25.0	8	28.6	4	15.4	4	15.4
	Don't know	1	3.6						
All Diagnoses with more than one Occurrence	Adductor partial tear					3	11.5	4	15.4
	MTSS/shin splints	2	7.1	2	7.1	3	11.5	3	11.5
	Quadriceps tear, thigh	2	7.1	3	10.7	2	7.7	2	7.7
	ITB friction syndrome	2	7.1	2	7.1	2	7.7	3	11.5
	Lower leg compartment syndrome					2	7.7	2	7.7
	Hamstring partial tear								
	Patellar tendinosis	2	7.1	2	7.1				
	Posterior tibialis tendinosis	2	7.1	2	7.1				
	Peroneal tendinosis	2	7.1	2	7.1				
	Achilles tendinosis	2	7.1	2	7.1				
	Lumbar spine / disc injury			2	7.1				

* Other includes; capsulitis ,effusion, blisters, disc injury, contusion/hematoma, neuroma

APPENDIX 7.1. INJURY SCENARIOS AS THEY APPEARED IN THE SURVEY, WITH THE POST-HOC DESIGNATION FOR THE ANALYSES

Scenario 1 (Scenario B): A baseball pitcher has been having elbow pain for over one month. He has been icing his elbow, but has declined injury assessment by the certified athletic trainer. He is unable to complete practice one day, late in the season due to pain. He reports that he was mid-pitch when the pain became "too much". Upon assessment, he has significant medial elbow tenderness, mild swelling and a positive Tinel's test for the ulnar nerve.

Scenario 2 (Scenario E): A swimmer presents to the athletic training room with low back pain after a session in the weight room. The athlete reports that he was doing plyometric trunk rotation by catching and throwing a 10 pound weighted medicine ball when he started to feel pain in his right lower back. He has been swimming two sessions a day and has been lifting five days a week for the past nine months with occasional complaints of non-specific soreness after a hard practice. Upon evaluation, there is significant muscle spasm in the right lumbar paraspinals and radicular pain along the anterior right thigh consistent with the L3 dermatome. There is no evidence of right quadriceps weakness. The quadrant test, which axially loads the right lumbar facets by overpressure through the shoulders when the athlete is seated and the lumbar spine is hyperextended with right rotation and side bend, amplifies the symptoms, indicating possible nerve root irritation.

Scenario 3 (Scenario F): A soccer goalkeeper has been complaining of dominant leg quadriceps pain and tightness for several weeks. His initial visit to the athletic training room was without an assessment and he has been receiving treatment of moist heat and stretching prior to practice and

games and ice after practice and games since then. After 3 weeks of daily heat, stretch and ice treatments, the athlete collapses after punting the ball in the second half of a game. He complains of significant dominant leg quadriceps pain, and there is a visible and palpable defect in the muscle. This game was played outside, and it had been snowing for a short time. The ball was in play in the opposing team's half of the field for the majority of the game as well.

Scenario 4 (Scenario G): A female gymnast has been working on a new skill on the balance beam which includes a back handspring. As a habit, she has always taped her wrists and ankles before and iced her wrists and ankles after each practice. After three weeks of practicing this balance beam skill she presents to the athletic training room with complaints of right wrist pain, and an inability to complete practice. She presents with significant redness and swelling over the right anterior wrist. She has pain and crepitus with active wrist flexion and passive wrist extension.

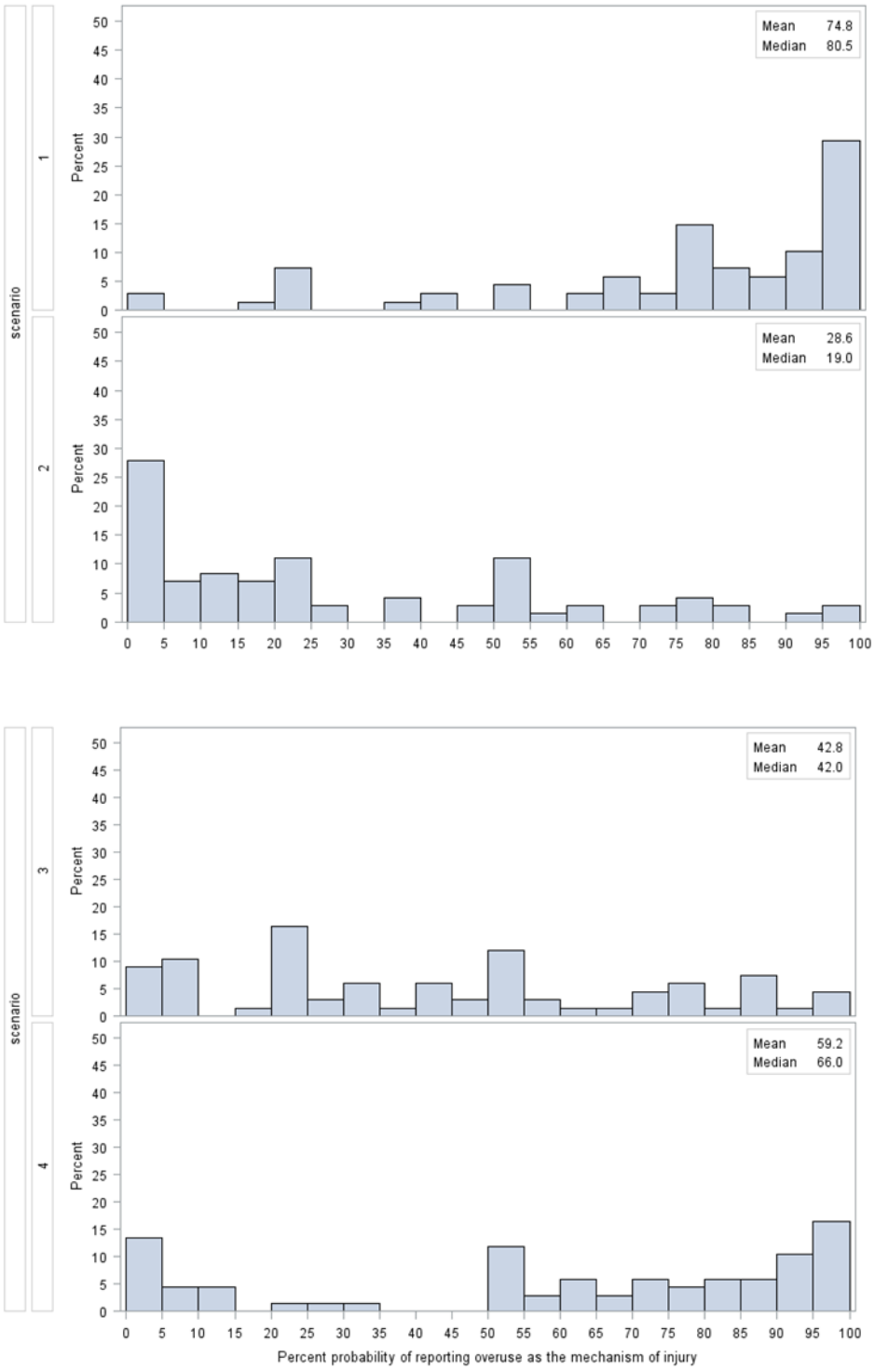
Scenario 5 (Scenario D): A freshman female with no history of participation in crew has just walked-on to the team. She has participated in all training, practices and weight lifting activities. She has been into the athletic training room with complaints of low back pain, where she was assessed with a diagnosis of muscle strain. No diagnostic tests (x-rays or MRIs) were performed. She has been heating before practice and icing after practice, as well as performing basic low back exercises as part of a rehab program. She presents to the athletic training room during one practice with reports of a significant increase in her back pain. She reports that she was lifting a boat with a teammate when the teammate lost her grip, and the boat shifted significantly. They did not drop the boat, but worked quickly and in an awkward position to lower it to the ground.

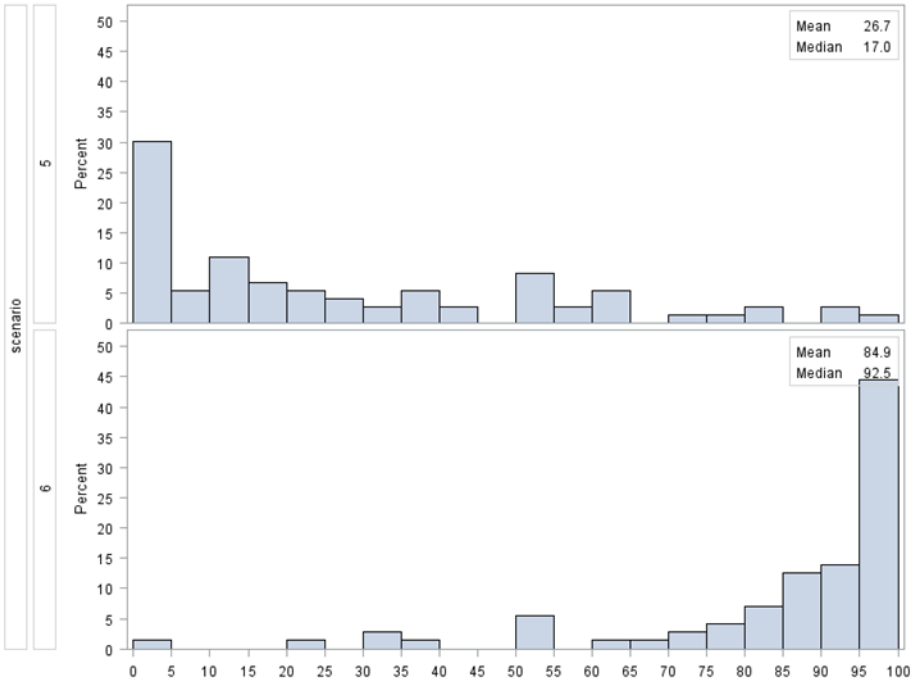
Upon evaluation she has significant paraspinal spasm, left more than right, and a left trunk shift. Diagnostic tests have not yet been performed.

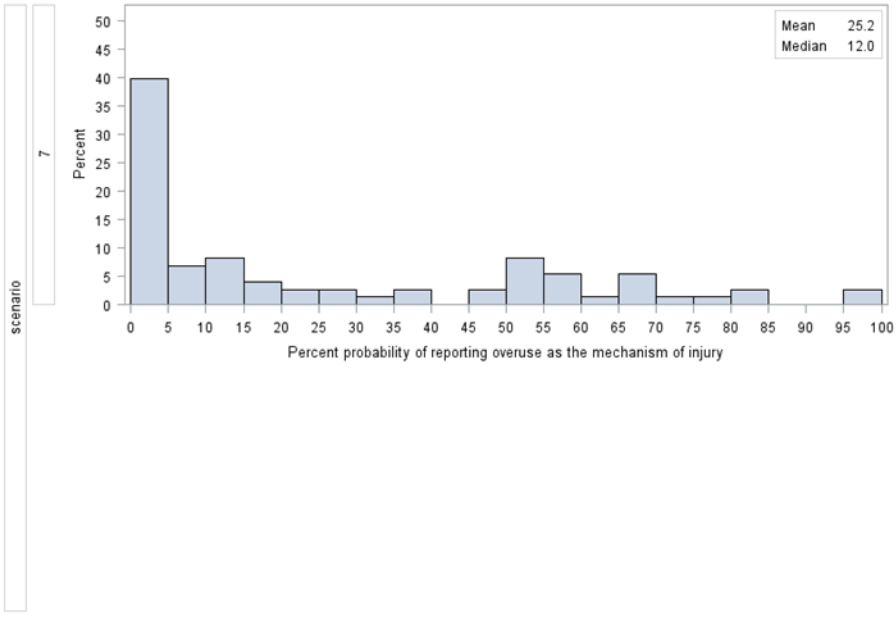
Scenario 6 (Scenario A): A junior female softball player with a history of right biceps tendonitis her freshman year presents in midseason with complaints of right anterior shoulder pain. She pitches with her right arm. Evaluation demonstrated rotator cuff weakness, biceps weakness, a positive Speed's test and positive impingement test resulting in an assessment of biceps tendonitis. The athlete receives treatment and is placed on a rehabilitation program.

Scenario 7 (Scenario C): This same softball player was compliant with her rehabilitation program, and performed exercises and received treatment daily for two weeks. She then returned to full participation. One week after this return to full participation the athlete fell on an outstretched right arm during softball practice. Physical assessment at the second visit, confirmed by MRI presents a diagnosis of right full thickness labral tear and biceps tear.

APPENDIX 7.2. DISTRIBUTION OF THE PROBABILITY, MEANS AND MEDIANS OF REPORTING AN OVERUSE MECHANISM OF INJURY BY SCENARIO (SCENARIOS LABELED AS APPEARED ONLINE)




scenario
5
Percent
Mean 26.7
Median 17.0
6
Percent
Mean 84.9
Median 92.5


scenario
7
Percent
Mean 25.2
Median 12.0
Percent probability of reporting overuse as the mechanism of injury

APPENDIX 7.3. ADDITIONAL METHODS AND RESUILTS

Methods:

The responses regarding the probability of reporting an overuse mechanism were analyzed by strata of covariates as well. The main covariates of interest were education/ qualifications (masters vs. no masters), years of clinical experience (>5 years vs. <=5 years, >10 years vs. <=10 years, and >15 years vs. <=15 years), and years of surveillance experience (>3 years vs. <=3 years, >5 years vs. <=5 years, and >10 years vs. <=10 years). T-tests were performed between strata of these covariates with the null hypothesis that there is no difference in the mean probability of reporting and overuse mechanism to a scenario according to these covariates.

Results:

Other potential influences on AT's responses to the role and reporting of overuse were considered. The covariates age, gender, year of certification and years participating in injury surveillance were also investigated to determine if any had an impact on the results. The distribution of responses regarding the role of overuse and the probability of reporting overuse as the mechanism of injury, as well as the percentage of treated injuries which were overuse, and the percentage of those injuries which were reported to injury surveillance were not affected by these covariates. There were no significant differences in responses regarding the role, reporting or burden of overuse between strata of age, gender, year of certification or years participating in injury surveillance. These covariates did not appear to influence the determination of the role or reporting of overuse within injury surveillance, and were therefore not included in the primary results.

APPENDIX 7.4. SHORT REPORT "AT PERCEPTINS ABOUT OVERUSE INJURY INCIDENCE AND REPORTING PRACTICES"

Introduction

It is widely believed that overuse injuries impose a significant burden on college athletes and their healthcare providers. Overuse injuries are primarily due to repetitive activity which results in the accumulation of microtrauma in the musculoskeletal system. [7, 17, 18, 124] These injuries typically progress over time without an isolated identifiable incident that predicates their onset. [6, 12] Due to the cumulative nature of these injuries, athletes with overuse injuries often receive treatment from ATs without a specific injury diagnosis. Therefore, these injuries may not be associated with a specific injury incidence in medical records. Even if the overuse injury is documented as a distinct injury event, it may not be reported to injury surveillance systems, which historically have required that an injury result in one more days of time-loss from sport in order to be included in injury surveillance. This likely results in an underrepresentation of the amount of overuse injuries which college ATs treat.

The National Collegiate Athletic Association's Injury Surveillance Program (ISP) depends on AT volunteers to collect data about sport-related injuries. [60, 75] The purpose of this investigation is to estimate the self-reported perceived burden of overuse injuries among college ATs, as well as the self-reported practices of the ATs who document these injuries with respect to reporting to injury surveillance.

Methods

Research design and setting

This investigation was part of a larger cross-sectional study, which submitted an online survey including both quantitative and qualitative questions regarding ATs assessment of overuse injuries. That study was submitted for IRB approval at the University of North Carolina at Chapel Hill and was determined to be exempt from review. The Qualtrics online survey platform was used for the creation and distribution of this study. [127]

Participants

This survey was conducted among ATs who volunteer to participate in sports injury surveillance. Eligible participants were recruited from college ATs who were contributing to the NCAA Injury Surveillance Program (ISP) in October 2014.

Instrumentation

ATs were asked about their experiences with diagnosing, treating and reporting overuse injuries. Participants were asked to estimate1) the percentage of the total injuries they treat on average that are overuse injuries, 2) the percentage of those injuries that they report to injury surveillance, and 3) the percent of total injuries reported to injury surveillance that were overuse injuries.

The survey instrument, has been developed by the primary author (KR) with input from other researchers and ATs working in college settings.

Procedures

The Datalys Center for Sports Injury Research and Prevention (Indianapolis, IN) conducts the ISP. All ATs participating in the ISP were contacted by the ISP director with an introductory email and anonymous link to the survey on October 1, 2014. The research team did not have any direct contact with the study population prior to their voluntary participation in this survey. Incentives, in the form of $25 gift cards, were mailed to all participants who provided contact information at the conclusion of the survey. Two survey reminders were sent to ATs who had not completed the survey as of October 8, 2014 and October 15, 2014. The survey closed on October 22, 2014. Only completed surveys were included for analysis.

Data analysis

The mean, median and interquartile range were calculated for the self-reported percentage of total treated injuries which were overuse, and the perceived percentage of those injuries which were reported to injury surveillance.

Results

Survey participants

All 293 ATs who were currently participating in the ISP on October 1, 2014 were emailed an invitation to participate in this survey. A total of 113 (38.6%) began the survey and 74 completed it (25%). The majority of participants were men (n=46, 62.2%), and the mean age was 37.6 years. The mean value for the years of participation in injury surveillance was 4.9 years. There were five ATs with 15 or more years of injury surveillance experience.

Experience with overuse injuries and injury surveillance

Participants' self-reported perception was that nearly half of the injuries they treat are overuse injuries (mean: 48.8%, range: 5.0% to 90.0%). Of those treated overuse injuries they perceived that a mean of 62.4% (range: 0 – 100.0%) are entered into the ISP. These ATs also reported that their perception was that roughly one third (mean: 37.2%, range: 0-80.0%) of the total treated injuries which were reported the ISP were overuse injuries. Both distributions contained extremely low values. There were nine responses at 0% for the perceived percentage of treated overuse injuries which were reported to injury surveillance, and four responses of 0% and three responses of 5% for the perceived percentage of surveillance reported injuries which were overuse.

Discussion

The primary finding of this investigation is that collegiate ATs perceive that the overuse injuries that are reported to account for almost half of all injuries treated by these college ATs. A previous study using the Big 10 Injury Surveillance System reported that overuse injuries accounted for 30% of total sports injuries.[7] The higher percentage in our study may reflect the AT's perception that overuse injuries require more intensive treatment resources and therefore have a larger impact on AT's perceived workload. Other surveillance studies reported that overuse injuries accounted for a range of proportions of total injuries from 1.1% of mens lacrosse and mens soccer practice injuries to 10.9% of mens baseball practice injuries, much lower than reported by the ATs in this study. [62] [55] [63]

Reasons for these discrepancies are unclear. One reason may be that this study presents the self-reported perception of the percentage of overuse injuries, while the Big 10 study [7]

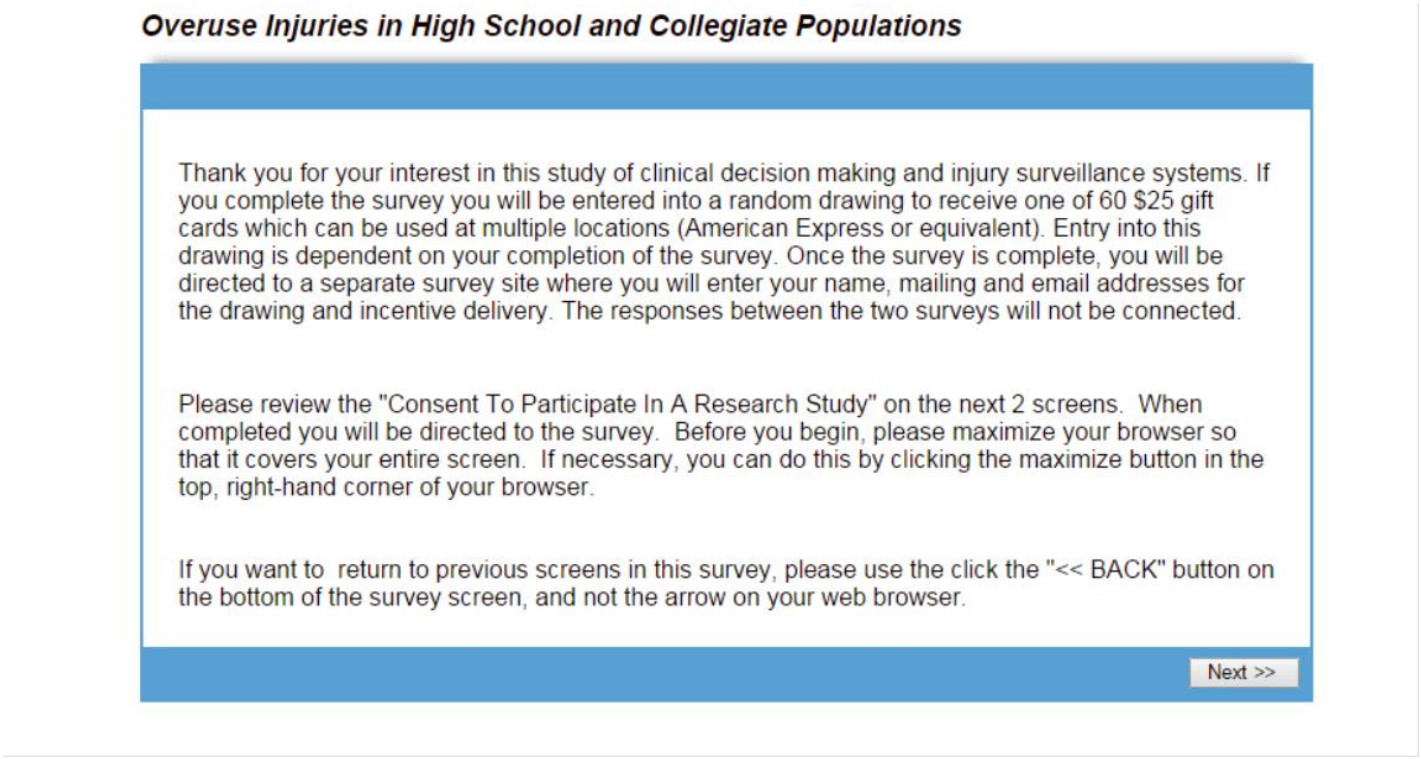
utilized their conference injury surveillance records. Another reason may be related to time loss. Many overuse injuries result in altered participation rather than absence from sport, and historically these injuries would not meet the criteria to be included in surveillance. [48, 80] However, in 2005/06, ATs participating in the ISP had the option to include injuries with no time loss. Likewise in the Big 10 study, any injury treated by the AT staff was eligible for inclusion in the study. A third possible explanation for our findings is that overuse injuries are under-reported to injury surveillance. Acute injuries are easier to identify and record than overuse injuries, which may make them more prevalent in injury surveillance. [121]

Further investigation will be needed to investigate these potential causes. However, it is clear that improved methods for injury surveillance are needed in order to obtain a more complete capture of overuse injuries in the college setting.

Conclusion:

ATs perceived that overuse injuries are a significant portion of their clinical workload, to a greater extent than would be predicted from surveillance data. Reasons for the discrepancy are unclear.

APPENDIX 7.5. SURVEY INSTRUMENT AS IT APPEARED ONLINE



Overuse Injuries in High School and Collegiate Populations

University of North Carolina at Chapel Hill
Consent to Participate in a Research Study
Adult Participants
Consent Form Version Date: 9/22/14
IRB Study # 13-2198
Title of Study: Overuse Injuries in High School and Collegiate Populations: Methodological Issues in Surveillance Data
Principal Investigator: Karen Roos MSPT, ATC
Principal Investigator Department: Epidemiology
Principal Investigator Phone number: 949-307-6101
Principal Investigator Email Address: kroos@email.unc.edu
Faculty Advisor: Stephen W. Marshall Ph.D.
Faculty Advisor Contact Information: smarshall@unc.edu

What is the purpose of this study?
The purpose of this research study is to learn about how individual Certified Athletic Trainers diagnose overuse injuries and report overuse injuries to surveillance systems (for example: NCAA ISP and High School RIO). Differences in how individual Certified Athletic Trainers define and report overuse injuries to injury surveillance systems may affect the information that these systems provide.

How long will your participation in this study last?
This is a one-time electronic survey which should take 20-25 minutes to complete. There is no follow up for this survey.

What will happen if you take part in the study?
If you take part in this study, you will be asked to complete an electronic survey consisting of questions regarding 6 brief injury scenarios, as well as questions regarding your educational and work experience. You may choose not to complete any question for any reason. You may also stop taking the survey at any time once the survey has begun.

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Overuse Injuries in High School and Collegiate Populations

What are the possible benefits from being in this study?
There are no direct benefits from participating in this study, however the results of this study will be used to better understand and potentially improve injury surveillance to better capture overuse injuries.

What are the possible risks or discomforts involved from being in this study?
There are no known risks or discomforts involved with participating in this study.

Is there an incentive for participation?
After the survey closes, there will be a random drawing for 60 $25 gift cards. All participants who complete the survey will be eligible for the random drawing.

How will information about you be protected?
All responses to this survey will be maintained on a protected system at the University of North Carolina at Chapel Hill. All responses will be de-identified before data analysis through the assignment of ID numbers. Names and email addresses will be stored in a separate file, which will be password protected. Only the primary investigator and dissertation advisor will have access to these files. Participants will not be identified in any report or publication about this study. Every effort will be made to keep the records private.

What if you have questions about your rights as a research participant?
If you have questions or concerns about your rights as a research subject, or if you would like to obtain information or offer input, you may contact the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

- ○ I have read the above consent form and agree to participate in this survey.
- ○ I do not consent to participate in this survey

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Overuse Injuries in High School and Collegiate Populations

You will be presented with 6 hypothetical injury scenarios, followed by questions regarding the mechanism of injury in each scenario. Each scenario will be numbered and highlighted.

For the purpose of this survey, please use the following definitions regarding specific mechanisms of injury:

- Overuse: Injury of a chronic or gradual onset in nature.

- Acute non-contact: Injury with a specific onset which does not result from contact.

- Contact with player: Injury occurred as a result of coming in direct contact with another player.

- Contact with playing surface: Injury occurred as a result of coming in direct contact with the ground.

- Contact with equipment: Injury occurred as a result of coming in direct contact with a sport specific apparatus.

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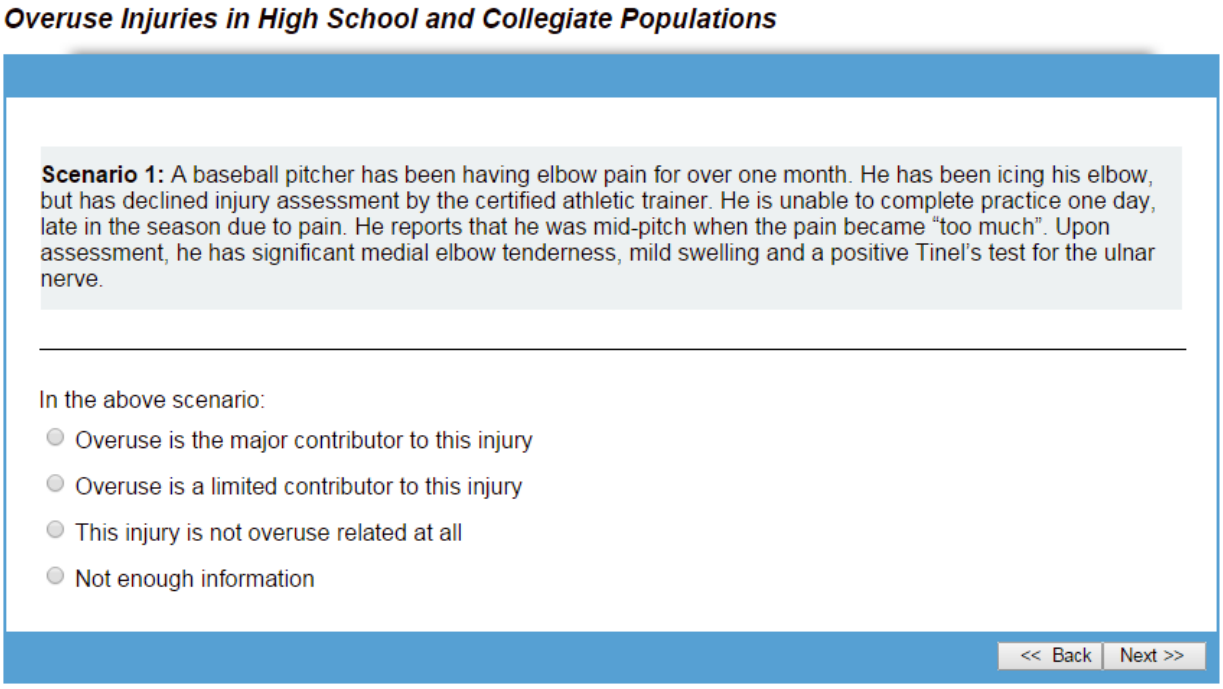
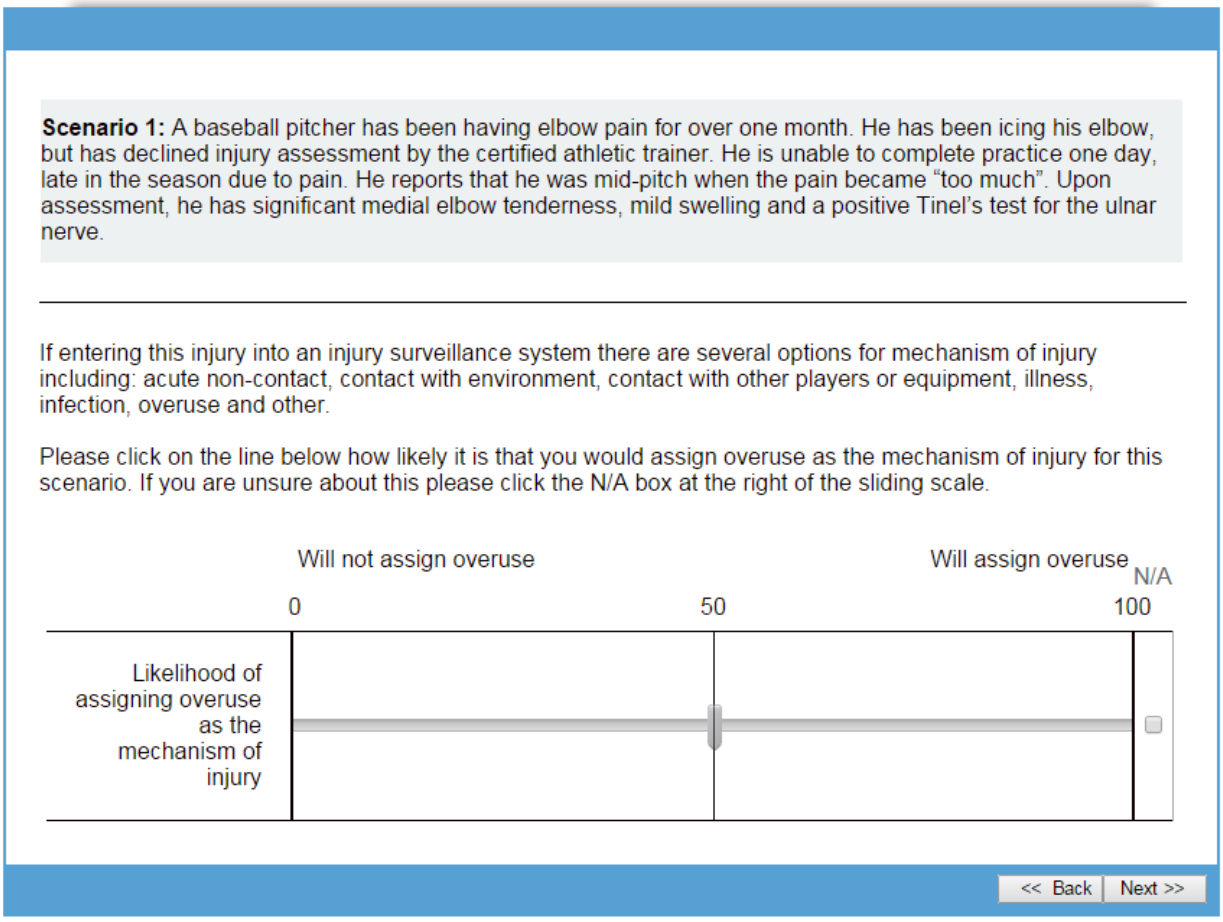
Each scenario was followed by three questions

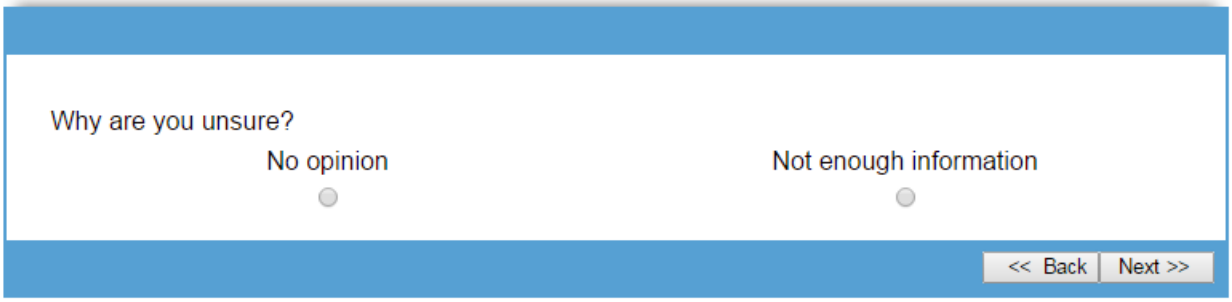


Overuse Injuries in High School and Collegiate Populations



If the N/A box was checked in the above question, the following question was displayed

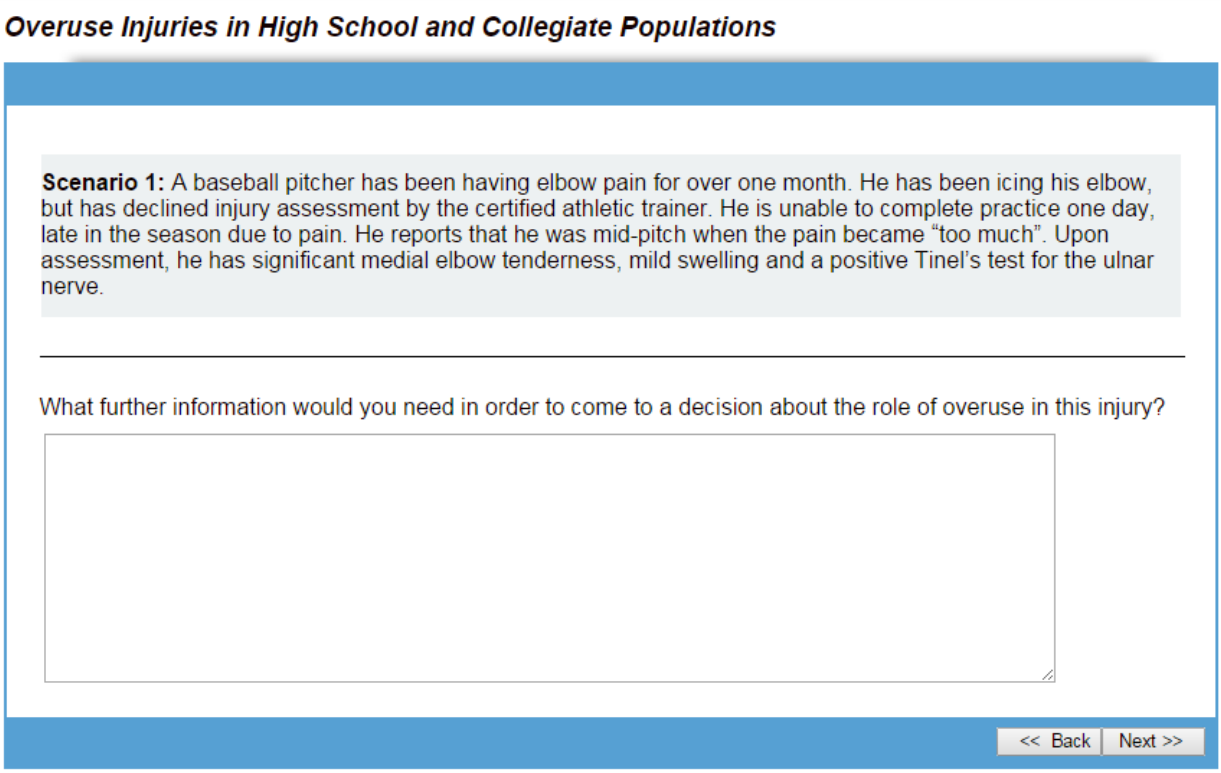
Overuse Injuries in High School and Collegiate Populations



Scenario 1: A baseball pitcher has been having elbow pain for over one month. He has been icing his elbow, but has declined injury assessment by the certified athletic trainer. He is unable to complete practice one day, late in the season due to pain. He reports that he was mid-pitch when the pain became "too much". Upon assessment, he has significant medial elbow tenderness, mild swelling and a positive Tinel's test for the ulnar nerve.

How did you reach those conclusions?

If “not enough information” was clicked from the question about the role of overuse, then the following question was displayed.



If “N/A” was clicked from the question about the reporting of overuse, then the following question was displayed

Overuse Injuries in High School and Collegiate Populations

The same questions as above were repeated for the next four scenarios:

Overuse Injuries in High School and Collegiate Populations

Scenario 2: A swimmer presents to the athletic training room with low back pain after a session in the weight room. The athlete reports that he was doing plyometric trunk rotation by catching and throwing a 10 pound weighted medicine ball when he started to feel pain in his right lower back. He has been swimming 2 sessions a day and has been lifting 5 days a week for the past 9 months with occasional complaints of non-specific soreness after a hard practice. Upon evaluation, there is significant muscle spasm in the right lumbar paraspinals and radicular pain along the anterior right thigh consistent with the L3 dermatome. There is no evidence of right quadriceps weakness. The quadrant test, which axially loads the right lumbar facets by overpressure through the shoulders when the athlete is seated and the lumbar spine is hyperextended with right rotation and side bend, amplifies the symptoms, indicating possible nerve root irritation.

In the above scenario:

- Overuse is the major contributor to this injury
- Overuse is a limited contributor to this injury
- This injury is not overuse related at all
- Not enough information

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Overuse Injuries in High School and Collegiate Populations

Scenario 3: A soccer goalkeeper has been complaining of dominant leg quadriceps pain and tightness for several weeks. His initial visit to the athletic training room was without an assessment and he has been receiving treatment of moist heat and stretching prior to practice and games and ice after practice and games since then. After 3 weeks of daily heat, stretch and ice treatments, the athlete collapses after punting the ball in the second half of a game. He complains of significant dominant leg quadriceps pain, and there is a visible and palpable defect in the muscle. This game was played outside, and it had been snowing for a short time. The ball was in play in the opposing team's half of the field for the majority of the game as well.

In the above scenario:

- Overuse is the major contributor to this injury
- Overuse is a limited contributor to this injury
- This injury is not overuse related at all
- Not enough information

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Scenario 4: A female gymnast has been working on a new skill on the balance beam which includes a back handspring. As a habit, she has always taped her wrists and ankles before and iced her wrists and ankles after each practice. After three weeks of practicing this balance beam skill she presents to the athletic training room with complaints of right wrist pain, and an inability to complete practice. She presents with significant redness and swelling over the right anterior wrist. She has pain and crepitus with active wrist flexion and passive wrist extension.

In the above scenario:

- Overuse is the major contributor to this injury
- Overuse is a limited contributor to this injury
- This injury is not overuse related at all
- Not enough information

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Scenario 5: A freshman female with no history of participation in crew has just walked-on to the team. She has participated in all training, practices and weight lifting activities. She has been into the athletic training room with complaints of low back pain, where she was assessed with a diagnosis of muscle strain. No diagnostic tests (x-rays or MRIs) were performed. She has been heating before practice and icing after practice, as well as performing basic low back exercises as part of a rehab program. She presents to the athletic training room during one practice with reports of a significant increase in her back pain. She reports that she was lifting a boat with a teammate when the teammate lost her grip, and the boat shifted significantly. They did not drop the boat, but worked quickly and in an awkward position to lower it to the ground. Upon evaluation she has significant paraspinal spasm, left more than right, and a left trunk shift. Diagnostic tests have not yet been performed.

In the above scenario:

- Overuse is the major contributor to this injury
- Overuse is a limited contributor to this injury
- This injury is not overuse related at all
- Not enough information

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The last two scenarios were linked and involved the same athlete

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Scenario 6a: A junior female softball player with a history of right biceps tendonitis her freshman year presents in midseason with complaints of right anterior shoulder pain. She pitches with her right arm. Evaluation demonstrated rotator cuff weakness, biceps weakness, a positive Speed's test and positive impingement test resulting in an assessment of biceps tendonitis. The athlete receives treatment and is placed on a rehabilitation program.

In the above scenario:

- ○ Overuse is the major contributor to this injury
- ○ Overuse is a limited contributor to this injury
- ○ This injury is not overuse related at all
- ○ Not enough information

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The second part of the scenario was linked to the first by the following two questions

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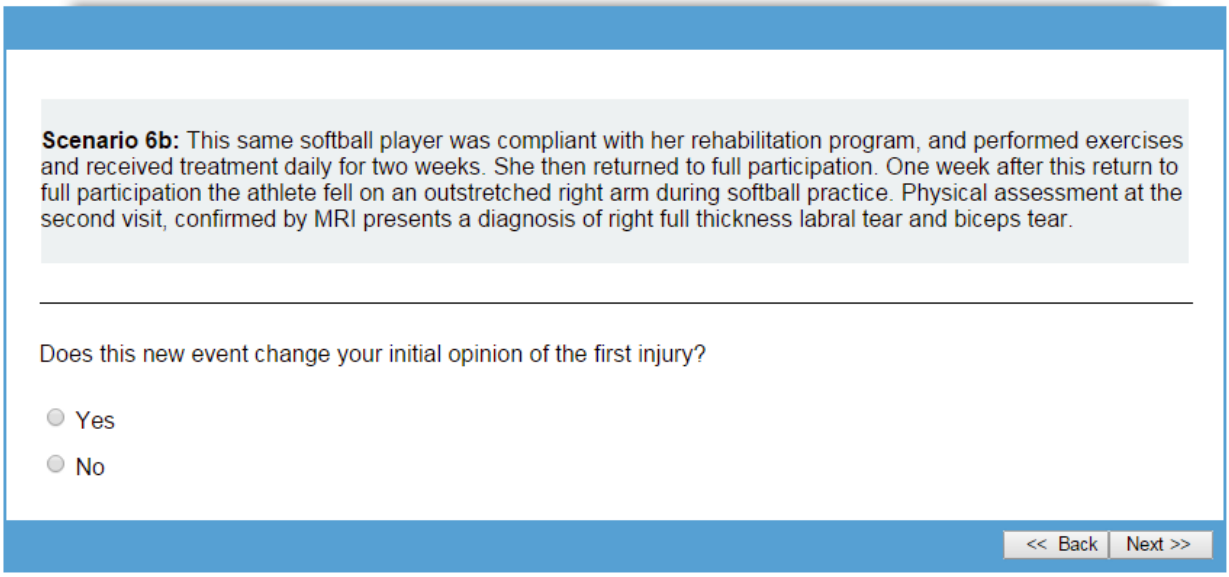

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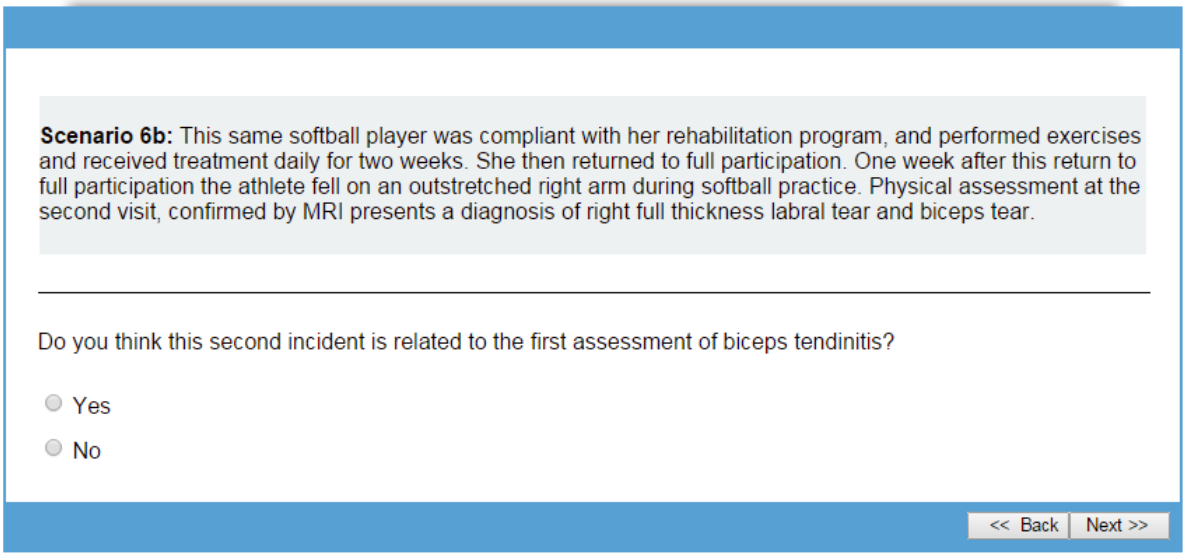
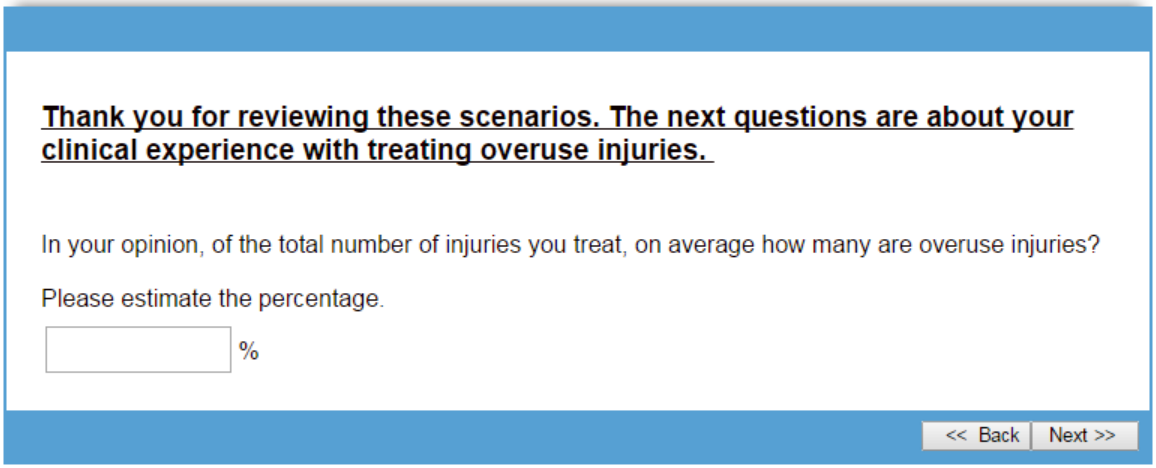
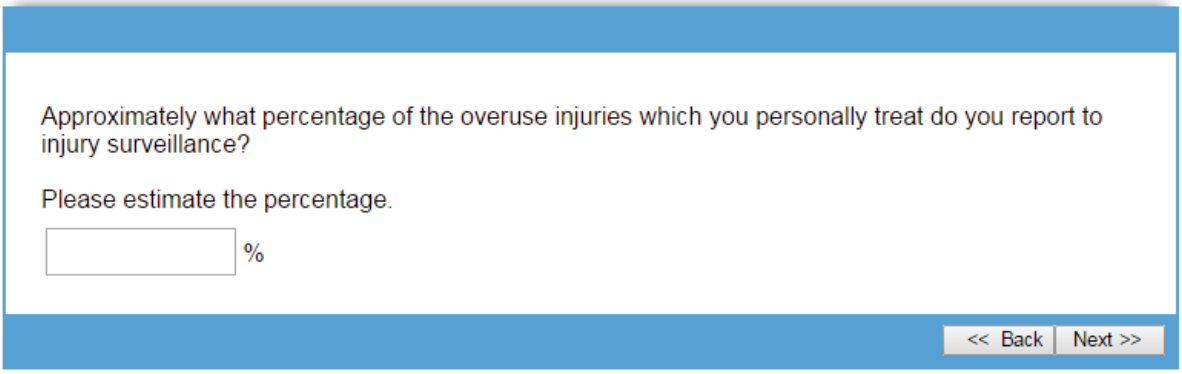


The following demographic and experience questions were asked of all participants

Overuse Injuries in High School and Collegiate Populations

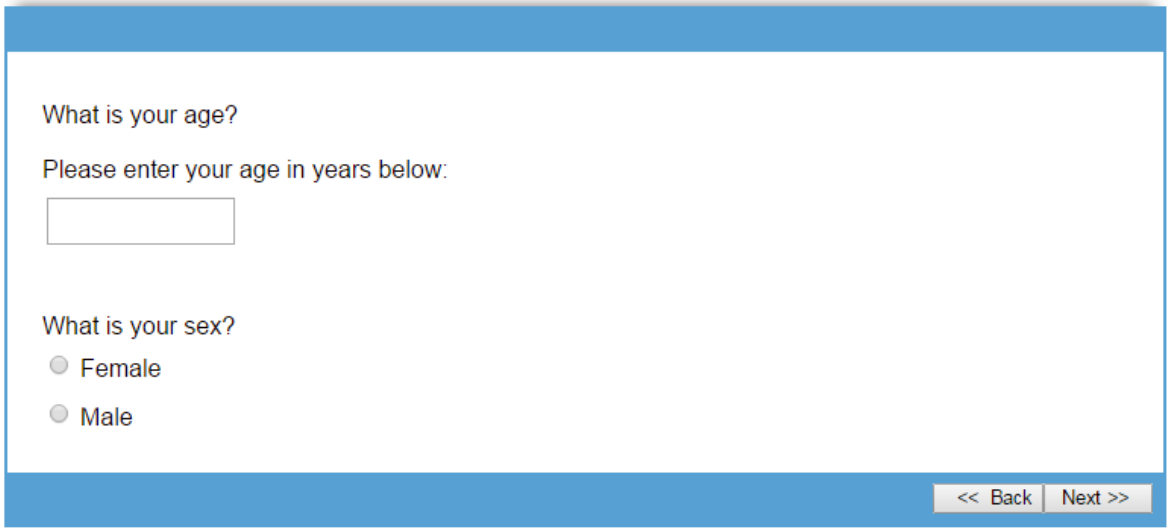


Overuse Injuries in High School and Collegiate Populations



Overuse Injuries in High School and Collegiate Populations

Overuse Injuries in High School and Collegiate Populations



What are your certifications and licenses?

Please check all that apply:

- [ ] ATC
- [ ] EMT
- [ ] PA
- [ ] PT
- [ ] PTA
- [ ] OT
- [ ] OTA
- [ ] RN
- [ ] CSCS or NCSA
- [ ] Other, please specify:

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In what year did you receive your Athletic Training certification?

Please specify year:

What is your level of education?

Please check all earned degrees that apply:

- [ ] Bachelor's Degree (example: BS or BA)
- [ ] Master's Degree (example: MS or MA)
- [ ] Ph.D.
- [ ] MD
- [ ] Applied Doctorate (example: Ed.D., DPT, DC), please specify:

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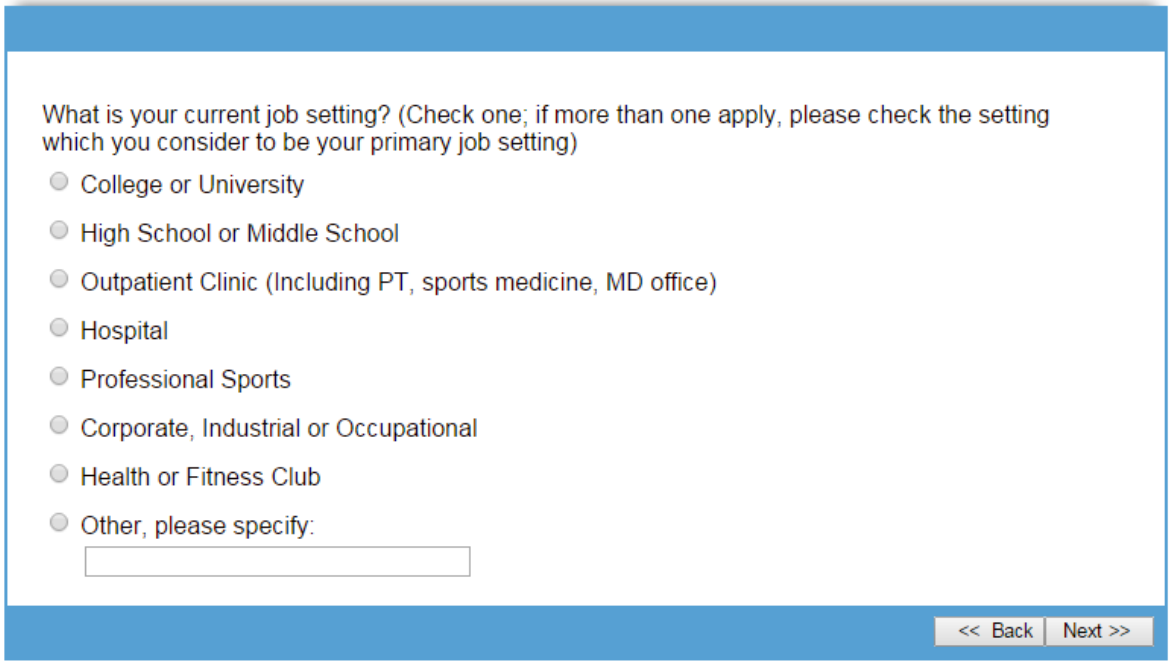

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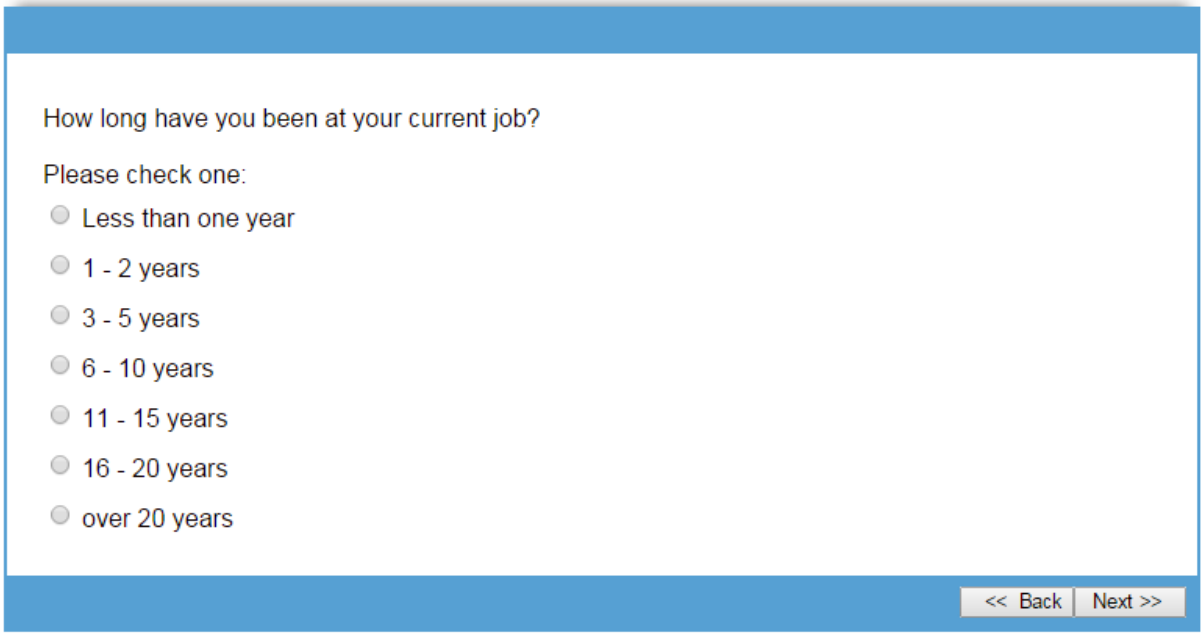

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