December 2020

Investigating the Extent of the Problem: Injury Epidemiology in Cross-Country and Track & Field

Christopher Lee Hopkins
Clemson University, hopkins@g.clemson.edu

INVESTIGATING THE EXTENT OF THE PROBLEM: INJURY EPIDEMIOLOGY IN CROSS-COUNTRY AND TRACK & FIELD

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Applied Health Research and Evaluation

---

by
Chris Hopkins
December 2020

Accepted by:
Dr. Joel Williams, Dissertation Chair
Dr. Sarah Griffin
Dr. Lu Zhang
Dr. Mitch Rauh
Dr. Chris Clemow

ABSTRACT

This dissertation aims to explore the problem of injuries in high school and collegiate cross-country and track and field by systematically reviewing and analyzing data from previous epidemiologic studies, comparing injury rates from a large dataset of collegiate track and field injuries, examining the psychology of injury reporting among adolescent runners, and identifying directions for future research in the field of sports injury epidemiology. Cross-country and track and field are popular modes of physical activity for many adolescents, but as with many sports, they have inherent injury risks that may lead participants to quit or increase their risk of conditions such as post-traumatic osteoarthritis.

In order to understand the injury problem in these sports and measure the effectiveness of injury prevention strategies, it is important to have accurate measurements of injury risk. Differing methodologies used in previous research have resulted in large variances in observed injury risk among cross-country and track and field athletes. This dissertation includes a systematic review and met-analysis, which pools injury-related data from previous original research to provide overall estimates of injury risk, while highlighting inconsistencies and current gaps in epidemiological research within these populations.

One current gap identified was the lack of epidemiological studies comparing injury patterns between diverse track and field disciplines such as sprinting, distance running, throwing, and jumping. The second study in this dissertation analyzed a large dataset of

collegiate track and field injuries to estimate injury risk, while also examining the patterns and burden of injury across track and field disciplines.

Another gap in sports injury research concerns the study of injury reporting behaviors. Previous epidemiological studies have cited injury underreporting as potentially skewing estimates of injury risk. Many of the injuries experienced by adolescent runners have a gradual onset and delays in their recognition and treatment can be detrimental to an athlete's health. The third study in this dissertation surveyed a large sample of adolescent runners to examine important factors regarding their decision to report overuse injury symptoms.

DEDICATION

I dedicate this dissertation to my wife, Casey, and our three children, Charleigh, Dane, and Clive. Each of you inspire me to be a better person, husband, and father.

ACKNOWLEDGEMENTS

I want to thank my dissertation committee for lending their expert guidance and support throughout this process. To my advisor, Dr. Joel Williams, thank you for the constant support and encouragement you have shown since I first considered enrolling in this wonderful PhD program. Dr. Sarah Griffin, when I was an undergraduate student you not only provided me with research experience, but also encouragement and affirmation that continues to inspire me. Drs. Lu Zhang, Mitch Rauh, and Chris Clemow, thank you for believing in my work and providing me with the guidance I needed. I could not have completed this work without your expertise.

I would also like to thank my current and past students at Furman and Anderson Universities and acknowledge Breanna Cole and Beth Donnelly for their assistance with the systematic review contained within this dissertation.

Thank you to the administrative staff at the Datalys Center and the many athletic trainers who contributed to the NCAA Injury Surveillance Program used in this dissertation. I am appreciative of all the study participants who contributed their time to this research.

Lastly, I would like to thank all my friends and family who have encouraged me and provided me with resources to be successful.

TABLE OF CONTENTS

Table of Contents (continued)

Page

LIST OF TABLES

List of Tables (continued)

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

BACKGROUND

Running is one of the most popular ways in which people throughout the world are physically active (Hulteen et al, 2017). The easy accessibility and relatively few expenses contribute to the popularity of running (Shipway et al 2010). Other contributing factors include the physical and mental health benefits associated with running (Hespanhol et al 2015, Morris et al 1994). In fact, distance running has been associated with improved body composition, reduced risk of cardiovascular disease and cancer, and increased life expectancy (Hespanhol et al 2015, Lee et al 2017, Lee et al 2014).

Many adolescents are introduced to the sport of running through participation in cross-country and track and field. In 2018-2019 there were over 1 million adolescents in the United States who participated in high school cross-country and track and field and another 50,000+ young adults who participated in college (NFHS 2019, NCAA 2019). Unfortunately, these athletes often incur injuries (Kluitenberg et al 2015, Kerr et al 2016, Pierpiont et al 2016, Brant et al 2019, Yang et al 2012). Injuries are a major problem among many athletes, but they can be especially detrimental to competitive runners. In addition to the painful symptoms runners experience with injuries, their restricted running participation following an injury has also been associated with increased anxiety and depression (Chan et al, 1988). Furthermore, running injuries are often cited as reasons for quitting the sport indefinitely, thus negating the short- and long-term health benefits of running (Koplan et al 1995). Another important long-term implication of sports injuries is the potential development of post-traumatic osteoarthritis (Carbone et al 2017).

This type of osteoarthritis often develops in younger and more active individuals who have sustained previous injuries. Individuals with post-traumatic osteoarthritis often suffer from osteoarthritis symptoms at a much earlier age and may require surgical intervention earlier in life compared to other individuals with osteoarthritis (Carbone et al 2017).

In terms of the overall risk of developing osteoarthritis, recreational running has been associated with a lower risk of developing hip and knee osteoarthritis. A recent meta-analysis found that the overall prevalence of hip and knee osteoarthritis was only 3.5% among recreational runners compared to 10.2% among sedentary adults (Alentorn-Geli et al 2017). However, this same study found that the prevalence of hip and knee osteoarthritis was much higher among competitive runners at 13.3% (Alentorn-Geli et al 2017). This higher prevalence among competitive runners may be due to greater amounts of exposure to strenuous running and the accumulation of running injuries over a greater amount of time. While the overall health benefits of running are wonderful, injuries and their long-term implications are a major problem for competitive runners. Therefore, to promote health in competitive runners and encourage their longevity in the sport, injury prevention models should be appropriately developed and implemented.

A leading framework for guiding sports injury prevention efforts is van Mechelen's Sequence of Prevention (van Mechelen et al 1992). This four-staged framework has been used to study and prevent injuries in many different sporting contexts (Blauwet et al

2018, Kilic et al 2018, Harmer 2015). As illustrated in Figure 1.1, the first step of injury prevention is to establish the extent of the injury problem. This is accomplished by using injury surveillance to describe the prevalence and incidence of sports injuries within their context. The incidence and prevalence of injuries can vary greatly by sport, participant ages and competition level, and positions or activities within specific sports. Thus, the population of athletes being studied should be clearly defined.

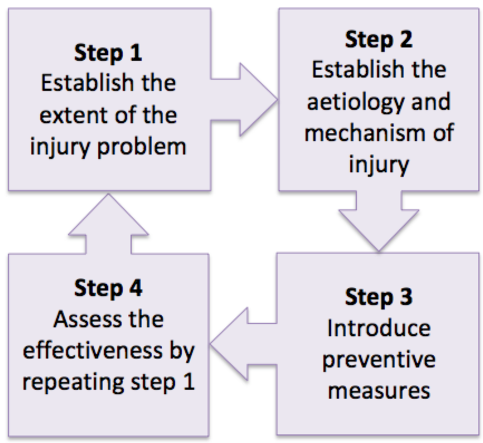


Figure 1.1. Sequence of Prevention by van Mechelen et al 1992

Once an injury problem is identified through injury surveillance then the mechanisms of the relevant injury should be established by identifying relevant risk and/or causal factors for injury. Most commonly, risk factors for sports injury are identified through biomechanical, biomedical, and epidemiological research (Verhagen et al 2010). Recently, however, complex systems approaches for studying sports injury etiology have been introduced (Bittencourt et al 2016, Hulme et al 2015, Hulme et al 2017). Once risk and/or causal factors are identified then injury prevention efforts move toward developing preventive measures. As suggested by Finch, the efficacy of these preventive measures should be established under ideal conditions while studying context of particular sport settings to inform implementation strategies and promote its use in a real-world setting (Finch 2006). Once prevention measures are implemented, then injury surveillance should be re-visited to assess their effectiveness at preventing injuries.

The importance of the first step, injury surveillance, should be highlighted. It is through injury surveillance that injury problems are recognized and thus brought forth for further examination. Once preventive measures are developed and implemented, it is the work of injury surveillance to assess their value by measuring how they affect injury rates and patterns. Therefore, given the importance of creating a safe sporting environment for young cross-country and track and field athletes it is imperative to understand the injury problems these athletes face through injury surveillance and epidemiological studies.

THE INJURY PROBLEM IN CROSS-COUNTRY AND TRACK AND FIELD

Research on injuries in cross-country and track and field has become more common in recent decades. However, establishing the true extent of the injury problem in these sports has been difficult because the reported injury risks in both sports have varied greatly and the researchers have employed differing methodologies. For example, running injury studies have used differing study designs highlighted by varied lengths of observation and methods of data collection (Kluitenberg et al 2015, Kerr et al 2016, Daoud et al 2012, Chandy et al 1985).

Designs of sports injury surveillance studies may vary based on the length of an observation or follow-up period. Some studies report on a runner's risk of injury over their lifetime, while others may only focus on a single race, event, or short training cycle. For example, one study reported 94.4% of collegiate cross-country runners experienced a pain-related running injury in their lifetime (Reinking 2006) while another reported 82.4% of high school cross-country runners had a lifetime history of exercise-related leg pain (Reinking 2010). However, studies focused on injury prevalence by medical encounters at a single event report as little as 0.47% of injured runners at a popular ten-mile race (Pasquina et al, 2013) or up to 12.3% among participants at the World Championships in Athletics (Alonso et al, 2012).

In addition to differing follow-up periods, sports injury studies also differ in the manner they estimate injury risk. When determining the risk of sustaining a sports injury, it is important to measure how much the subjects actively participated in the sport of interest. For most sports, injury risk should be estimated by the amount of injuries that occur in a given time participating in the sport. In the case of running, the risk of injury should be estimated by the amount of injuries sustained during a specified amount of running. This approach provides runners, coaches, and sports medicine professionals insight into the risk of sustaining an injury over a specified amount of running. Many published training programs for runners prescribe running workouts in terms of distance (eg. kilometers) or time (eg. minutes) and intensity (eg. pace or perceived exertion). Thus, it may be beneficial for individuals to receive injury risk estimations by the amount of injuries occurring in a standard amount of time or distance ran, such as X number of injuries per 1,000 hours or kilometers. These estimations would better inform coaches and athletes about injury risk by using the same measurements considered when planning workouts and training plans. However, many large running injury surveillance studies report injury risk by the number of "athletic exposures" (AEs) or simply the number of times they ran instead of the distance or time they spent running. In fact, a 2015 systematic review and meta-analysis found only thirteen studies who reported injury rates per hours of running and none of the included studies reported on adolescent or collegiate runners (Videbæk et al 2015).

While estimating sport exposure by the number of practices and competitions is less ideal than distance or time, it has been used to estimate injury risk among adolescent and collegiate cross-country and track and field athletes. However, these studies still may differ by another important methodological component: the method of collecting injury data. For example, a study that collected injury reports from athletic trainers covering multiple sports described substantially lower injury rates in adolescent runners compared with a study that collected injury reports directly from coaches (0.61 and 0.94 injuries per 1,000 AEs among boys and girls respectively versus 15.0 and 19.6 injuries per 1,000 AEs among boys and girls respectively; Brant et al 2019, Rauh et al 2006). These large discrepancies in injury rates may be due to many factors, but the sources of injury-related data are important to consider as many high school and collegiate athletes tend to under-report injuries (Wallace et al 2017, Register-Mihalik et al 2013, Baugh et al 2019).

Further research using qualitative or behavioral approaches may help clarify injury-reporting behaviors among cross-country and track and field athletes.

Another problem facing injury epidemiology studies in track and field is the heterogeneity of athletes that participate in the sport. Unlike cross-country where all athletes compete in similar distance-running events, track and field athletes vary greatly by the types of events they compete in. This diversity among the types of athletes and the events they compete in likely predispose track and field athletes to various types of injuries over the course of a season. This has been explored some among high school track and field athletes, but not collegiate. Among high school athletes, Pierpoint et al (2016) reported higher proportions of thigh strains from sprinting, lower leg strains and stress fractures from distance running, and ankle sprains from jumping when compared with other events. However, this study did not explore how such injuries affected time-loss among different types of athletes, which would provide further context to the extent of injury problems in track and field.

These gaps in research and the varied methodologies implemented in sports injury research make it difficult to fully understand the extent of the injury problem in cross-country and track and field. A better understanding of the injury problem should lead to a more efficient and purposeful sequence of injury prevention and improved efforts to increase the safety and well-being of young cross-country and track and field athletes who have great potential for lifelong physical activity through continued sport participation (Dohle et al 2013, Murphy et al 2015).

PURPOSE

The purpose of this PhD dissertation is to explore injury epidemiology in high school and collegiate cross-country and track and field. This includes systematically reviewing and analyzing data from previous epidemiologic studies, comparing injury rates from a large dataset of collegiate track and field injuries, examining the psychology of injury reporting among adolescent runners, and identifying directions for future research in the field of sports injury epidemiology.

OVERVIEW OF PROPOSAL WITH AIMS

To achieve the stated purpose above, this dissertation contains five chapters. This first chapter is an introduction to the topic and description of aims, followed by three chapters intended to be individual works suitable for publication in appropriate peer-reviewed journals, and a fifth chapter providing a summary of overall findings and directions for future research.

Chapter 1 – Introduction

Aims:

1) Introduce the health benefits and injury problems associated with cross-country and track and field

2) Briefly summarize the Sequence of Prevention model and current gaps in cross-country and track and field injury epidemiology research
3) Define the overall dissertation purposes and aims
4) Summarize the main details associated with each chapter

Chapter 2 – Injury Risk in High School and Collegiate Cross-Country and Track & Field: A Systematic Review and Meta-Analysis

Aims:

1) Review published studies on injury risk in high school and collegiate cross-country and track and field
2) Extract and analyze data regarding injuries and injury rates to estimate pooled injury rates and injury rate ratios between male and female cross-country and track and field
3) Compare injury rates by competition level to assess injury risk among high school and collegiate athletes
4) Compare injury proportions by injury reporting mechanisms

Significance: This meta-analysis extracts data from studies with season-long injury data for high school and collegiate cross-country and track and field injuries. A similar meta-analysis examined injury proportions in different types of runners including track and cross-country, however, it also included adult, recreational, and elite athletes all pooled together into one category and did not seek to compare differences in competition level or reporting mechanisms. It also only compared injury proportions and not injury rates. This present study will increase knowledge of cross-country and track and field injuries by pooling data from all relevant studies and comparing them by competition level and reporting mechanisms. This provides greater context to define the injury problem as described by van Mechelen's Sequence of Prevention step one.

Chapter 3 – Epidemiology of NCAA Track and Field Injuries: 2009-2010 Through 2013-2014

Aims:

1) Compare NCAA track and field injury rates by sex, event setting, and season
2) Describe injuries by different track and field disciplines through comparisons of injury proportions

Significance: This study leverages data from a large injury surveillance program to examine collegiate track and field injuries. The data were retrieved from the NCAA Injury Surveillance Program, which requires a lengthy review process and is currently on an extended moratorium and is not currently open for data requests. I received the data in 2018 before the moratorium took place. In comparison to this present study, only one similar study with this large of a sample size exists. However, the other study is 16-years old and doesn't provide any comparisons between event settings, seasons, or disciplines and events. This study provides greater context to the injury problem by defining injury patterns specific to different and distinct types of collegiate track and field athletes.

Chapter 4 – Investigating adolescent runners' reporting of overuse injuries: An application of the Disclosure Decision-Making Model

Aims:

1) Describe the rate of injury reporting behaviors among adolescent cross-country runners
2) Apply the Disclosure Decision-Making Model to explore factors related to adolescent cross-country runners' decision to report overuse injury symptoms

Significance: This study will be the first to report overuse injury reporting behaviors using a behavioral theory. Similar research has been conducted regarding concussion reporting among contact-sport athletes, however, this research is warranted given the prevalence of overuse injuries, their gradual-onset, and apparent differences in self-reported injuries compared to athletic trainer-reported injuries in running populations. This study provides context to injury-reporting mechanisms often used to define the injury problem in adolescent athletes.

Chapter 5 – Summary of findings and directions for future research

Aims:

1) Provide an overview of findings in this dissertation

2) Report the strengths and limitations of this dissertation

3) State the significance of dissertation findings on sports injury research

4) Provide direction for future research on injury epidemiology in high school and collegiate cross-country and track and field.

REFERENCES

Alentorn-Geli, E., Samuelsson, K., Musahl, V., Green, C. L., Bhandari, M., & Karlsson, J. (2017). The association of recreational and competitive running with hip and knee osteoarthritis: A systematic review and meta-analysis. *The Journal of Orthopaedic and Sports Physical Therapy, 47*(6), 373-390. doi:10.2519/jospt.2017.7137 [doi]

Alonso, J. M., Edouard, P., Fischetto, G., Adams, B., Depiesse, F., & Mountjoy, M. (2012). Determination of future prevention strategies in elite track and field: Analysis of daegu 2011 IAAF championships injuries and illnesses surveillance. *British Journal of Sports Medicine, 46*(7), 505-514. doi:10.1136/bjsports-2012-091008 [doi]

Baugh, C. M., Meehan, W. P., Kroshus, E., McGuire, T. G., & Hatfield, L. A. (2019). College football players less likely to report concussions and other injuries with increased injury accumulation. *Journal of Neurotrauma, 36*(13), 2065-2072. doi:10.1089/neu.2018.6161 [doi]

Bittencourt, N. F. N., Meeuwisse, W. H., Mendonca, L. D., Nettel-Aguirre, A., Ocarino, J. M., & Fonseca, S. T. (2016). Complex systems approach for sports injuries: Moving from risk factor identification to injury pattern recognition-narrative review and new concept. *British Journal of Sports Medicine, 50*(21), 1309-1314. doi:10.1136/bjsports-2015-095850 [doi]

Blauwet, C., Webborn, N., Kissick, J., Lexell, J., Stomphorst, J., van de Vliet, P., . . . Derman, W. (2019). When van mechelen's sequence of injury prevention model requires pragmatic and accelerated action: The case of para alpine skiing in pyeong chang 2018. *British Journal of Sports Medicine, 53*(22), 1390-1391. doi:10.1136/bjsports-2018-099997 [doi]

Brant, J. A., Johnson, B., Brou, L., Comstock, R. D., & Vu, T. (2019). Rates and patterns of lower extremity sports injuries in all gender-comparable US high school sports. *Orthopaedic Journal of Sports Medicine, 7*(10), 2325967119873059. doi:10.1177/2325967119873059 [doi]

Carbone, A., & Rodeo, S. (2017). Review of current understanding of post-traumatic osteoarthritis resulting from sports injuries. *Journal of Orthopaedic Research : Official Publication of the Orthopaedic Research Society, 35*(3), 397-405. doi:10.1002/jor.23341 [doi]

Chan, C. S., & Grossman, H. Y. (1988). Psychological effects of running loss on consistent runners. *Perceptual and Motor Skills, 66*(3), 875-883. doi:10.2466/pms.1988.66.3.875 [doi]

Chandy, T.A., & Grana, W. A. (1985) Secondary school athletic injury in boys and girls: a three-year comparison. *The Physician and Sports Medicine, 13, 106-111.*

Daoud, A. I., Geissler, G. J., Wang, F., Saretsky, J., Daoud, Y. A., & Lieberman, D. E. (2012). Foot strike and injury rates in endurance runners: A retrospective study. *Medicine and Science in Sports and Exercise, 44*(7), 1325-1334. doi:10.1249/MSS.0b013e3182465115 [doi]

Dohle, S., & Wansink, B. (2013). Fit in 50 years: participation in high school sports best predicts one's physical activity after age 70. *BMC Public Health*, *13*, 1100.

Finch, C. (2006). A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport, 9*(1-2), 3-9; discussion 10. doi:S1440-2440(06)00023-5 [pii]

Hardie Murphy, M., Rowe, D. A., & Woods, C. B. (2016). Sports Participation in Youth as a Predictor of Physical Activity: A 5-Year Longitudinal Study. *Journal of physical activity & health*, *13*(7), 704–711.

Harmer, P. A. (2015). Preventing penetrating hand injuries in sabre fencing: An application and critique of the van mechelen model by the federation internationale d'escrime. *British Journal of Sports Medicine, 49*(17), 1138-1143. doi:10.1136/bjsports-2015-094823 [doi]

Hespanhol Junior, L. C., Pillay, J. D., van Mechelen, W., & Verhagen, E. (2015). Meta-analyses of the effects of habitual running on indices of health in physically inactive adults. *Sports Medicine (Auckland, N.Z.), 45*(10), 1455-1468. doi:10.1007/s40279-015-0359-y [doi]

Hulme, A., & Finch, C. F. (2015). From monocausality to systems thinking: A complementary and alternative conceptual approach for better understanding the development and prevention of sports injury. *Injury Epidemiology, 2*(1), 31-1. Epub 2015 Dec 8. doi:10.1186/s40621-015-0064-1 [doi]

Hulme, A., Salmon, P. M., Nielsen, R. O., Read, G. J. M., & Finch, C. F. (2017). From control to causation: Validating a 'complex systems model' of running-related injury development and prevention. *Applied Ergonomics, 65*, 345-354. doi:S0003-6870(17)30159-X [pii]

Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., & Lubans, D. R. (2017). Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Preventive medicine*, *95*, 14–25.

Kerr, Z. Y., Kroshus, E., Grant, J., Parsons, J. T., Folger, D., Hayden, R., & Dompier, T. P. (2016). Epidemiology of national collegiate athletic association men's and women's cross-country injuries, 2009-2010 through 2013-2014. *Journal of Athletic Training, 51*(1), 57-64. doi:10.4085/1062-6050-51.1.10 [doi]

Kilic, O., Kemler, E., & Gouttebarge, V. (2018). The "sequence of prevention" for musculoskeletal injuries among adult recreational footballers: A systematic review of the scientific literature. *Physical Therapy in Sport : Official Journal of the Association of Chartered Physiotherapists in Sports Medicine, 32*, 308-322. doi:S1466-853X(17)30208-0 [pii]

Kluitenberg, B., van Middelkoop, M., Diercks, R., & van der Worp, H. (2015). What are the differences in injury proportions between different populations of runners? A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.), 45*(8), 1143-1161. doi:10.1007/s40279-015-0331-x [doi]

Koplan, J. P., Rothenberg, R. B., & Jones, E. L. (1995). The natural history of exercise: a 10-yr follow-up of a cohort of runners. *Medicine and Science in Sports and Exercise*, *27*(8), 1180–1184.

Lee, D. C., Brellenthin, A. G., Thompson, P. D., Sui, X., Lee, I. M., & Lavie, C. J. (2017). Running as a key lifestyle medicine for longevity. *Progress in Cardiovascular Diseases, 60*(1), 45-55. doi:S0033-0620(17)30048-8 [pii]

Lee, D. C., Pate, R. R., Lavie, C. J., Sui, X., Church, T. S., & Blair, S. N. (2014). Leisure-time running reduces all-cause and cardiovascular mortality risk. *Journal of the American College of Cardiology, 64*(5), 472-481. doi:10.1016/j.jacc.2014.04.058 [doi]

McCrea, M., Hammeke, T., Olsen, G., Leo, P., & Guskiewicz, K. (2004). Unreported concussion in high school football players: Implications for prevention. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine, 14*(1), 13-17. doi:10.1097/00042752-200401000-00003 [doi]

Morris, M., & Salmon, P. (1994). Qualitative and quantitative effects of running on mood. *The Journal of Sports Medicine and Physical Fitness, 34*(3), 284-291.

National Collegiate Athletic Association. (2019). *1981-82 – 2018-19 NCAA SPORTS SPONSORSHIP AND PARTICIPATION RATES REPORT*. https://ncaaorg.s3.amazonaws.com/research/sportpart/2018-19RES_SportsSponsorshipParticipationRatesReport.pdf.

Pasquina, P. F., Griffin, S. C., Anderson-Barnes, V. C., Tsao, J. W., & O'Connor, F. G. (2013). Analysis of injuries from the army ten miler: A 6-year retrospective review. *Military Medicine, 178*(1), 55-60. doi:10.7205/milmed-d-11-00447 [doi]

Pierpoint, L. A., Williams, C. M., Fields, S. K., & Comstock, R. D. (2016). Epidemiology of Injuries in United States High School Track and Field: 2008-2009 Through 2013-2014. *The American Journal of Sports Medicine*, *44*(6), 1463–1468.

Rauh, M. J., Koepsell, T. D., Rivara, F. P., Margherita, A. J., & Rice, S. G. (2006). Epidemiology of musculoskeletal injuries among high school cross-country runners. *American Journal of Epidemiology, 163*(2), 151-159. doi:kwj022 [pii]

Register-Mihalik, J. K., Guskiewicz, K. M., McLeod, T. C., Linnan, L. A., Mueller, F. O., & Marshall, S. W. (2013). Knowledge, attitude, and concussion-reporting behaviors among high school athletes: A preliminary study. *Journal of Athletic Training, 48*(5), 645-653. doi:10.4085/1062-6050-48.3.20 [doi]

Reinking, M. F. (2006). Exercise-related leg pain in female collegiate athletes: The influence of intrinsic and extrinsic factors. *The American Journal of Sports Medicine, 34*(9), 1500-1507. doi:0363546506287298 [pii]

Reinking, M. F., Austin, T. M., & Hayes, A. M. (2010). Risk factors for self-reported exercise-related leg pain in high school cross-country athletes. *Journal of Athletic Training, 45*(1), 51-57. doi:10.4085/1062-6050-45.1.51 [doi]

Shipway, R., & Holloway, I. (2010). Running free: embracing a healthy lifestyle through distance running. *Perspectives in public health*, *130*(6), 270–276.

The National Federation of State High School Associations. (2019). *2018-19 High School Athletics Participation Survey*. https://www.nfhs.org/media/1020412/2018-19_participation_survey.pdf.

van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine (Auckland, N.Z.)*, *14*(2), 82–99.

Verhagen, E. A., van Stralen, M. M., & van Mechelen, W. (2010). Behaviour, the key factor for sports injury prevention. *Sports Medicine (Auckland, N.Z.), 40*(11), 899-906. doi:10.2165/11536890-000000000-00000 [doi]

Videbaek, S., Bueno, A. M., Nielsen, R. O., & Rasmussen, S. (2015). Incidence of running-related injuries per 1000 h of running in different types of runners: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.), 45*(7), 1017-1026. doi:10.1007/s40279-015-0333-8 [doi]

Wallace, J., Bretzin, A., Beidler, E., Hibbler, T., Delfin, D., Gray, H., & Covassin, T. (2020). The underreporting of concussion: Differences between black and white high school athletes likely stemming from inequities. *Journal of Racial and Ethnic Health Disparities,* doi:10.1007/s40615-020-00864-x [doi]

Yang, J., Tibbetts, A. S., Covassin, T., Cheng, G., Nayar, S., & Heiden, E. (2012). Epidemiology of overuse and acute injuries among competitive collegiate athletes. *Journal of Athletic Training, 47*(2), 198-204. doi:10.4085/1062-6050-47.2.198 [doi]

CHAPTER 2

INJURY RISK IN HIGH SCHOOL AND COLLEGIATE CROSS-COUNTRY AND TRACK & FIELD: A SYSTEMATIC REVIEW AND META-ANALYSIS

1 INTRODUCTION

Running is one of the most popular physical activities throughout the world (Hulteen et al, 2017) and has been associated with many valuable health benefits such as improved body composition, reduced risk of cardiovascular disease and cancer, and increased life expectancy (Hespanhol et al 2015, Lee et al 2017, Lee et al 2014). Many adolescents are introduced to the sport of running through participation in cross-country and track and field. In 2018-2019 there were over 1 million adolescents in the United States who participated in high school cross-country and track and field and over 50,000 participants in college (NFHS 2019, NCAA 2019). Unfortunately, these athletes often incur injuries (Kluitenberg et al 2015, Kerr et al 2016, Pierpiont et al 2016, Brant et al 2019, Yang et al 2012). While injuries are a problem in many sports, they can be especially detrimental to competitive runners. In addition to painful symptoms that can accompany running injuries, restricted running participation due to injury has been associated with increased anxiety and depression (Chan et al, 1988). Furthermore, running injuries may cause individuals to quit the sport indefinitely and therefore lose its associated health benefits (Koplan et al 1995). Another long-term implication of injury is the potential for developing post-traumatic osteoarthritis (Carbone et al 2017). Recreational running has been associated with reduced risk of hip and knee osteoarthritis, and competitive running may increase its risk (Alentorn-Geli et al 2017). Therefore, to promote health among runners and assist in their continued participation in the sport, injury prevention models should be appropriately developed and implemented.

Two frameworks providing sports injury prevention guidance are van Mechelen's *Sequence of Prevention* and Finch's *Translating Research into Injury Prevention Practice (TRIPP)* (van Mechelen et al 1992, Finch 2006). Both frameworks highlight important stages of injury prevention, beginning with measuring the incidence and severity of sports injuries to better understand how they affect athletes. Both frameworks have subsequent stages that provide information about understanding injury etiology, developing and implementing intervention strategies, and evaluating intervention effectiveness in practice.

While research studies on cross-country and track and field injuries have become more common in recent decades, the findings on injury risk within these sports vary depending on a number of methodological factors such as the length of observation, varied definitions of injury, and different measures of risk (Kluitenberg et al 2015, Kerr et al 2016, Daoud et al 2012, Chandy et al 1985). These varied definitions make it difficult to understand the extent of the injury problem in cross-country and track and field, particularly among high school and collegiate participants who have great potential for lifelong physical activity (Dohle et al 2013, Murphy et al 2015). As it is important to gain better insight into how these methodological factors influence our understanding of injury risk within these sports, one objective of this study was to systematically review literature regarding injury risk within high school and collegiate cross-country and track and field. Another objective was to quantitatively summarize injury risk within this population given different measures of risk and data collection methods across available studies.

2 METHODS

2.1 Search Strategy

Databases were searched in June 2020 with no date restrictions to identify studies that reported data on injury incidences in cross-country and track and field athletes. Two members of the research team independently searched PubMed, SPORTDiscus, and Web of Science. Full details about the search strategy are provided in Appendix 1.

2.2 Study Selection

Studies were screened for the following inclusion criteria: 1) study participants were identified as adolescent or young adult cross-country and/or track and field athletes; 2) the study measured and reported overall or running-related injury incidence by complete sport season(s); 3) the study was based on original research with prospective or retrospective cohort designs; and 4) the article was written in English.

The rationale for requiring season-length observation periods was due to limitations of previous reviews on running injury incidence (Videbaek et al 2015; Kluitenberg et al 2015). These reviews cited variance in estimated injury risk among studies with longer or shorter observation periods. Studies with observation periods shorter than a full season are more likely affected by censoring where athletes who sustain injuries will have considerably less sport exposure and less opportunity to return to the sport prior to the end of the study. Further, if a study only observes injury risk during a portion of the season then it may not include periods of the season where athletes may have heightened risk, such as the early season when athletes might be acclimating to the sport or during intense championship meets at the end of the season. Studies with observation periods longer than a full season would include periods in the off-season when athletes' training frequency or intensity are likely different than in-season. Having season-long observation periods for all studies in this review creates equitable comparisons as participants will share similar experiences in cross country or track and field seasons.

All studies potentially meeting inclusion criteria were reviewed in full text and evaluated for eligibility. Full-text analysis of studies included searching reference lists for additional eligible studies. After full-text review, studies were excluded if they: only reported specific injury diagnoses (anterior knee pain, stress fractures, etc.), specific injury severity (only injuries observed in emergency departments), or if they reported on the same participants and observation period as an already selected study.

2.3 Data Collection

In addition to injury incidence, other data were collected to provide increased context regarding the study populations and original methods of data collection such as: study design, operationalized definition of injury, reported measure of injury incidence (proportion, rate, or both), injury incidence by sex (if reported), participants' sport (cross-country, track and field, or both), participants' level of competition (high school, collegiate, or club), and method of injury reporting (self-report, coaches, athletic trainers and/or physicians).

2.4 Risk of Bias Assessment

To evaluate the risk of bias for studies included in the systematic review and meta-analysis, an established assessment tool was selected that had previously been used to assess research on running injuries in a systematic review (Saragiotto et al 2014) and a meta-analysis (Videbæk et al 2015). The 11-item assessment tool is designed to assess the risk of bias, or systematic error, and uses a point rating system to indicate the quality of the study. Much like in a previous meta-analysis (Videbaek et al 2015), three items were omitted for irrelevance for the present study. Two of these items pertain to the selection and comparison of a non-exposed cohort. The purpose of the present study was to assess the risk of injury during sport participation. Therefore, all participants were exposed to either cross-country and/or track and field. The other omitted item pertains to the use of risk association (odds ratio, relative risk), however, our outcome of interest is injury proportion or rates and not associations with specific risk factors. The risk of bias assessment tool as used in this study is provided in Appendix 2. Two study team members independently reviewed each study for risk of bias. The results of these Risk of Bias Assessments were compared and disagreements were resolved in a consensus meeting.

2.5 Data Analysis

The studies in the meta-analysis were classified into three groups based on their method of measuring and reporting injury risk. One study was excluded from the meta-analysis, as it only reported injury risk in terms of injuries per 1,000 miles (Daoud et al 2012). No other studies used a distance-based measurement of exposure.

1. Injury proportion, defined by the number of participants sustaining at least one injury divided by the total number of participants.
2. Injury rate per athlete-season, defined by the total number of injuries during the observed study period divided by the total number of participants in a season.
3. Injury rate per athletic exposures (AEs), defined by the total number of injuries during the observed study period divided by the total number of sport exposures (i.e., total number of participant competitions and practices).

Some studies presented sufficient data to measure injury risk by one or more of these methods, thus some studies were included in multiple groups. For example, injury proportions could be measured from studies that reported the number of participants who were injured over the course of a season, but did not report the total number of injuries sustained by participants. Other studies reported the total number of injuries and the total number of exposures during the study period, but did not provide any individual-level injury data. Thus, while injury rate per AEs could be measured from these studies, injury proportions were not determinable. One study reported the number of participants who did and did not sustain an injury during the season, the total number of injuries, and the total number of sport exposures and thus its relevant data was included in each of the three groups (Rebella 2015).

Meta-analyses were performed within each group to provide a pooled estimate of injury risk for each measurement. To provide greater context to how injury definitions affect injury risk, separate meta-analyses were performed on studies reporting time-loss injuries and studies reporting all injuries, even if they did not result in an athlete missing a practice or competition. To provide greater context to the injury risk among high school and collegiate cross-country and track and field participants, sub-group meta-analyses were conducted to provide pooled estimates of injury risk for high school, collegiate, cross-country, and track and field participants. To maintain consistency, only time-loss injuries were included in these sub-analyses. Some studies with collegiate athletes reported non-time-loss injuries, therefore including all injuries would likely inflate the risk of injuries among collegiate athletes compared to high school athletes.

Meta-analyses were also conducted based on sex and injury reporting mechanisms. Pooled estimates of injury risk ratio were used to assess the association between female and male participants. Pooled estimates of injury proportion among studies with self-reported injury data and studies with coach or athletic trainer reported injury data were used to measure differences in injury proportion by reporting mechanisms. Meta-analyses were performed using the Metan package in Stata 14.2 statistical software (Stata Corp LP, College Station, Texas, USA). Heterogeneity among studies was expected, so random effect models were used for all analyses unless otherwise noted. I^2 and Tausquared statistics were used to calculate heterogeneity among studies. Less heterogeneity existed in some smaller sub-analyses, where more similar studies were pooled together. In these instances, fixed effect models were used if the I^2 value was below 20%.

3 RESULTS

The initial search resulted in 8,912 potentially eligible studies, whose titles and abstracts were screened for inclusion criteria. Title and abstract screening led to 124 studies appearing to meet inclusion criteria. These 124 studies were retrieved in full text for further evaluation of eligibility. During full-text reviews, 11 more eligible studies found in reference lists were added resulting in 135 studies that were reviewed in full-text. Of these, 108 were excluded for the following reasons: the studies reported only specific injury diagnoses (anterior knee pain, stress fractures, etc.), the studies reported on the same participants and injury observations as an already selected study, the studies reported injury incidence over a period other than a complete cross-country or track and field season (year-round, championship events only, partial season, etc.), and studies that reported only injuries seen in emergency departments. Therefore, this resulted in 27 studies included in the systematic review, details of which can be found in Table 2.1. Of these 27 studies, 16 measured injury risk at the high school level, 10 measured injury risk at the collegiate level, and one study included both high school and collegiate athletes.

Twenty-five of the twenty-seven studies included in the systematic review used prospective designs and only two used retrospective designs. Eight studies used data collected from large multi-sports injury surveillance programs where sports injury information is collected from numerous sports at a collection of schools over time, whereas the other 19 studies collected data from smaller samples of participants from cross-country or track and field and occasionally athletes from other sports. Only studies reporting injury risk separately for cross-country and/or track and field were included in the review.

Nine studies reported injury risk per AEs. Three of these studies measured injury rates in both cross-country and track and field athletes (Brant et al 2019, Powell et al 2004, Yang et al 2012), but only two reported injuries separately for cross-country and track and field (Brant et al 2019, Powell et al 2004) instead of pooling them together (Yang et al 2012). Three studies measured injury risk specifically among cross-country athletes (Kerr et al 2016, Rauh et al 2000, Rauh et al 2006) and four measured injury risk specifically among track and field athletes (Rebella 2015, Rebella et al 2008, Wik et al 2020, Yang et al 2012). The estimated pooled injury rate was 5.33 per 1,000 AEs for all time-loss injuries and 13.1 per 1,000 AEs for studies also measuring non-time-loss injuries. All but one study (Yang et al 2012) reported the rate of time-loss injuries and three studies reported non-time loss injuries (Powell et al 2004, Kerr et al 2016, Yang et al 2012). Figure 2.2 displays detail on the meta-analysis for the rate of time-loss injuries including subgroup analyses by sex where possible. Two studies did not report injuries or injury rates by sex and one study only included males; thus, fewer studies were used to estimate male and female-specific injury risks.

Twelve studies reported data to compute injury rates per athlete-seasons. Three of these studies measured injury rates in both cross-country and track and field, but reported them separately (Beachy et al 1997, Chandy et al 1985, Garrick et al 1978). Three studies measured injury rates per athlete-season in cross-country athletes alone (Dudley et al 2017, Kuhman et al 2016, Rauh et al 2006). Five studies measured injury rates per athlete-season in track and field athletes (Fourchet et al 2011, Leetun et al 2004, Rebella 2015, Rebella et al 2008, Wik et al 2020), but two of them were focused solely on pole vaulters (Rebella 2015, Rebella et al 2008). One study reported injury rate per 100 athlete-seasons in a mixed group of high school participants competing in both cross-country and track and field (Rauh et al 2014). The estimated time-loss injury rate per 100 athlete-seasons for all twelve studies was 39.5. One study additionally reported the non-time-loss injury rate as 68.4 injuries per 100 athlete-seasons. Figure 2.3 displays detail on the meta-analysis for all twelve studies including subgroup analyses by sex where possible. One study (Rauh et al 2014) only measured injuries in girls' cross-country athletes, two studies only measured injuries in boys track and field athletes, and one study did not report injuries or injury rates by sex (Rebella 2015).

Fifteen studies presented data that made it possible to report injury risk as injury proportions. Three studies measured injury proportions in both high school cross-country and track and field, but reported them separately (Beachy et al 1997, McLain et al 1989, Shivley et al 1981). Five studies measured injury risk among cross-country athletes only (Dudley et al 2017, Hayes et al 2019, Kuhman et al 2016, Rauh et al 2007, Ruffe et al

2019) and five measured injury risk in track and field athletes only (Beukeboom et al 2000, DuRant et al 1992, Leetun et al 2004, Rebella 2015, Watson et al 1987). Two studies reported injury proportions with a mixed group of participants competing in both cross-country and track and field (Bring et al 2018, Rauh et al 2014). The estimated pooled injury proportion was 25.3% for time-loss injuries and 49.3% for studies including non-time-loss injuries. Figure 2.4 displays detail on the meta-analysis for all fifteen studies including subgroup analyses by sex where possible. One study (Rauh et al 2014) only measured injuries in girl's cross-country athletes three studies did not report injuries or injury rates by sex (Beukeboom et al 2000, Bring 2018, Leetun et al 2004). Figure 2.4 displays detail on the meta-analysis for all fifteen studies including subgroup analyses by sex where possible.

Only one study reported injury risk in terms of injury rate per miles and it measured injury incidence in a cohort of collegiate cross-country runners (n=52) for the purpose of measuring if any association was present between the type of foot strike runners use and injury risk (Daoud et al 2012). This study observed 248 injuries over a 5-year period when cross-country runners accumulated 182,879 miles, translating to 1.36 injuries per 1,000 miles.

Table 2.3 displays the different injury risks presented by studies when measuring only time-loss injuries versus studies including all injuries regardless if an athlete missed any practice or competition. Only five studies recorded non-time-loss injuries compared to

21 studies only recording time-loss injuries. However, four of the five studies recording non-time-loss injuries also reported the frequency of time-loss injuries so these studies were included in the meta-analyses of time loss injuries by athletic exposure, athlete-seasons, and injury proportions. As expected, the risk of injury was higher in the studies recording non-time-loss injuries.

Table 2.4 displays the results of sub-group meta-analyses on time-loss injury risk among high school, collegiate, cross-country, and track and field athletes for each measurement type. Table 2.5 displays a comparison of male and female injury rates using Injury Rate Ratios for Injuries per 1,000 AEs and Injuries per 100 Athlete-seasons. Female injury risk was significantly higher for Injuries per 1,000 AEs and nearing significance for Injuries per 100 Athlete-seasons (95% CI 0.99-1.13).

Only three studies collected injury data directly from athletes (DuRant et al 1992, Kuhman et al 2016, Hayes et al 2019), whereas the rest collected injury data from coaches, athletic trainers, or physicians. All three studies collecting self-reported injury data from athletes used injury proportion as a measure of injury risk, so a meta-analysis was conducted to estimate the pooled injury proportions from these studies while a separate meta-analysis was used to estimate the pooled injury proportion from fourteen other studies. The estimated time-loss injury proportion was 37.5% for studies with athlete-reported and 24% for studies with injured reported by coaches or athletic trainers.

4 DISCUSSION

This meta-analysis estimated injury risk in cross-country and track and field athletes by pooling measures of injury risk from studies ranging in publication from 1978 to 2020. Some of the key findings include an estimated time-loss injury risk of 5.3 injuries per 1,000 AEs, 39.5 injuries per 100 athlete-seasons, and a prevalence of 25.3% injured over the course of a season. Females tended to have similar or slightly elevated risk of injury compared to males across two measurement types with the largest injury risk ratio reported in studies measuring injury rates per AEs (IRR=1.28, 1.11-1.48 95% CI). There were no large discrepancies in injury risk between cross-country and track and field except for studies that measured injury risk as injuries per athlete-seasons, 37.4 and 53.3 per 100 Athlete-seasons. However, much of this difference can be contributed to one study with adolescent track and field athletes that reported an injury risk four-times higher than most other studies (Fourchet et al 2011). The authors of this study used a time-loss definition of injury. Although speculative, it may be possible that the coaches and medical staff were more sensitive to evaluating injuries thus more injuries were recorded than most studies. Additionally, the purpose of their study was to investigate how biological maturation influenced injury risk and found that late-maturing or pre-pubertal adolescents were at greater risk of certain lower extremity injuries. It may be possible that their study involved more late-maturing adolescents competing at an elite-level compared to other studies, which may also contribute to a greater injury risk. Regardless of the reasons this study had significantly higher injury rates, it presents as an outlier in the meta-analysis. If it were to be removed from the sub-analysis then estimated track and field injury rates per 100 Athlete-seasons becomes 37.7, almost identical to the 37.4 injuries per 100 cross-country athlete-seasons.

While cross country and track and field injury risks appear relatively similar, there were notable differences of estimated injury risk between high school and collegiate athletes. When measuring injuries by the number of AEs, high school athletes displayed a higher estimate of injury risk than collegiate athletes (6.11 and 3.90 injuries per 1,000 AEs, respectively). However, collegiate athletes tended to have a greater injury risk when comparing injuries per 100 athlete-seasons (47.6 and 38.1, respectively) or injury proportion (45.6 and 17.5, respectively). There may be multiple explanations for these differing patterns. First, collegiate athletes may be more likely to suffer an injury during the season due to their seasons providing a substantially greater exposure to the sport. For instance, if collegiate cross-country or track and field athletes have greater number of practices and competitions over the course of longer seasons then their frequency of injury per athletic exposure would be relatively lower than high school athletes'. Secondly, differences in injuries per athletic exposures could partially be due to data collection methods. When comparing studies reporting injury by AEs, each of the studies with collegiate athletes used injury reports attained from athletic trainers; whereas studies with high school athletes used injury reports attained from either athletic trainers or coaches. This may be an important difference as the employment status and availability of athletic trainers can influence injury reporting so that less-available or part-time athletic trainers tend to report fewer injuries (McGuine et al 2018, Kerr et al 2016).

When athletic trainers only work in a setting part-time or if they are responsible for caring for larger numbers of athletes then there may be a time delay in which an injured athlete may seek care elsewhere or may be more likely to self-manage an injury without disclosing it to a trainer. Athletic trainers in college settings often have fewer athletes to care for and are thus more readily available to evaluate and report injuries compared to athletic trainers in high school settings. Recent reports measured a ratio of 87 athletes to 1 athletic trainer in some collegiate settings compared to 515 athletes to 1 athletic trainer in public high schools (Bradley et al 2015, Pryor et al 2015). Among the studies in the current review, injury rates among high school athletes tended to be much lower when reported by an athletic trainer compared to coaches. A sub-group analysis on the three studies using athletic trainers or physiotherapists to report injuries in high school athletes revealed a pooled estimate of only 1.09 injuries per 1,000 AEs compared to an estimated 14.9 injuries per 1,000 AEs among the two studies which used injury reports from coaches. This large discrepancy may be due in part to an increased availability of high school coaches compared to athletic trainers and the consistent daily interactions coaches have with their athletes. These more consistent interactions may provide more opportunities for athletes to disclose injury symptoms or for coaches to observe changes in athletes' technique or performance that may indicate the presence of an injury.

This review also examined how injury risks differ when injuries are self-reported as opposed to injury reports from coaches and athletic trainers. Among 14 studies using coach and/or athletic trainers to report injuries, a pooled estimate revealed an injury prevalence of 24% among athletes while three studies using self-reported injuries estimated an injury prevalence of 37.5%. Some of this difference may be explained by the availability of athletic trainers as many of the studies in the coach or athletic trainer group were with high school athletes, while the two of the three studies using self-reported injuries involved collegiate athletes. However, studies have revealed underreporting of injuries with or without athletic trainers present (Wallace et al 2017, McCrea et al 2004, Register-Mihalik et al 2013, Baugh et al 2019, Kox et al 2019). While literature regarding the underreporting of sports injuries is dominated by concussion research, it is important to understand what factors are related to athletes' timing and decision to report the gradual-onset overuse injuries prevalent in cross-country and track and field. To continue providing context into sports injury surveillance findings, it is important for future research to understand factors pertaining to when and how athletes disclose overuse injury symptoms to coaches and trainers. If symptoms are reported at an earlier and milder stage of injury then perhaps progression to more severe injury may be avoided. Similarly, it is also important to better understand how coaches, athletic trainers, and other healthcare professionals evaluate and manage overuse injuries when athletes first present with symptoms.

This systematic review only identified one study on high school or collegiate cross-country and/or track and field that reported injury risk over a season in terms of injuries per distance ran (Daoud et al 2012) and no studies reporting injury risk in terms of injuries per hours of sport exposure. Reporting injury risk in terms of sport exposure expressed in time or distance is an effective method to control for censoring effects while also conveying injury risk in measures most compatible with how many training plans are designed for runners (running for time or distance). Some studies do report injuries in track and field athletes per 1,000 hours with injury rates ranging from 2.5 per 1,000 hours in distance runners to 5.8 per 1,000 hours in sprinters (Lysholm et al 1987, Bennell et al 1996, von Rosen et al 2018, Jacobsson et al 2013). However, each of these studies observed injuries for a full year mostly in elite youth or club-level athletes who did not match the participants included in this review.

A limitation of this meta-analysis is the heterogeneity of included studies. The eligibility criteria controlled for the length of the observation period and the ages of participants, but many other factors may have resulted in the heterogeneity of injury rates. Many studies used different injury definitions, which is why most analyses conducted in this study used time-loss injury definitions to control bias that may be encountered from less concrete injury definitions. The risk of bias assessment revealed variances in how injuries were assessed, how sport exposure was measured, and how participants were followed throughout the study period. Each of these are examples of heterogeneity of the included studies, which may have impacted the injury rates they reported. We used random effects models to help control for analyses with heterogenous studies, but it is still an important limitation affecting sports injury research.

The main findings of this systematic review and meta-analysis indicate a likely greater risk of injury by sex and competition level. Females tended to exhibit greater injury risk than males and collegiate athletes exhibited a higher prevalence of injury over the course of a season compared to high school athletes, however, high school athletes demonstrated a higher rate of injury when accounting for their relative decreased sport exposure. Continued efforts to prevent injuries in female and high school cross-country and track and field athletes are warranted, but improved methods of measuring sport exposure should be implemented to better assess the risk of injury among these athletes. Specifically, using time, distance, and/or intensity when accounting for sport exposure should provide a more accurate assessment of injury risk. Another important observation in this review is the effect of injury reporting mechanisms on injury rates. Studies using self-reported injuries may be more sensitive than other reporting mechanisms such as coaches or athletic trainers. This may indicate the underreporting of injuries in cross-country and track and field. To continue advancing sports injury prevention and develop effective injury prevention programs it is important to accurately measure the rate of injuries within sports. Future research should provide more context to the process of reporting injuries by using qualitative and behavior-science approaches to better understand factors related to how and when injuries are reported in cross-country and track and field and in turn, how this affects injury data collected in research.

REFERENCES

Baugh, C. M., Meehan, W. P., Kroshus, E., McGuire, T. G., & Hatfield, L. A. (2019). College football players less likely to report concussions and other injuries with increased injury accumulation. *Journal of Neurotrauma, 36*(13), 2065-2072. doi:10.1089/neu.2018.6161 [doi]

Beachy, G., Akau, C. K., Martinson, M., & Olderr, T. F. (1997). High school sports injuries. A longitudinal study at punahou school: 1988 to 1996. *The American Journal of Sports Medicine, 25*(5), 675-681. doi:10.1177/036354659702500515 [doi]

Bennell, K. L., & Crossley, K. (1996). Musculoskeletal injuries in track and field: incidence, distribution and risk factors. *Australian Journal of Science and Medicine in Sport*, *28*(3), 69–75.

Beukeboom, C., Birmingham, T. B., Forwell, L., & Ohrling, D. (2000). Asymmetrical strength changes and injuries in athletes training on a small radius curve indoor track. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine, 10*(4), 245-250. doi:10.1097/00042752-200010000-00004 [doi]

Bolling, C., van Mechelen, W., Pasman, H. R., & Verhagen, E. (2018). Context matters: Revisiting the first step of the 'sequence of prevention' of sports injuries. *Sports Medicine (Auckland, N.Z.), 48*(10), 2227-2234. doi:10.1007/s40279-018-0953-x [doi]

Bradley, R., Cromartie, F., Briggs, J., Battenfield, F., & Boulet, J. (2015). Ratios of Certified Athletic Trainers' to Athletic Teams and Number of Athletes in South Carolina Collegiate Settings. *The Sport Journal*.

Brant, J. A., Johnson, B., Brou, L., Comstock, R. D., & Vu, T. (2019). Rates and patterns of lower extremity sports injuries in all gender-comparable US high school sports. *Orthopaedic Journal of Sports Medicine, 7*(10), 2325967119873059. doi:10.1177/2325967119873059 [doi]

Bring, B. V., Chan, M., Devine, R. C., Collins, C. L., Diehl, J., & Burkam, B. (2018). Functional movement screening and injury rates in high school and collegiate runners: A retrospective analysis of 3 prospective observational studies. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine, 28*(4), 358-363. doi:10.1097/JSM.0000000000000459 [doi]

Carbone, A., & Rodeo, S. (2017). Review of current understanding of post-traumatic osteoarthritis resulting from sports injuries. *Journal of Orthopaedic Research : Official Publication of the Orthopaedic Research Society, 35*(3), 397-405. doi:10.1002/jor.23341 [doi]

Chan, C. S., & Grossman, H. Y. (1988). Psychological effects of running loss on consistent runners. *Perceptual and Motor Skills, 66*(3), 875-883. doi:10.2466/pms.1988.66.3.875 [doi]

Chandy, T.A., & Grana, W. A. (1985) Secondary school athletic injury in boys and girls: a three-year comparison. *The Physician and Sports Medicine, 13, 106-111.*

Daoud, A. I., Geissler, G. J., Wang, F., Saretsky, J., Daoud, Y. A., & Lieberman, D. E. (2012). Foot strike and injury rates in endurance runners: A retrospective study. *Medicine and Science in Sports and Exercise, 44*(7), 1325-1334. doi:10.1249/MSS.0b013e3182465115 [doi]

Dohle, S., & Wansink, B. (2013). Fit in 50 years: participation in high school sports best predicts one's physical activity after age 70. *BMC Public Health*, *13*, 1100.

Dudley, R. I., Pamukoff, D. N., Lynn, S. K., Kersey, R. D., & Noffal, G. J. (2017). A prospective comparison of lower extremity kinematics and kinetics between injured and non-injured collegiate cross country runners. *Human Movement Science, 52*, 197-202. doi:S0167-9457(17)30124-0 [pii]

Finch, C. (2006). A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport, 9*(1-2), 3-9; discussion 10. doi:S1440-2440(06)00023-5 [pii]

Garrick, J. G., & Requa, R. K. (1978). Injuries in high school sports. *Pediatrics, 61*(3), 465-469. doi:10.1542/peds.61.3.465 [doi]

Gonzalez, L., Jones, L. E., Fakeh, M., Shah, N., Panchella, J. A., & Shendell, D. G. (2020). Incidence reporting via online high school concussion surveillance by certified athletic trainers and school nurses, 2015-2018. *Injury Epidemiology, 7*(1), 1-5. doi:10.1186/s40621-019-0228-5 [doi]

Hardie Murphy, M., Rowe, D. A., & Woods, C. B. (2016). Sports Participation in Youth as a Predictor of Physical Activity: A 5-Year Longitudinal Study. *Journal of physical activity & health*, *13*(7), 704–711.

Hayes, L. E., Boulos, A., & Cruz, A. I. (2019). Risk factors for in-season injury in varsity collegiate cross-country athletes: An analysis of one season in 97 athletes. *The Journal of Sports Medicine and Physical Fitness, 59*(9), 1536-1543. doi:10.23736/S0022-4707.19.09221-1 [doi]

Hespanhol Junior, L. C., Pillay, J. D., van Mechelen, W., & Verhagen, E. (2015). Meta-analyses of the effects of habitual running on indices of health in physically inactive adults. *Sports Medicine (Auckland, N.Z.), 45*(10), 1455-1468. doi:10.1007/s40279-015-0359-y [doi]

Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., & Lubans, D. R. (2017). Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Preventive medicine*, *95*, 14–25.

Jacobsson, J., Timpka, T., Kowalski, J., Nilsson, S., Ekberg, J., Dahlstrom, O., & Renstrom, P. A. (2013). Injury patterns in swedish elite athletics: Annual incidence, injury types and risk factors. *British Journal of Sports Medicine, 47*(15), 941-952. doi:10.1136/bjsports-2012-091651 [doi]

Kerr, Z. Y., Kroshus, E., Grant, J., Parsons, J. T., Folger, D., Hayden, R., & Dompier, T. P. (2016). Epidemiology of national collegiate athletic association men's and women's cross-country injuries, 2009-2010 through 2013-2014. *Journal of Athletic Training, 51*(1), 57-64. doi:10.4085/1062-6050-51.1.10 [doi]

Kerr, Z. Y., Lynall, R. C., Mauntel, T. C., & Dompier, T. P. (2016). High school football injury rates and services by athletic trainer employment status. *Journal of Athletic Training, 51*(1), 70-73. doi:10.4085/1062-6050-51.3.02 [doi]

Kiernan, D., Hawkins, D. A., Manoukian, M. A. C., McKallip, M., Oelsner, L., Caskey, C. F., & Coolbaugh, C. L. (2018). Accelerometer-based prediction of running injury in national collegiate athletic association track athletes. *Journal of Biomechanics, 73*, 201-209. doi:S0021-9290(18)30265-3 [pii]

Kluitenberg, B., van Middelkoop, M., Diercks, R., & van der Worp, H. (2015). What are the differences in injury proportions between different populations of runners? A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.), 45*(8), 1143-1161. doi:10.1007/s40279-015-0331-x [doi]

Koplan, J. P., Rothenberg, R. B., & Jones, E. L. (1995). The natural history of exercise: a 10-yr follow-up of a cohort of runners. *Medicine and Science in Sports and Exercise*, *27*(8), 1180–1184.

Kox, L. S., Kuijer, P., Opperman, J., Kerkhoffs, G., Maas, M., & Frings-Dresen, M. (2019). Content validity of the SOS-WRIST questionnaire for timely identification of wrist overuse in young athletes. *The Physician and Sportsmedicine*, *47*(3), 341–349.

Kuhman, D. J., Paquette, M. R., Peel, S. A., & Melcher, D. A. (2016). Comparison of ankle kinematics and ground reaction forces between prospectively injured and uninjured collegiate cross country runners. *Human Movement Science, 47*, 9-15. doi:S0167-9457(16)30013-6 [pii]

Lee, D. C., Brellenthin, A. G., Thompson, P. D., Sui, X., Lee, I. M., & Lavie, C. J. (2017). Running as a key lifestyle medicine for longevity. *Progress in Cardiovascular Diseases, 60*(1), 45-55. doi:S0033-0620(17)30048-8 [pii]

Lee, D. C., Pate, R. R., Lavie, C. J., Sui, X., Church, T. S., & Blair, S. N. (2014). Leisure-time running reduces all-cause and cardiovascular mortality risk. *Journal of the American College of Cardiology, 64*(5), 472-481. doi:10.1016/j.jacc.2014.04.058 [doi]

McCrea, M., Hammeke, T., Olsen, G., Leo, P., & Guskiewicz, K. (2004). Unreported concussion in high school football players: Implications for prevention. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine, 14*(1), 13-17. doi:10.1097/00042752-200401000-00003 [doi]

McGuine, T. A., Pfaller, A. Y., Post, E. G., Hetzel, S. J., Brooks, A., & Broglio, S. P. (2018). The influence of athletic trainers on the incidence and management of concussions in high school athletes. *Journal of Athletic Training, 53*(11), 1017-1024. doi:10.4085/1062-6050-209-18 [doi]

National Collegiate Athletic Association. (2019). *1981-82 – 2018-19 NCAA SPORTS SPONSORSHIP AND PARTICIPATION RATES REPORT.*

https://ncaaorg.s3.amazonaws.com/research/sportpart/2018-19RES_SportsSponsorshipParticipationRatesReport.pdf.

Pierpoint, L. A., Williams, C. M., Fields, S. K., & Comstock, R. D. (2016). Epidemiology of Injuries in United States High School Track and Field: 2008-2009 Through 2013-2014. *The American Journal of Sports Medicine*, *44*(6), 1463–1468.

Powell, J. W., & Dompier, T. P. (2004). Analysis of injury rates and treatment patterns for time-loss and non-time-loss injuries among collegiate student-athletes. *Journal of Athletic Training, 39*(1), 56-70.

Pryor, R. R., Casa, D. J., Vandermark, L. W., Stearns, R. L., Attanasio, S. M., Fontaine, G. J., & Wafer, A. M. (2015). Athletic training services in public secondary schools: a benchmark study. *Journal of Athletic Training*, *50*(2), 156–162.

Rauh, M. J. (2014). Summer training factors and risk of musculoskeletal injury among high school cross-country runners. *The Journal of Orthopaedic and Sports Physical Therapy, 44*(10), 793-804. doi:10.2519/jospt.2014.5378 [doi]

Rauh M. J. (2018). Leg-length inequality and running-related injury among high school runners. *International Journal of Sports Physical Therapy*, *13*(4), 643–651.

Rauh, M. J., Barrack, M., & Nichols, J. F. (2014). Associations between the female athlete triad and injury among high school runners. *International Journal of Sports Physical Therapy, 9*(7), 948-958.

Rauh, M. J., Koepsell, T. D., Rivara, F. P., Margherita, A. J., & Rice, S. G. (2006). Epidemiology of musculoskeletal injuries among high school cross-country runners. *American Journal of Epidemiology, 163*(2), 151-159. doi:kwj022 [pii]

Rauh, M. J., Koepsell, T. D., Rivara, F. P., Rice, S. G., & Margherita, A. J. (2007). Quadriceps angle and risk of injury among high school cross-country runners. *The Journal of Orthopaedic and Sports Physical Therapy, 37*(12), 725-733. doi:10.2519/jospt.2007.2453 [doi]

Rauh, M. J., Margherita, A. J., Rice, S. G., Koepsell, T. D., & Rivara, F. P. (2000). High school cross country running injuries: A longitudinal study. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine, 10*(2), 110-116. doi:10.1097/00042752-200004000-00005 [doi]

Rebella, G. (2015). A prospective study of injury patterns in collegiate pole vaulters. *The American Journal of Sports Medicine, 43*(4), 808-815. doi:10.1177/0363546514564542 [doi]

Rebella, G. S., Edwards, J. O., Greene, J. J., Husen, M. T., & Brousseau, D. C. (2008). A prospective study of injury patterns in high school pole vaulters. *The American Journal of Sports Medicine, 36*(5), 913-920. doi:10.1177/0363546507313571 [doi]

Register-Mihalik, J. K., Guskiewicz, K. M., McLeod, T. C., Linnan, L. A., Mueller, F. O., & Marshall, S. W. (2013). Knowledge, attitude, and concussion-reporting behaviors among high school athletes: A preliminary study. *Journal of Athletic Training, 48*(5), 645-653. doi:10.4085/1062-6050-48.3.20 [doi]

Requa, R. K., & Garrick, J. G. (1981). Injuries in interscholastic track and field. *The Physician and Sportsmedicine, 9*(3), 42-49. doi:10.1080/00913847.1981.11711030 [doi]

Ruffe, N. J., Sorce, S. R., Rosenthal, M. D., & Rauh, M. J. (2019). Lower quarter- and upper quarter Y balance tests as predictors of running-related injuries in high school cross-country runners. *International Journal of Sports Physical Therapy, 14*(5), 695-706.

Saragiotto, B. T., Yamato, T. P., Hespanhol Junior, L. C., Rainbow, M. J., Davis, I. S., & Lopes, A. D. (2014). What are the main risk factors for running-related injuries? *Sports Medicine (Auckland, N.Z.), 44*(8), 1153-1163. doi:10.1007/s40279-014-0194-6 [doi]

The National Federation of State High School Associations. (2019). *2018-19 High School Athletics Participation Survey*. https://www.nfhs.org/media/1020412/2018-19_participation_survey.pdf.

van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine (Auckland, N.Z.)*, *14*(2), 82–99.

Videbaek, S., Bueno, A. M., Nielsen, R. O., & Rasmussen, S. (2015). Incidence of running-related injuries per 1000 h of running in different types of runners: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.), 45*(7), 1017-1026. doi:10.1007/s40279-015-0333-8 [doi] von Rosen, P., Heijne, A., Frohm, A., Friden, C., & Kottorp, A. (2018). High injury burden in elite adolescent athletes: A 52-week prospective study. *Journal of Athletic Training, 53*(3), 262-270. doi:10.4085/1062-6050-251-16 [doi]

Wallace, J., Covassin, T., Nogle, S., Gould, D., & Kovan, J. (2017). Knowledge of concussion and reporting behaviors in high school athletes with or without access to an athletic trainer. *Journal of Athletic Training, 52*(3), 228-235. doi:10.4085/1062-6050-52.1.07 [doi]

Watson, M. D., & DiMartino, P. P. (1987). Incidence of injuries in high school track and field athletes and its relation to performance ability. *The American Journal of Sports Medicine, 15*(3), 251-254. doi:10.1177/036354658701500310 [doi]

Yang, J., Tibbetts, A. S., Covassin, T., Cheng, G., Nayar, S., & Heiden, E. (2012). Epidemiology of overuse and acute injuries among competitive collegiate athletes. *Journal of Athletic Training, 47*(2), 198-204. doi:10.4085/1062-6050-47.2.198 [doi]

Yard, E. E., Collins, C. L., & Comstock, R. D. (2009). A comparison of high school sports injury surveillance data reporting by certified athletic trainers and coaches. *Journal of Athletic Training, 44*(6), 645-652. doi:10.4085/1062-6050-44.6.645 [doi]

TABLES & FIGURES

Figure 2.1. Flow of the selection process of studies in the systematic review

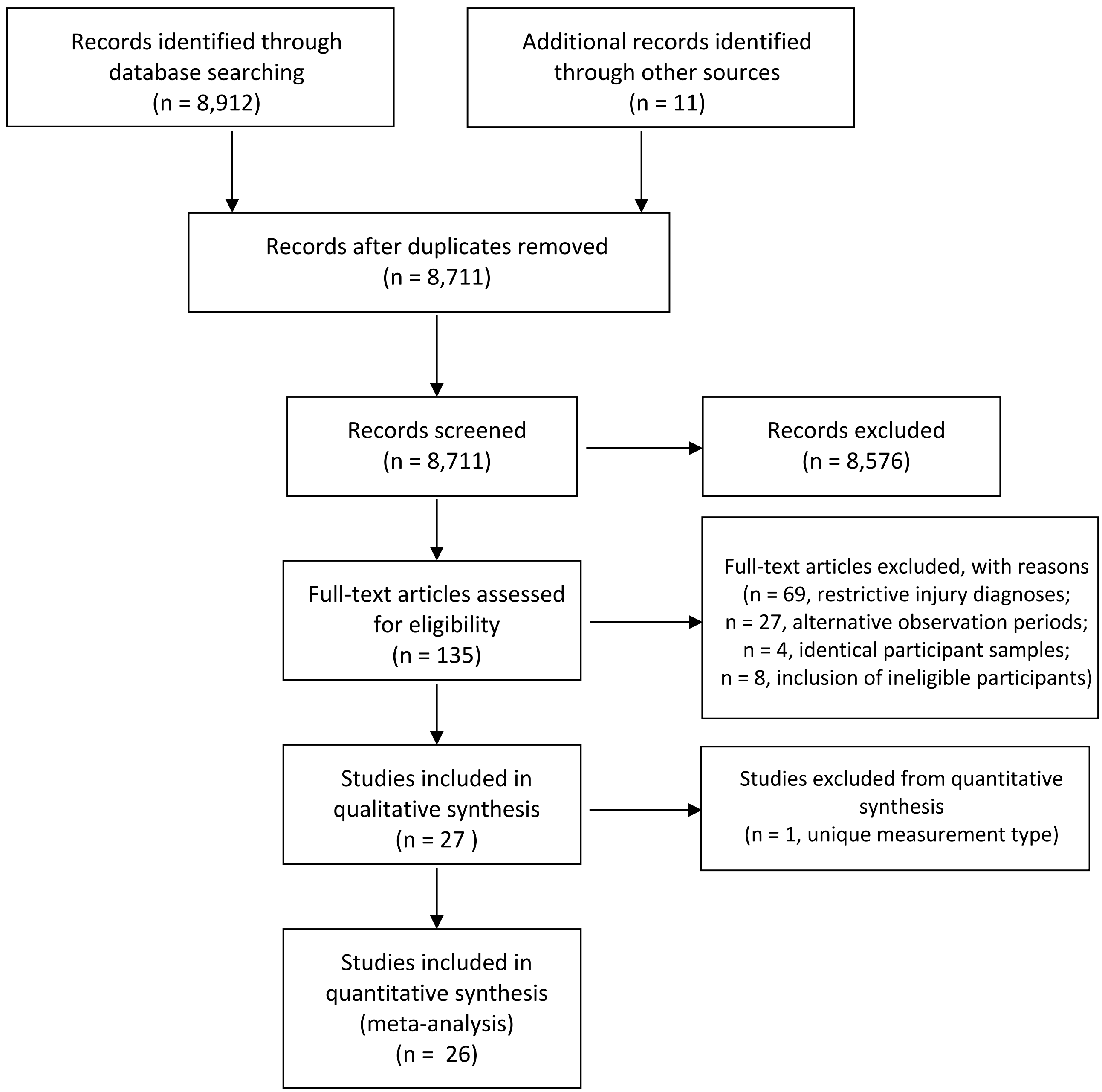


Table 2.1. Characteristics of studies included in the systematic review

Author	Study Design	Study population	Injury definition	Measure(s) of injury risk
Beachy et al 1997	Prospective Cohort	1,288 high school cross-country athletes 2,736 high school track and field athletes	"Any athlete complaint that required the attention of the athletic trainer, regardless of the time lost from activity"	Injury proportion, Injury rate per 100 athlete-seasons
Beukeboom et al 2000	Prospective Cohort	25 collegiate track and field athletes	"An injury was defined as any physical incident reported to the trainer, or directly to the sport medicine clinic, that resulted in cessation, reduction, or alteration in training."	Injury proportion Injury rate per 1,000 AEs Injury rate per 100 athlete-seasons
Brant et al 2019	Prospective Cohort	High school cross-country and track and field athletes at schools participating in Reporting Injuries Online (RIO)	"A reportable injury was one which (1) occurred as a result of participation in practice or competition, (2) required medical attention from an AT or physician, and (3) either restricted the athlete's participation in the sport for at least 1 day beyond the date of injury or resulted in any fracture, concussion, dental injury, or heat illness regardless of whether it resulted in a restriction of the student-athlete's participation"	Injury rate per 1,000 AEs
Bring et al 2018	Prospective Cohort	183 high school and collegiate cross country and track and field athletes	"Any musculoskeletal complaint from participation in a team organized event that requires evaluation by an AT or any physician. An injury was one that required modification, limitation, or exclusion from workouts, practice, or games"	Injury proportion
Chandy et al 1985	Prospective Cohort	10,642 High school track and field athletes (4,235 female; 6,407 male) 2,278 high school cross-country athletes (711 female; 1,567 male)	"Any problem that resulted in an altered or lost practice session or game"	Injury rate per 100 athlete-seasons
Daoud et al 2012	Retrospective Cohort	52 collegiate cross-country athletes (23 females; 29 males)	"Injuries defined as mild, moderate, and severe based on Running Injury Severity Score, which sums days at 5	Injury rate per 1,000 miles

			different severity levels ranging from full (no restrictions) to off (no running or cross-training)"	
Dudley et al 2017	Prospective Cohort	31 collegiate cross-country athletes (16 female; 15 male)	"A RRI was defined as any musculoskeletal complaint of the lower extremities or back causing the restriction of participation in one full practice session"	Injury proportion
DuRant et al 1992	Retrospective Cohort	160 high school track and field athletes (57 females; 103 males)	"An injury was sustained during participation in school-sponsored sports that either required them to seek medical care from a physician and/or caused them to miss one or more games"	Injury proportion
Fourchet et al 2011	Prospective Cohort	110 male high school track and field athletes	"An injury was defined as a trauma occurring during track and field training or competition, which required one or more physiotherapy treatments and prevented the athlete from participating in one or more training sessions or competitive events"	Injury rate per 100 athlete-seasons
Garrick et al 1978	Prospective Cohort	167 high school cross-country athletes (26 female; 141 male) 516 high school track and field athletes (208 female; 308 male)	"An injury was defined as "a medical problem resulting from athletic participation necessitating removal from a practice or competitive event and/or resulting in missing a subsequent practice or competitive event"	Injury rate per 100 athlete-seasons
Hayes et al 2019	Prospective Cohort	97 collegiate cross-country athletes (57 female; 40 male)	No clear injury definition reported	Injury proportion
Leetun et al 2004	Prospective Cohort	36 collegiate cross-country athletes (20 female; 16 male)	"An injury was defined as an event that occurred during athletic participation and required treatment or attention from the athletic trainer, team doctor, or other medical staff. Further, the event must have resulted in at least one full missed day of practice or sport participation."	Injury proportion Injury rate per 100 athlete-seasons
Kerr et al 2016	Prospective Cohort	25 male collegiate cross-country teams & 22 female collegiate cross-country teams	"A reportable injury in the ISP was defined as an injury that (1) occurred as a result of participation in an organized intercollegiate practice or competition and (2) required attention from an AT or physician."	Injury rate per 1,000 AEs
Kuhman et al 2016	Prospective Cohort	19 collegiate cross-country athletes (8 female; 11 male)	No clear injury definition reported	Injury proportion

				Injury rate per 100 athlete-seasons
McLain et al 1989	Prospective Cohort	94 high school cross-country athletes and 135 high school track and field athletes	Paraphrased definition: An injury was defined as occurring in practice or a game, examined immediately by the head athletic trainer or assistant and causing the athlete to not return to sport the same day	Injury proportion
Powell et al 2004	Prospective Cohort	Collegiate cross-country and track and field teams	"Injuries and/or illnesses (cases and problems) meeting any of the following definitions are reportable, even if they are not sport related. A. When the evaluation identifies a complaint to be sufficient to require the player to be restricted from participation B. Any injury or illness that is not sufficient to be initialized as a case (time-loss incident) and that causes the athletic trainer to conduct an evaluation of the player's complaint is reported as a problem (non–time-loss incident). "	Injury rate per 1,000 AEs
Rauh et al 2000	Prospective Cohort	23 high school cross-country teams	"An injury was defined as a medical problem resulting from athletic participation that required an athlete to be removed from a practice or competitive event or to miss a subsequent practice or competitive event"	Injury rate per 1,000 AEs
Rauh et al 2006	Prospective Cohort	421 high school cross-country athletes (186 female; 235 male)	"Any reported muscle, joint, or bone problem/injury of the back or lower extremity (i.e., hip, thigh, knee, shin, calf, ankle, foot) resulting from running in a practice or meet and requiring the runner to be removed from a practice or meet or to miss a subsequent one "	Injury rate per 1,000 AEs Injury rate per 100 athlete-seasons
Rauh et al 2007	Prospective Cohort	393 high school cross-country athletes (171 girls; 222 boys)	Same as Rauh et al 2006	Injury proportion
Rauh et al 2014	Prospective Cohort	89 girls high school cross-country and track athletes	Same as Rauh et al 2006	Injury proportion
Rebella et al 2008	Prospective Cohort	140 high school track and field athletes (pole vaulters)	"The authors defined a reportable injury as one that caused the athlete to stop participating that day or miss a subsequent practice/competition, any head or neck injury, or any injury that caused the athlete to seek medical attention"	Injury rate per 1,000 AEs Injury rate per 100 athlete-seasons

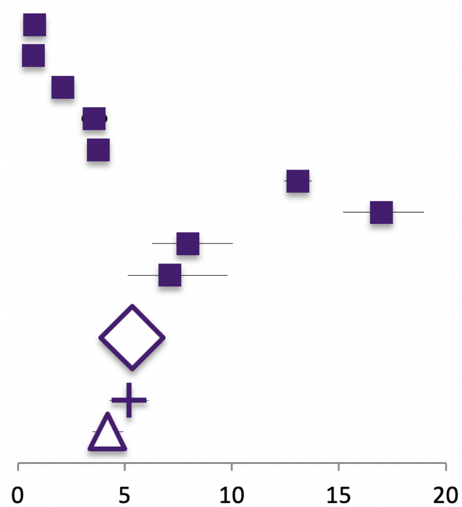
Rebella 2015	Prospective Cohort	135 collegiate track and field athletes (52 female; 83 male pole vaulters)	"A reportable injury was defined as one that (1) occurred during any pole vault–related activity and (2) caused the athlete to cease participation that day or miss a subsequent practice/competition or included any head, neck, or dental trauma"	Injury proportion Injury rate per 1,000 AEs Injury rate per 100 athlete-seasons
Ruffe et al 2019	Prospective Cohort	148 high school cross-country athletes (80 female; 68 male)	"A running- related injury (RRI) was defined as any reported muscle, bone, or joint problem/injury to the low back or lower extremity (hip, thigh, knee, lower leg [shin, calf], ankle, or foot) that required the runner to be removed from a practice and/or competitive event or miss a subsequent practice and/or competitive event."	Injury proportion
Shivley et al 1981	Prospective Cohort	567 high school cross-country athletes; 2,823 high school track and field athletes	"An injury was defined as any event that altered the ability of a participant to compete or practice in the usual manner"	Injury proportion
Watson et al 1987	Prospective Cohort	234 high school track and field athletes (78 female; 156 male)	"An injury was defined as any mishap that occurred during a track meet or practice which 1) caused the athlete to miss a track meet or two or more practice sessions, or 2) caused the athlete to decrease or change his/her workout routine because of pain for two or more practice sessions"	Injury proportion
Wik et al 2020	Prospective Cohort	74 male high school track and field athletes	"Only time-loss injuries were included in the analysis, defined as the athlete not being able to fully take part in athletics training and/or competition the day after the incident occurred"	Injury rate per 1,000 AEs Injury rate per 100 athlete-seasons
Yang et al 2012	Prospective Cohort	Collegiate cross-country and track and field teams participating in Big Ten Athletic Conference injury surveillance program	"Injuries included in this study met the following 2 criteria: clinical signs of tissue damage determined by team athletic trainers or team physicians and inability of the player to return to practice or game the same day"	Injury rate per 1,000 AEs

Table 2.2. Risk of Bias Assessment

Study	#1	#2	#3	#4	#5	#6	#7	#8	Total
Beachy et al 1997	1	1	1	0	0	1	1	0	5/8
Beukeboom et al 2000	1	0	1	0	1	1	1	0	5/8
Brant et al 2019	1	1	1	1	0	1	1	0	6/8
Bring et al 2018	1	1	1	1	1	1	1	1	8/8
Chandy et al 1985	1	1	1	1	0	1	1	0	6/8
Daoud et al 2012	1	0	1	0	0	1	1	1	5/8
Dudley et al 2017	1	0	1	1	1	1	1	1	7/8
DuRant et al 1992	1	1	1	1	0	0	1	0	5/8
Fourchet et al 2011	1	0	1	1	0	1	1	1	6/8
Garrick et al 1978	1	1	1	1	0	1	1	1	7/8
Hayes et al 2019	1	0	1	0	0	0	1	1	4/8
Kerr et al 2016	1	0	1	1	0	1	1	0	5/8
Kuhman et al 2016	1	0	0	1	1	1	1	1	6/8
Leetun et al 2004	1	0	1	1	1	1	1	1	7/8
McLain et al 1989	1	1	1	1	0	1	1	1	7/8
Powell et al 2004	1	1	1	1	1	1	1	0	7/8
Rauh et al 2000	1	1	1	1	0	1	1	0	6/8
Rauh et al 2006	1	1	1	1	0	0	1	1	6/8
Rauh et al 2007	1	1	1	1	1	0	1	1	7/8
Rauh et al 2014	1	0	1	1	0	1	1	1	6/8
Rebella et al 2008	1	0	1	1	0	1	1	0	5/8
Rebella 2015	1	0	1	1	0	1	1	0	5/8
Ruffe et al 2019	1	1	1	1	1	1	1	1	8/8
Shivley et al 1981	1	1	1	1	0	1	1	0	6/8
Watson et al 1987	1	1	1	1	0	1	1	1	7/8
Wik et al 2020	1	0	1	1	0	1	1	1	6/8
Yang et al 2012	1	0	1	0	0	1	1	0	4/8

Figure 2.2. Meta-analysis performed on the estimates of injury rate per 1,000 AEs

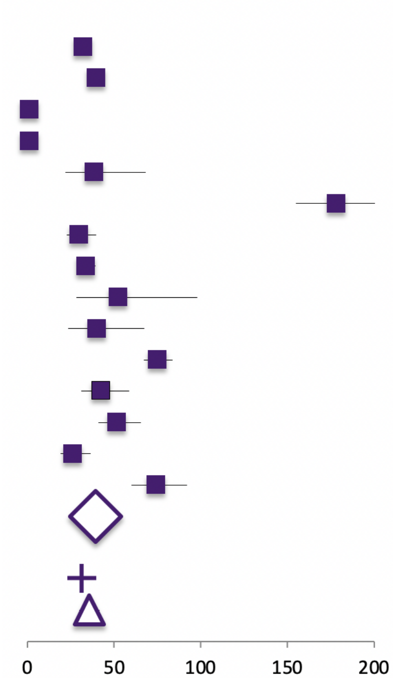
Reference	Injuries	Injuries / 1,000 AEs	95% CI
Total Population			
Brant et al 2019 (XC)	819	0.76	0.71, 0.82
Brant et al 2019 (T&F)	2901	0.72	0.70, 0.75
Kerr et al 2016	191	2.10	1.83, 2.42
Powell et al 2004 (XC)	334	3.56	3.19, 3.96
Powell et al 2004 (T&F)	1226	3.76	3.56, 3.98
Rauh et al 2000	1622	13.1	12.5, 13.7
Rauh et al 2006	316	17.0	15.2, 18.9
Rebella 2015	70	7.93	6.28, 10.0
Rebella et al 2008	37	7.09	5.13, 9.78
Wik et al 2020	87	4.76	3.86, 5.87
Pooled Estimate (n=8)	**7603**	**5.33**	**4.58, 6.08**
I^2=99.9%, Random Effects			
Female Estimate (n=5)	**3789**	**5.17**	**4.26, 6.09**
Male Estimate (n=6)	**3707**	**4.20**	**3.48, 4.93**



CI, Confidence Interval; AEs, Athletic Exposures; XC, Cross-country; T&F, Track and Field.

Figure 2.3. Meta-analysis performed on the estimates of injury rate per 100 athlete-seasons

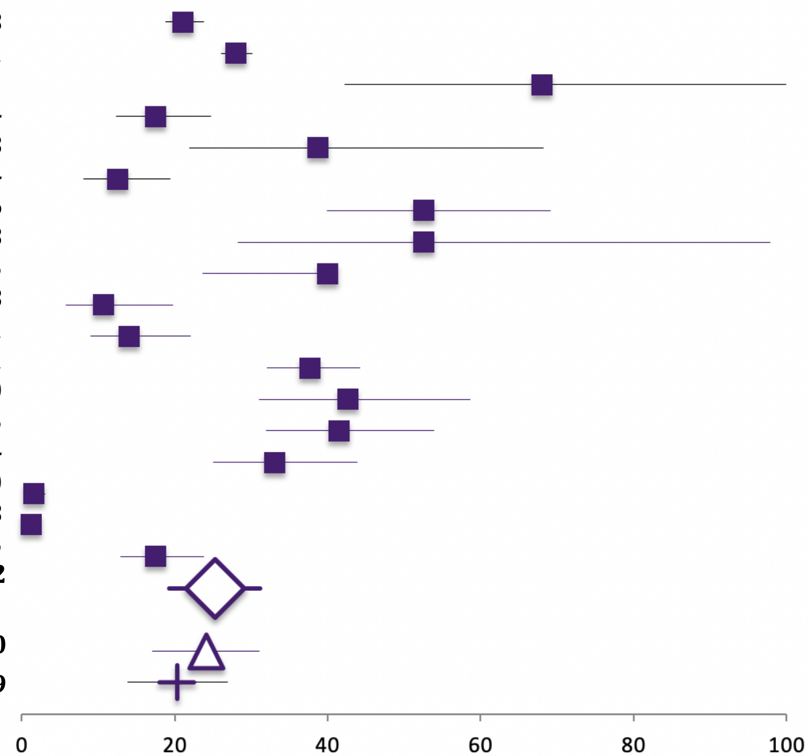
Reference	Injuries	Injuries / 100 Athlete-seasons	95% CI
Total Population			
Beachy et al 1997 (XC)	417	32.4	29.4, 35.6
Beachy et al 1997 (T&F)	1088	39.8	37.5, 42.2
Chandy et al 1985 (XC)	31	1.36	0.94, 1.91
Chandy et al 1985 (T&F)	149	1.40	1.19, 1.64
Dudley et al 2017	12	38.7	21.0, 65.8
Fourchet et al 2011	196	178	155, 205
Garrick et al 1978 (XC)	50	29.9	22.5, 39.2
Garrick et al 1978 (T&F)	174	33.7	29.0, 39.0
Kuhman et al 2016	10	52.6	26.7, 93.8
Leetun et al 2004	14	40.0	23.7, 67.5
Rauh et al 2006	316	75.1	67.1, 83.7
Rauh et al 2014	38	42.7	30.6, 58.0
Rebella 2015	70	51.9	31.6, 53.5
Rebella et al 2008	37	26.4	18.9, 36.1
Wik et al 2020	87	74.4	60.3, 91.8
Pooled Estimate (n=12)	**2689**	**39.5**	**34.1, 44.9**
I^2=99.6%, Random Effects			
Female Estimate (n=8)	**1200**	**31.5**	**24.4, 38.5**
Male Estimate (n=9)	**1404**	**35.8**	**30.1, 41.4**



CI, Confidence Interval; AEs, Athletic Exposures; XC, Cross-country; T&F, Track and Field.

Figure 2.4. Meta-analysis performed on the estimates of injury proportions

Reference	Injuries	Injury Proportion	95% CI
Total Population			
Beachy et al 1997 (XC)	272	21.1	18.8, 23.8
Beachy et al 1997 (T&F)	767	28.0	26.1, 30.1
Beukeboom et al 2000	17	68.0	42.3, 100
Bring et al 2018	32	17.5	12.2, 24.4
Dudley et al 2017	12	38.7	21.0, 65.8
DuRant et al 1992	20	12.5	8.06, 19.4
Hayes et al 2019	51	52.6	39.6, 68.6
Kuhman et al 2016	10	52.6	26.7, 93.8
Leetun et al 2004	14	40.0	23.7, 67.5
McLain et al 1989 (XC)	10	10.6	5.72, 19.8
McLain et al 1989 (T&F)	19	14.1	8.98, 22.1
Rauh et al 2007	148	37.7	32.0, 44.1
Rauh et al 2014	38	42.7	30.7, 58.0
Rebella 2015	56	41.5	31.6, 53.5
Ruffe et al 2019	49	33.1	24.8, 43.4
Shivley et al 1981 (XC)	9	1.56	0.81, 3.00
Shivley et al 1981 (T&F)	36	1.28	0.93, 1.78
Watson et al 1987	41	17.5	12.7, 23.5
Pooled Estimate (n=15)	**1601**	**25.3**	**19.3, 31.2**
I^2=99.2%, Random Effects			
Female Estimate (n=12)	**837**	**24.1**	**17.1, 31.0**
Male Estimate (n=11)	**701**	**20.3**	**13.8, 26.9**



CI, Confidence Interval; AEs, Athletic Exposures; XC, Cross-country; T&F, Track and Field

Table 2.3. Non-Time-loss and Time-loss Injury Risk

Measurement Type (# of TL / Total Studies)	Time-loss Injury Risk (95% CI)	Total Injury Risk* (95% CI)
Injury Rate per 1,000 AEs (n=9 / n=3)	5.33 (4.58 to 6.08)	13.1 (2.70 to 23.5)
Injuries per 100 Athlete-seasons (n=12 / n=1)	39.5 (34.1 to 44.9)	68.4 (63.1 to 73.7)
Injury Proportion (n=15 / n=2)	25.3 (19.3 to 31.2)	49.3 (47.2 to 51.5)

*Total Injury Risk only includes studies reporting non-time-loss injuries in addition to time-loss injuries

Table 2.4. Meta-analyses of injury risk by competition level and sport (Time-loss Injuries Only)

Study Population	Pooled Injury Risk	95% CI	I^2
Injury rate per 1,000 AEs			
High School (n=5)	6.11	5.26, 6.96	99.7%
Collegiate (n=3)	3.90	2.79, 5.00	97.2%
Cross-Country (n=5)	7.15	4.02, 10.3	99.8%
Track and Field (n=5)	4.65	2.57, 6.72	99.6%
Injury rate per 100 Athlete-seasons			
High School (n=8)	38.1	32.3, 43.9	99.5%
Collegiate (n=4)	47.6	38.3, 57.0	0%*
Cross-Country (n=6)	37.4	15.0, 59.8	99.3%
Track and Field (n=8)	53.3	32.9, 73.7	99.5%
Injury proportions			
High School (n=7)	17.5	10.5, 24.4	99.2%
Collegiate (n=6)	45.6	38.3, 52.9	0%*
Cross-Country (n=8)	28.4	16.1, 40.7	98.2%
Track and Field (n=8)	26.6	14.3, 38.9	99.0%

**Fixed Effects Meta-analysis; all other analyses use Random Effects*

Table 2.5. Injury Rate Ratios by sex

Measurement Type	IRR*	95% CI	I^2
Injury Rate per 1,000 AEs (n=5)	1.28	1.11, 1.48	88.4%
Injury rate per 100 athlete-seasons (n=7)	1.00	0.88, 1.14	32.1%

**Injury Rate Ratio = Female Injury Rate / Male Injury Rate*

Table 2.6. Pooled estimates of injury risk by injury reporting mechanism (Time-loss Injuries only)

Injury Reporter	Injury Proportion (95% CI)	I^2
Coach or Athletic Trainer (n=14)	24.0% (17.6, 30.3)	98.9%
Self-report (n=3)	37.5% (4.69, 70.2)	93.1%

CHAPTER 3

EPIDEMIOLOGY OF NCAA TRACK AND FIELD INJURIES: 2009-2010 THROUGH 2013-2014

INTRODUCTION

By the number of participants, track and field was the most popular sport in US high schools and second in the NCAA in 2018-2019 after football (NFHS 2019, NCAA 2019). While the number of football participants in high school and college have increased over the last decade by 12% and 18% respectively, track and field has experienced a more significant growth. Participation in outdoor track and field has increased by 76% in high schools and 25% in the NCAA in the past decade. Indoor track and field has experienced an even more staggering increase in participation of 249% in high school athletes. With growth in track and field, an increase of track and field-related injuries are also expected. Thus, it is important to understand and examine the incidence, types and severity of injuries associated with participation.

Epidemiological studies on injuries have previously been reported in high school track and field athletes (Brant et al 2019, Pierpoint et al 2016). To date, only two large epidemiological studies have reported on collegiate track and field injuries (Powell et al 2004, Yang et al 2012). Both studies were a part of a multi-sport assessment that reported on the incidence injuries but not the nature of injuries specific to track and field (Powell et al 2004, Yang et al 2012). In addition to understanding the overall rate of injury among track and field athletes, it is important to examine the type and severity of injuries by track and field disciplines. Track and field has diverse types of athletes who compete in distinctive events that may predispose them to certain types of injuries. Thus, a large epidemiological study is necessary to investigate how collegiate track and field sprinters, distance runners, jumpers, and throwers might differ in the types and severity of injuries they sustain. The purpose of this study was to examine data from the NCAA

Injury Surveillance Program (NCAA ISP) from 2009-2010 through 2013-2014 to describe the epidemiology of men's and women's track and field injuries. Objectives of our study were to: 1) describe and compare injury rates by sex, setting, and time of season, and 2) to examine injury patterns by discipline and events.

METHODS

Data Collection

Data for NCAA track and field for the academic years of 2009-2010 through 2013-2014 were provided by the NCAA ISP, which is managed by the Datalys Center for Sports Injury Research and Prevention. The ISP collects data from a convenience sample of NCAA Divisions I, II, and III varsity sports teams with athletic trainers (ATs) reporting injury data. The ATs at participating programs report injuries in real-time throughout the academic year as well as the number of student-athletes at varsity practice and competition events. The methods of the ISP have been recorded and summarized previously (Kerr et al 2014, Kerr et al 2016)

When injury events were detected by or reported to an AT, the AT completed a detailed event report on the athlete (eg, sport, position, class year), their injury (eg, body site, diagnosis), and the circumstances of their injury (eg, mechanism of injury, practice or competition, new or recurrent). Before arriving at the Datalys Center for Sports Injury Research and Prevention, common data elements were recoded, stripped of any identifiers and personally identifiable information, and retained only relevant variables and values (Kerr et al 2014). An automated verification process conducted consistency checks on exported data and data were reviewed and flagged for invalid values. The reporting AT and data quality-assurance staff would be notified of any flagged values and would work together to resolve the concern. Verified data were then placed into sport-specific aggregate datasets for use by external researchers

Operational Definitions

The NCAA ISP defines a reportable injury as one that (1) occurred as a result of participation in an organized intercollegiate practice or competition and (2) required attention from an AT or physician. Multiple injuries occurring from one injury event could be included. Injuries that resulted in time loss were included, as were injuries that resulted in no-time loss (NTL). The amount of time lost due to an injury was recorded and injuries that resulted in restricted for less than one day were considered NTL injuries. NTL injuries were further categorized in terms of how they affected the injured athlete's participation. Non-time-loss categories included: "Did not interfere with activity", "returned to team activity within the same session", and "removed from team activity session (returned within 24 hours)".

A reportable athlete-exposure (AE) was defined as one student-athlete participating in one NCAA-sanctioned practice or competition in which he or she was exposed to the possibility of athletic injury, regardless of the time associated with that participation. Competition AEs only included student-athletes with actual playing time recorded in a given competition.

The study was approved by the Anderson University Institutional Review Board.

Statistical Analysis

Injury rates and rate ratios (RRs) per 1,000 AEs were calculated by the number injuries divided by the number of AEs. Overall injury rates, time-loss injury rates, and no-time loss injury rates were determined for the entire sample and stratified by sex, sports seasons (Men's/Women's Indoor & Men's Women's/Outdoor), and event types (practice and competition). Rate ratios and 95% confidence intervals were used for comparisons of injury risk between sexes, seasons, and event types.

Injuries were also described by the activity an injured athlete was engaged in at the time of injury. These activities were categorized as follows: sprinting, distance running, jumping, throwing, and other or unknown. Injuries were also described by injury diagnoses after evaluation by sports medicine staff and further categorized into affected body regions. The following body regions were used for analysis: hip/thigh, knee, lower leg, foot/ankle, wrist/hand, elbow/forearm, shoulder, spine, and other. The percentage of injuries resulting in time loss were determined for participants and stratified by sex, sports seasons, event types, and track and field (T&F) activities. Using these same categories, the number of days missed per injury was compared using Negative Binomial Regression controlling for sex and injury diagnoses. Negative Binomial Regression was chosen due to overdispersion of the dependent variable (number of days missed per injury) defined as having greater variance than mean values. In this study Negative Binomial Regression results are reported as rate ratios with 95% confidence intervals. This method allows for results to be interpreted as the ratio of days missed per injury by sex, sports seasons, event types, and T&F activities. For example, the ratio of days missed per injury between injuries experienced during competitions versus practices while controlling for sex and injury diagnoses.

Injuries were reported as contact, non-contact, overuse, illness, or other/unknown. The proportion of overuse injuries were calculated for each track and field activity and then compared using injury proportion ratios (IPRs). IPRs allow the comparison of relative proportions across categorical variables and are commonly used in injury epidemiology research when certain exposure data may be unavailable (Knowles et al 2010). An example IPR in this instance would be the proportion of overuse injuries during men's sprinting compared to the proportion of overuse injuries during all other men's track and field activities.

$$IPR = \frac{\text{(No. of overuse injuries during men's sprinting / Total No. of injuries during men's sprinting)}}{\text{(No. of overuse injuries during all other men's T\&F activities / Total No. of injuries during all other men's T\&F activities)}}$$

This type of ratio allows the comparison of injury patterns across T&F activities to understand if certain injury types constitute a greater proportion among certain activities compared to others. IPRs were used to compare the proportion of overuse to acute injuries within each track and field activity and also to compare the proportions of overuse injuries between track and field activities. IPRs are reported as ratios and 95% confidence intervals.

The proportions of injuries by body region were also compared between sexes and activities using injury proportion ratios (IPRs). An example IPR in this instance would be the proportion of knee injuries during sprinting compared with the proportion of knee injuries during all other track and field activities. This type of analysis allows the comparison of injury patterns to determine if injuries sustained during particular track and field activities account for greater proportions of injuries to specific body regions compared to other activities.

All data analyses were conducted using STATA 14.2 statistical software (Stata Corp LP, College Station, Texas, USA)

RESULTS

Over five NCAA track and field seasons (2008-09 through 2013-14) there were 1,466 injuries sustained during 367,285 AEs among participating schools. This resulted an overall injury rate of 3.99 injuries per 1,000 AEs for track and field athletes (95% Confidence Interval (CI) 3.79 – 4.20). There were 595 injuries classified as time loss, 810 injuries classified as non-time loss, and 61 injuries with unknown time-loss classifications. Therefore, the time loss and non-time loss injury rates were 1.62 injuries per 1,000 AEs (95% CI 1.50 – 1.76) and 2.21 injuries per 1,000 AEs (95% CI 2.06 – 2.36), respectively.

See Tables 3.1a-3.1c for injuries, athletic exposures, and injury rates classified by sex, event type, and season. The overall rate of injury was 18% higher among women compared to men (95% CI 7% to 31%, $p<0.05$). The rate of time-loss injuries was 22% higher among women compared to men (95% CI 4% to 43%), but there was no significant difference in the rate of non-time loss injuries between sexes. The overall injury rate was 71% higher during competition compared to practice (95% CI 50% to

95%, $p<0.05$). The rate of time-loss injuries was 107% higher during competition compared to practice (95% CI 71% to 151%) and the rate of non-time loss injuries was also 39% higher during competition compared to practice (95% CI 15% to 68%). Additionally, injury rates were 16% higher during the indoor track and field season compared to the outdoor track and field season (95% CI 4% to 29%, $p<0.05$). There was no difference in the rate of time loss injuries between indoor and outdoor seasons, but the rate of non-time loss injuries was 27% higher during the indoor season (95% CI 10% to 46%).

Of the 1,405 injuries with a known time-loss classification, 42.4% of them required time-loss. The average time lost from an injury, including non-time loss injuries, was 7.13 days. Table 3.2 displays the proportions of injuries requiring time loss and the average time lost due to injury by sex, event type, and season. Controlling for injury diagnoses, female track and field athletes missed 41% more time than males (4% to 93%) and injuries occurring during competitions required 59% more time loss than injuries occurring during practice (7% to 135%). There was no significant difference in the amount of time lost between injuries during the indoor and outdoor seasons.

Table 3.3 displays the proportions of injuries requiring time loss and the average time lost by the track and field activity athletes were engaged in at the time of injury. Compared to all other activities, distance running injuries resulted in 168% more time loss (78% to 304%) when controlling for sex and injury diagnoses. Conversely, injuries that occurred during activities classified as “other” resulted in 52% less time loss (34% to 66%) compared with sprinting, distance running, jumping, and throwing injuries. Some of the injuries classified as “other” activity were injuries occurring general strength and conditioning activities.

During the study period 35.5% of injuries were recorded as overuse or gradual-onset injuries. Table 3.4 reports the number and percentage of overuse and acute injuries for each activity. The proportions of overuse and acute injuries within each activity were compared using injury proportion ratios. Sprinting, jumping, and throwing injuries each had a significantly lower proportion of overuse injuries compared to acute injuries; however, no difference was observed among distance running injuries. IPRs were also used to estimate differences in overuse injury proportions between activities. Distance running accounted for a significantly higher proportion of overuse injuries compared to all other activities (IPR 1.70, 95% CI 1.40-2.05). Conversely, throwing accounted for a significantly lower proportion of overuse injuries compared to all other activities (IPR 0.57, 95% CI 0.37-0.88). Additionally, men’s jumping accounted for a lower proportion of overuse injuries compared to all other men’s activities (IPR 0.69, 95% CI 0.47-0.99), however, this difference was not observed among women’s jumping injuries or the combination of men’s and women’s jumping injuries.

Tables 3.5a-3.5d list commonly injured body regions for sprinting, distance running, jumping, and throwing injuries. The proportion of injuries affecting each body region was compared by track and field activity. For instance, Table 3.5a displays the proportion of sprinting injuries affecting the hip/thigh region and compares it to the proportion of hip/thigh injuries sustained during all other track and field activities. These proportions are compared using injury proportion ratios to reveal a higher proportion of hip/thigh injuries among sprinting injuries compared to injuries occurring from all other track and field activities. These IPRs are reported separately for each body region among women's injuries and men's injuries. Additionally, a separate injury proportion ratio was calculated to compare the proportion of particular injuries between sexes within the same activity. For instance, the last column in Table 3.5a displays the IPR comparing women's sprinting injuries affecting the hip/thigh (46.8% of women's sprinting injuries) with men's sprinting injuries affecting the hip/thigh (53.3% of men's sprinting injuries). This IPR revealed no significant difference between women's and men's proportions of sprinting injuries affecting the hip and thigh (IPR 0.88, 95% CI 0.65-1.19).

Sprinting accounted for 21% of women's and 25% of men's Track and Field (T&F) injuries. As displayed in Table 5a, women's sprinting injuries most commonly involved the hip/thigh (46.8%), foot/ankle (11.5%), and knee (10.3%). Women's sprinting injuries accounted for a significantly greater proportion of hip/thigh injuries compared to all other women's T&F activities (IPR=2.06, 95% CI:1.55-2.73, $p<0.05$). Men's sprinting injuries most commonly involved the hip/thigh (53.3%), lower leg (12.8%), and foot/ankle (12.2%). Men's sprinting injuries accounted for a significantly higher proportion of hip/thigh injuries compared to all other men's T&F activities (IPR=2.06, 95% CI: 1.59-2.67, $p<0.05$).

Distance running accounted for 25.9% of women's and 18.3% of men's T&F injuries. As displayed in Table 3.5b, women's distance running injuries most commonly involved the hip/thigh (24.2%), lower leg (23.7%), and foot/ankle (20.1%). Women's distance running injuries accounted for a significantly greater proportion of lower leg

(IPR=1.43, 95% CI:1.00-2.04, $p<0.05$) and foot/ankle injuries (IPR= 1.83, 95% CI:1.22-2.73, $p<0.05$)compared to all other women's T&F activities. Men's distance running injuries most commonly involved the foot/ankle (26.7%), lower leg (22.9%), and hip/thigh (20.6%). Men's distance running injuries accounted for a greater proportion of lower leg (IPR= 2.00, 95%CI:1.30-3.08, $p<0.05$) and foot/ankle (IPR= 1.89, 95% CI:1.27-2.80, $p<0.05$) injuries compared to all other men's T&F activities.

Jumping accounted for 16.8% of women's and 19.3% of men's T&F injuries. As displayed in Table 3.5c, women's jumping injuries most commonly involved the foot/ankle (26.2%), lower leg (17.5%), and hip/thigh (16.7%). Women's jumping injuries accounted for a significantly greater proportion of foot/ankle injuries compared to all other women's T&F activities (IPR 1.51). Men's jumping injuries most commonly involved the hip/thigh (29.7%), foot/ankle (18.8%), and knee (15.2%). No differences were found between proportion of body location injured and activity status for men.

Throwing accounted for 6.4% of women's and 7.5% of men's T&F injuries. As displayed in Table 3.5d, women's throwing injuries most commonly involved the spine (27.1%), hip/thigh (18.8%), and foot/ankle (18.8%). Men's throwing injuries most commonly involved the spine (22.2%), hip/thigh (18.5%), and wrist/hand (13.0%). Women's throwing injuries accounted for a greater proportion of wrist/hand (IPR= 3.98, 95% CI:1.11-14.30, $p<0.05$) and spine (IPR= 2.57, 95% CI:1.42-4.63, $p<0.05$) injuries compared to all other women's T&F activities. Men's throwing injuries accounted for a greater proportion of elbow/forearm (IPR= 12.3, 95% CI:4.31-35.0, $p<0.05$), wrist/hand

(IPR= 11.2, 95% CI:4.74-26.3, $p<0.05$), and spine (IPR= 2.42, 95% CI:1.30-4.49, $p<0.05$) injuries compared to all other men's T&F activities.

DISCUSSION

This study presents epidemiologic data on injuries in collegiate track and field from the years 2009-2010 through 2013-2014. The overall injury rate for collegiate track and field was 3.99 injuries per 1,000 AEs. This rate is similar to the three-year injury rate of 3.47 injuries per 1,000 AEs reported study by Yang et al., which combined cross-country and track and field injuries in the Big Ten Athletic Conference (Yang et al 2012). However, the current study's injury rate was significantly lower than the 23.68 injuries per 1,000 AEs reported by Powell et al. in collegiate track and field during a 2-year observation period with 50 colleges (Powell et al 2004). This large discrepancy may be due to differences in how the athletic trainers examined and reported non-time-loss (NTL) injuries. For example, NTL injuries accounted for almost 83% of track and field injuries (19.6 NTL injuries per 1,000 AEs) in the Powell et al. study compared with 36% of injuries in the Yang et al. study (2.3 NTL injuries per 1,000 AEs) and 57.7% (2.2 NTL injuries per 1,000 AEs) in the current study. The Powell et al. study measured all injuries and illnesses, even if they were not sport related, whereas the current study defined injuries as occurring as a result of participation in an organized practice or competition. As other authors have previously described (Kerr et al 2016), there may have been fewer minor injuries recorded in the NCAA ISP than those reported in the Powell et al. study. However, the Powell et al. study did not report injury diagnoses which may contribute to the difference in findings. For example, the current study had fewer than 1% of total injuries reported as abrasions or lacerations. If athletic trainers in the Powell et al. study recorded these types of minor injuries more frequently, then it may explain the higher rates of NTL injuries observed in their study.

Sex, Event Type, and Season

Overall, women's track and field athletes had 18% higher injury risk than males which is a similar finding among other studies with collegiate (Powell et al 2004) and high school (Pierpoint et al 2016) track and field athletes. Females experienced 22% higher rates of time loss injuries and took 41% more time to recover from injuries and return to sport compared to males. This increased recovery time may be due to their higher rates of time loss and overuse injuries. Although only a small occurrence, females also experienced over twice the rate of stress fractures compared to males. This is consistent with previous research in both collegiate (Yang et al 2012) and high school track and field (Pierpoint et al 2016). There may be multiple reasons females experience higher injury rates than males in track and field, but an often-cited cause is the Relative Energy Deficiency in Sport model (RED-S). This model refers to impaired physiological function caused by an imbalance between dietary energy intake and the energy expenditure required for sporting activities (Mountjoy et al 2014). In track and field female athletes are observed to have lower energy availability and lower bone mineral density than males, thus placing female track and field athletes at a greater risk of bone-stress injuries, impair their recovery from training, and reduce their neuromuscular function (Melin et al 2019). These physiological consequences of RED-S may not only increase female athletes' risk of injury, but also increase the time needed to recover from an injury, which was also a finding in the current study.

The risk of injury during competitions was 71% higher than during practice. This higher rate of injury during competitions was consistent among time loss injuries as well as non-time loss injuries. Additionally, the severity of injuries during competitions was also greater as the time necessary to return to sport was 59% longer than injuries sustained during practice. Previous studies observing injuries in high school track and field (Pierpoint et al 2016) and other collegiate sports (Kerr et al 2016, Wasserman et al 2019, Clifton et al 2018, Pierpoint et al 2019, Lynall et al 2018, DiSefano et al 2018, Kerr et al 2018) have consistently found increased injury risk during competitions. It is likely that the higher intensity in competition places athletes at a greater risk of injury compared to practice, especially among acute injuries. Athletes experienced acute injuries at twice the rate during competitions compared to practices, whereas there was no observed difference in the rate of overuse injuries between competitions and practices.

This study also observed a 16% higher risk of injury during the indoor season compared to the outdoor season. The indoor season precedes the outdoor season each year, so this higher risk may be similar to the higher injury risk often observed during the preseason during other sports (Dick et al 2007, Pierpoint et al 2019, Kerr et al 2018). This finding may suggest athletes are more acclimated to the rigor of the sport once the outdoor season begins and possibly less susceptible to injury. Other important differences between the indoor and outdoor season pertain to the events athletes compete in and the equipment they use. Most notably, indoor tracks are traditionally half the length of outdoor tracks with more narrow lanes and smaller curve radii. Athletes compete in different running and throwing events between seasons which may contribute to different injury risks. For example, the longest running event during the indoor season is 5,000 kilometers whereas outdoor track and field meets include 5,000 kilometer and 10,000 kilometer races. Additionally, the shortest running event during the indoor season is a 60 meter sprint compared to the 100 meter sprint during the outdoor season. Throwing events also differ between seasons due to the size of venues. These differing events may cause athletes to train and compete differently between the indoor and outdoor seasons, which may also contribute to differences in injury risks.

Injury Activities

To date, very little research has compared injury types between various track and field disciplines. Sprinting, distance running, jumping, and throwing require varying demands on athletes' bodies, so differences in injuries should be expected between them. The current study observed greater proportions of hip and thigh injuries during sprinting in women and men compared with all other track and field activities. A high frequency of hamstring strains during sprinting accounted for much of this difference as 32% of sprinting injuries involved the hamstring muscle group. Previous studies have found similarly high rates of hamstring strains in sports which require high speed running, such as football, soccer, and rugby in addition to track and field (Feeley et al 2008, Woods et al 2004, Brooks et al 2006, Askling et al 2007). Many studies have focused on the biomechanics of high speed running to understand the mechanism of hamstring injury and they generally observe forceful eccentric contractions by the hamstring muscles during the late swing phase of the gait cycle when the muscle is the most lengthened and thus susceptible to a strain injury (Yu et al 2017, Sun et al 2015, Huygaerts et al 2020).

The current study found distance running to have greater injury proportions to the lower leg, foot, and ankle when compared with all other activities. Not surprisingly distance running also had the greatest proportion of overuse injuries compared with other activities and the lower leg was the most common body region to experience overuse injuries such as Medial Tibial Stress Syndrome and Achilles Tendonitis. Distance running places repetitive stress on the lower leg structures associated with these overuse injuries (Fletcher et al 2018, Reinking et al 2017). Women's jumping also accounted for higher proportions of foot and ankle injuries compared to other activities, however, jumping injuries to the foot and ankle were more commonly acute injuries such as lateral ankle sprains compared to the frequent overuse injuries observed with distance running.

While throwing accounted for the smallest percentage of injuries in this study, it also had the most unique injury profile with the highest proportion of injuries to the upper extremities and spine. As described by Meron et al, different throwing events such as shot put, discus, hammer, and javelin all rely on efficient transfer of energy from the lower extremities through the spine and the upper extremities (Meron et al 2017). Breakdowns in this kinetic chain can result in injuries affecting any of these regions. Given the demands placed on the upper extremities compared to running and jumping, it is not surprising that throwing accounts for higher proportions of wrist and hand injuries. Furthermore, each type of throw involves hyperextension and rotation of the lumbar spine, which may increase the risk for strain of the core and lumbar musculature and chronic injuries due to the repetitive heightened stress on these axial structures (Meron et al).

Limitations

The findings from the current study may not be generalizable to other competition levels such has high school, professional, or recreational track and field athletes. This surveillance study also did not account for the many individual- or institutional-related factors that may have contributed to injury risk such as the injury history or training load particular to each athlete or injury-prevention programs implemented by coaching and training staff at each college. Additionally, injuries were compared by the activity athletes were engaged in at the time of injury as opposed to their specific discipline. For instance, if an athlete who primarily competes in jumping events suffers an injury while sprinting then her injury may have been included in this analysis as a sprinting injury if the activity was recorded as such. Similarly, athletes competing in combined events such as the decathlon or heptathlon were not analyzed separately in this study but their injury was included in whichever activity they were engaged in at the time of injury. Each athlete's position was typically reported at the time of injury; however, the "Runner" position category did not differentiate between sprinters and distance runners and the position was more often a missing variable than the activity at the time of injury. Lastly, the exposure data were not specific to positions or activities so injury rates could not be calculated between track and field disciplines. Instead injury proportions were presented and compared. Injury proportions provide information on the common types of injuries experienced in different disciplines or events, but not the risk of sustaining injuries or the cause of injuries. Future investigations should aim to measure exposures specific to each discipline to effectively compare injury risks between them and incorporate prospective designs to better understand causal factors responsible for the risk and proportions of injuries experienced between track and field disciplines.

Conclusions

The key findings from this study include a higher injury rate among women compared to men, higher injury rates during competitions compared to practices, and higher injury rates during the indoor season compared to the outdoor season. The hip and thigh were the most common body region injured in track and field; however, injury types can vary by track and field discipline due to the unique demands of each event. This study provides an assessment of the frequency and risk of injury in collegiate track and field, while highlighting differing injury patterns across track and field disciplines. These findings from the NCAA ISP can help athletic administrators, coaches, athletes, and sports medicine professionals understand the risk and types of injuries in collegiate track and field, while also suggesting areas for future research and injury prevention.

REFERENCES

Askling, C. M., Tengvar, M., Saartok, T., & Thorstensson, A. (2007). Acute first-time hamstring strains during high-speed running: A longitudinal study including clinical and magnetic resonance imaging findings. *The American Journal of Sports Medicine, 35*(2), 197-206. doi:0363546506294679 [pii]

Brant, J. A., Johnson, B., Brou, L., Comstock, R. D., & Vu, T. (2019). Rates and patterns of lower extremity sports injuries in all gender-comparable US high school sports. *Orthopaedic Journal of Sports Medicine, 7*(10), 2325967119873059. doi:10.1177/2325967119873059 [doi]

Brooks, J. H., Fuller, C. W., Kemp, S. P., & Reddin, D. B. (2006). Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *The American Journal of Sports Medicine, 34*(8), 1297-1306. doi:0363546505286022 [pii]

Clifton, D. R., Onate, J. A., Hertel, J., Pierpoint, L. A., Currie, D. W., Wasserman, E. B., . . . Kerr, Z. Y. (2018). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school boys' basketball (2005-2006 through 2013-2014) and national collegiate athletic association men's basketball (2004-2005 through 2013-2014). *Journal of Athletic Training, 53*(11), 1025-1036. doi:10.4085/1062-6050-148-17 [doi]

Dick, R., Romani, W. A., Agel, J., Case, J. G., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's lacrosse injuries: National collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training, 42*(2), 255-261.

DiStefano, L. J., Dann, C. L., Chang, C. J., Putukian, M., Pierpoint, L. A., Currie, D. W., . . . Kerr, Z. Y. (2018). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school girls' soccer (2005-2006 through 2013-2014) and national collegiate athletic association women's soccer (2004-2005 through 2013-2014). *Journal of Athletic Training, 53*(9), 880-892. doi:10.4085/1062-6050-156-17 [doi]

Feeley, B. T., Kennelly, S., Barnes, R. P., Muller, M. S., Kelly, B. T., Rodeo, S. A., & Warren, R. F. (2008). Epidemiology of national football league training camp injuries from 1998 to 2007. *The American Journal of Sports Medicine, 36*(8), 1597-1603. doi:10.1177/0363546508316021 [doi]

Fletcher, J. R., & MacIntosh, B. R. (2018). Changes in Achilles tendon stiffness and energy cost following a prolonged run in trained distance runners. *PloS one*, *13*(8), e0202026.

Huygaerts, S., Cos, F., Cohen, D. D., Calleja-Gonzalez, J., Guitart, M., Blazevich, A. J., & Alcaraz, P. E. (2020). Mechanisms of hamstring strain injury: Interactions between fatigue, muscle activation and function. *Sports (Basel, Switzerland), 8*(5), 10.3390/sports8050065. doi:E65 [pii]

Kerr, Z. Y., Dompier, T. P., Snook, E. M., Marshall, S. W., Klossner, D., Hainline, B., & Corlette, J. (2014). National collegiate athletic association injury surveillance system: Review of methods for 2004-2005 through 2013-2014 data collection. *Journal of Athletic Training, 49*(4), 552-560. doi:10.4085/1062-6050-49.3.58 [doi]

Kerr, Z. Y., Kroshus, E., Grant, J., Parsons, J. T., Folger, D., Hayden, R., & Dompier, T. P. (2016). Epidemiology of national collegiate athletic association men's and women's cross-country injuries, 2009-2010 through 2013-2014. *Journal of Athletic Training, 51*(1), 57-64. doi:10.4085/1062-6050-51.1.10 [doi]

Kerr, Z. Y., Putukian, M., Chang, C. J., DiStefano, L. J., Currie, D. W., Pierpoint, L. A., . . . Marshall, S. W. (2018). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school boys' soccer (2005-2006 through 2013-2014) and national collegiate athletic association men's soccer (2004-2005 through 2013-2014). *Journal of Athletic Training, 53*(9), 893-905. doi:10.4085/1062-6050-166-17 [doi]

Knowles, S. B., Kucera, K. L., & Marshall, S. W. (2010). Commentary: the injury proportion ratio: what's it all about?. *Journal of athletic training*, *45*(5), 475–479.

Lynall, R. C., Mihalik, J. P., Pierpoint, L. A., Currie, D. W., Knowles, S. B., Wasserman, E. B., . . . Kerr, Z. Y. (2018). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school boys' ice hockey (2008-2009 through 2013-2014) and national collegiate athletic association men's and women's ice hockey (2004-2005 through 2013-2014). *Journal of Athletic Training, 53*(12), 1129-1142. doi:10.4085/1062-6050-176-17 [doi]

Melin, A. K., Heikura, I. A., Tenforde, A., & Mountjoy, M. (2019). Energy Availability in Athletics: Health, Performance, and Physique. *International journal of sport nutrition and exercise metabolism*, *29*(2), 152–164.

Meron, A., & Saint-Phard, D. (2017). Track and field throwing sports: Injuries and prevention. *Current Sports Medicine Reports, 16*(6), 391-396. doi:10.1249/JSR.0000000000000416 [doi]

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., . . . Ljungqvist, A. (2014). The IOC consensus statement: Beyond the female athlete triad--relative energy deficiency in sport (RED-S). *British Journal of Sports Medicine, 48*(7), 491-497. doi:10.1136/bjsports-2014-093502 [doi]

National Collegiate Athletic Association. (2019). *1981-82 – 2018-19 NCAA SPORTS SPONSORSHIP AND PARTICIPATION RATES REPORT*. https://ncaaorg.s3.amazonaws.com/research/sportpart/2018-19RES_SportsSponsorshipParticipationRatesReport.pdf.

Pierpoint, L. A., Lincoln, A. E., Walker, N., Caswell, S. V., Currie, D. W., Knowles, S. B., . . . Kerr, Z. Y. (2019). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school boys' lacrosse (2008-2009 through 2013-2014) and national collegiate athletic association men's lacrosse (2004-2005 through 2013-2014). *Journal of Athletic Training, 54*(1), 30-41. doi:10.4085/1062-6050-200-17 [doi]

Pierpoint, L. A., Williams, C. M., Fields, S. K., & Comstock, R. D. (2016). Epidemiology of injuries in united states high school track and field: 2008-2009 through 2013-2014. *The American Journal of Sports Medicine, 44*(6), 1463-1468. doi:10.1177/0363546516629950 [doi]

Powell, J. W., & Dompier, T. P. (2004). Analysis of injury rates and treatment patterns for time-loss and non-time-loss injuries among collegiate student-athletes. *Journal of Athletic Training, 39*(1), 56-70.

Reinking, M. F., Austin, T. M., Richter, R. R., & Krieger, M. M. (2017). Medial Tibial Stress Syndrome in Active Individuals: A Systematic Review and Meta-analysis of Risk Factors. *Sports health*, *9*(3), 252–261.

Sun, Y., Wei, S., Zhong, Y., Fu, W., Li, L., & Liu, Y. (2015). How joint torques affect hamstring injury risk in sprinting swing-stance transition. *Medicine and Science in Sports and Exercise, 47*(2), 373-380. doi:10.1249/MSS.0000000000000404 [doi]

The National Federation of State High School Associations. (2019). *2018-19 High School Athletics Participation Survey*. https://www.nfhs.org/media/1020412/2018-19_participation_survey.pdf.

Wasserman, E. B., Sauers, E. L., Register-Mihalik, J. K., Pierpoint, L. A., Currie, D. W., Knowles, S. B., . . . Kerr, Z. Y. (2019). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school boys' baseball (2005-2006 through 2013-2014) and national collegiate athletic association men's baseball (2004-2005 through 2013-2014). *Journal of Athletic Training, 54*(2), 198-211. doi:10.4085/1062-6050-239-17 [doi]

Woods, C., Hawkins, R. D., Maltby, S., Hulse, M., Thomas, A., Hodson, A., & Football Association Medical Research Programme. (2004). The football association medical research programme: An audit of injuries in professional football--analysis of hamstring injuries. *British Journal of Sports Medicine, 38*(1), 36-41. doi:10.1136/bjsm.2002.002352 [doi]

Yang, J., Tibbetts, A. S., Covassin, T., Cheng, G., Nayar, S., & Heiden, E. (2012). Epidemiology of overuse and acute injuries among competitive collegiate athletes. *Journal of Athletic Training, 47*(2), 198-204. doi:10.4085/1062-6050-47.2.198 [doi]

Yu, B., Liu, H., & Garrett, W. E. (2017). Mechanism of hamstring muscle strain injury in sprinting. *Journal of Sport and Health Science, 6*(2), 130-132. doi:10.1016/j.jshs.2017.02.002 [doi]

TABLES AND FIGURES

Table 3.1a. Track and Field Injury Rates by Sex

	Women's		Men's		IRR (95% CI)
	Injuries	Injury Rate (95% CI)	Injuries	Injury Rate (95% CI)	
Time Loss Injuries	309	1.79 (1.60-2.00)	286	1.47 (1.31-1.65)	**1.22* (1.04-1.43)**
Non-Time Loss Injuries	403	2.33 (2.12-2.57)	407	2.09 (1.90-2.30)	1.12 (0.97-1.28)
Total Injuries	749	4.34 (4.04-4.66)	717	3.68 (3.42-3.96)	**1.18* (1.07-1.31)**

Injury Rates per 1,000 Athletic Exposures (AEs): 172,603 Women's AEs; 194,682 Men's AEs
IRR=Injury Rate Ratio (Women's Injury Rate / Men's Injury Rate)
**p<0.05*

Table 3.1b. Track and Field Injury Rates by Event Type

	Competition		Practice		IRR (95% CI)
	Injuries	Injury Rate (95% CI)	Injuries	Injury Rate (95% CI)	
Time Loss Injuries	131	2.97 (2.51-3.53)	464	1.44 (1.31-1.57)	**2.07* (1.71-2.51)**
Non-Time Loss Injuries	129	2.93 (2.46-3.48)	681	2.11 (1.96-2.27)	**1.39* (1.15-1.68)**
Total Injuries	277	6.29 (5.59-7.07)	1,189	3.68 (3.48-3.89)	**1.71* (1.50-1.95)**

Injury Rates per 1,000 AEs: 44,072 Practice AEs; 323,213 Competition AEs
IRR=Injury Rate Ratio (Competition Injury Rate / Practice Injury Rate)
**p<0.05*

Table 3.1c. Track and Field Injury Rates by Season

	Indoor T&F		Outdoor T&F		IRR (95% CI)
	Injuries	Injury Rate (95% CI)	Injuries	Injury Rate (95% CI)	
Time Loss Injuries	361	1.72 (1.55-1.91)	234	1.48 (1.31-1.69)	1.16 (0.99-1.37)
Non-Time Loss Injuries	508	2.42 (2.22-2.64)	302	1.92 (1.71-2.14)	**1.27* (1.10-1.46)**
Total Injuries	889	4.24 (3.97-4.53)	577	3.66 (3.37-3.97)	**1.16* (1.04-1.29)**

Injury Rates per 1,000 AEs: 209,545 Indoor AEs; 157,740 Outdoor AEs
IRR=Injury Rate Ratio (Competition Injury Rate / Practice Injury Rate)
**p<0.05*

Table 3.2. Time Lost from Injury by Sex, Event Type, and Season

	No. of Injuries Requiring Time Loss (%)	Mean Days Lost per Injury (SD)	Ratio of Days Lost per Injury^ (95% CI)
Sex			
Women's	309 (43.4%)	8.32 (18.8)	**1.41 (1.04 – 1.93)***
Men's	286 (41.3%)	5.91 (13.8)	1.00 (ref)
Event Type			
Competition	131 (50.4%)	9.16 (17.6)	**1.59 (1.07 – 2.35)***
Practice	464 (40.5%)	6.67 (16.3)	1.00 (ref)
Season			
Indoor	361 (41.5%)	6.33 (15.3)	0.82 (0.60 – 1.13)
Outdoor	234 (43.7%)	8.43 (18.4)	1.00 (ref)

^Negative Binomial Regression Models Controlling for Sex & Injury Diagnoses
**p<0.05*

Table 3.3. Time Lost from Injury by T&F Activity

	No. of Injuries Requiring Time Loss (%)	Mean Days Lost per Injury (SD)	Ratio of Days Lost per Injury^ (95% CI)
Sprinting	174 (54.2%)	7.81 (15.9)	1.33 (0.93 – 1.90)
Distance Running	136 (45.2%)	10.7 (21.3)	**2.68 (1.78 – 4.04)****
Jumping	100 (38.3%)	5.95 (13.7)	0.74 (0.51 – 1.09)
Throwing	39 (40.2%)	4.07 (9.03)	0.79 (0.41 – 1.54)
Other	146 (34.4%)	5.49 (15.8)	**0.48 (0.34 – 0.66)****
Total	595 (42.4%)	7.13 (16.6)	-

^Negative Binomial Regression Models Controlling for Sex, Activity, & Injury Diagnoses
***p<0.01*

Table 3.4. Proportion of overuse injuries by T&F activity

	No. of Overuse Injuries (%)	No. of Acute Injuries (%)	IPR within Activity[a] (95% CI)	IPR between Activities[b] (95% CI)
Sprinting	108 (33.6%)	213 (66.4%)	**0.51 (0.40-0.64)****	0.93 (0.75-1.16)
Women's	53 (36.1%)	94 (64.0%)	**0.56 (0.40-0.79)****	0.95 (0.70-1.28)
Men's	55 (31.6%)	119 (68.4%)	**0.46 (0.34-0.64)****	0.94 (0.69-1.27)
Distance Running	159 (52.1%)	146 (47.9%)	1.09 (0.87-1.36)	**1.70 (1.40-2.05)****
Women's	92 (49.5%)	94 (50.5%)	0.98 (0.74-1.31)	**1.48 (1.15-1.90)****
Men's	67 (56.3%)	52 (43.7%)	1.29 (0.90-1.85)	**2.00 (1.50-2.66)****
Jumping	77 (29.9%)	181 (70.2%)	**0.43 (0.33-0.56)****	0.81 (0.64-1.04)
Women's	44 (36.1%)	78 (63.9%)	**0.57 (0.39-0.81)****	0.95 (0.69-1.31)
Men's	33 (24.3%)	103 (75.7%)	**0.32 (0.22-0.48)****	**0.69 (0.47-0.99)***
Throwing	21 (20.8%)	80 (79.2%)	**0.26 (0.16-0.43)****	**0.57 (0.37-0.88)***
Women's	10 (20.8%)	38 (79.2%)	**0.26 (0.13-0.53)****	0.54 (0.28-1.01)
Men's	11 (20.8%)	42 (79.2%)	**0.26 (0.14-0.51)****	0.61 (0.33-1.11)
Total	492 (35.5%)	895 (64.5%)	**0.55 (0.49-0.61)****	
Women's	268 (37.7%)	443 (62.3%)	**0.61 (0.52-0.70)****	
Men's	224 (33.1%)	452 (686.9%)	**0.50 (0.42-0.58)****	

[a] IPR within Activity (e.g. Sprinting Overuse Injury Proportion / Sprinting Acute Injury Proportion)
[b]IPR by Activity (e.g. Sprinting Overuse Injury Proportion / Non-Sprinting Overuse Injury Proportion)
**p<0.05; **p<0.01*

Table 3.5a. Sprinting Injuries by Sex and Body Region

	Women's Injuries			Men's Injuries			
	Sprinting Injuries (%)	Non-Sprinting Injuries (%)	IPR[a] (95% CI)	Sprinting Injuries (%)	Non-Sprinting Injuries (%)	IPR[a] (95% CI)	IPR by Sex[b] (95% CI)
Hip/Thigh	73 (46.8%)	135 (22.8%)	**2.06 (1.55-2.73)***	96 (53.3%)	139 (25.9%)	**2.06 (1.59-2.67)***	0.88 (0.65-1.19)
Knee	16 (10.3%)	66 (11.1%)	0.92 (0.53-1.59)	17 (9.4%)	65 (12.1%)	0.78 (0.46-1.33)	1.09 (0.55-2.15)
Lower Leg	32 (20.5%)	106 (17.9%)	1.15 (0.77-1.70)	23 (12.8%)	74 (13.8%)	0.93 (0.58-1.48)	0.80 (0.42-1.52)
Foot/Ankle	18 (11.5%)	82 (13.8%)	0.83 (0.50-1.39)	22 (12.2%)	96 (17.9%)	0.68 (0.43-1.09)	0.94 (0.51-1.76)
Spine	8 (5.1%)	79 (13.3%)	0.39 (0.19-0.80)	11 (6.1%)	62 (11.6%)	0.53 (0.28-1.01)	0.84 (0.34-2.09)
Other	9 (5.8%)	109 (18.4%)		11 (6.1%)	101 (18.8%)		
Total	156 (100%)	593 (100%)		180 (100%)	537 (100%)		

[a] *IPR (Sprinting Injury Proportion / Non-Sprinting Injury Proportion)*

[b] *IPR by Sex (Women's Sprinting Injury Proportion / Men's Sprinting Injury Proportion)*

**p*<0.05*

Table 3.5b. Distance Running Injuries by Sex and Body Region

	Women's Injuries			Men's injuries			
	Distance Running Injuries (%)	Non-Distance Running Injuries (%)	IPR[a] (95% CI)	Distance Running Injuries (%)	Non-Distance Running Injuries (%)	IPR[a] (95% CI)	IPR by Sex[b] (95% CI)
Hip/Thigh	47 (24.2%)	161 (29.0%)	0.84 (0.60-1.16)	27 (20.6%)	208 (35.5%)	**0.58 (0.39-0.87)***	1.18 (0.73-1.89)
Knee	27 (13.9%)	55 (9.9%)	1.40 (0.89-2.23)	16 (12.2%)	66 (11.3%)	1.08 (0.63-1.87)	1.14 (0.61-2.11)
Lower Leg	46 (23.7%)	92 (16.6%)	**1.43 (1.00-2.04)***	30 (22.9%)	67 (11.4%)	**2.00 (1.30-3.08)***	1.04 (0.65-1.64)
Foot/Ankle	39 (20.1%)	61 (11.0%)	**1.83 (1.22-2.73)***	35 (26.7%)	83 (14.2%)	**1.89 (1.27-2.80)***	0.75 (0.48-1.19)
Spine	13 (6.7%)	74 (13.3%)	**0.50 (0.28-0.91)***	7 (5.3%)	66 (11.3%)	0.47 (0.22-1.03)	1.25 (0.50-3.14)
Other	22 (11.3%)	112 (20.2%)		16 (12.3%)	95 (16.2%)		
Total	194 (100%)	555 (100%)		131 (100%)	586 (100%)		

[a] *IPR (Distance Running Injury Proportion / Non-Distance Running Injury Proportion)*

[b] *IPR by Sex (Women's Distance Running Injury Proportion / Men's Distance Running Injury Proportion)*

**p*<0.05*

Table 3.5c. Jumping Injuries by Sex and Body Region

	Women's Injuries			Men's Injuries			
	Jumping Injuries (%)	Non-Jumping Injuries (%)	Women's Jumping IPR[a] (95% CI)	Jumping Injuries (%)	Non- Jumping Injuries (%)	Men's Jumping IPR[a] (95% CI)	IPR by Sex[b] (95% CI)
Hip/Thigh	22 (17.5%)	186 (29.9%)	**0.59 (0.38-0.91)***	41 (29.7%)	194 (33.5%)	0.89 (0.63-1.24)	**0.59 (0.35-0.99)***
Knee	18 (14.3%)	64 (10.3%)	1.39 (0.82-2.34)	21 (15.2%)	61 (10.5%)	1.45 (0.88-2.38)	0.94 (0.50-1.77)
Lower Leg	22 (17.5%)	116 (18.6%)	0.94 (0.60-1.48)	14 (10.1%)	83 (14.3%)	0.71 (0.40-1.24)	1.73 (0.89-3.39)
Foot/Ankle	33 (26.2%)	108 (17.3%)	**1.52 (1.03-2.24)***	26 (18.8%)	92 (15.9%)	1.18 (0.77-1.83)	1.39 (0.83-2.33)
Spine	20 (15.9%)	67 (10.8%)	1.47 (0.89-2.43)	18 (13.0%)	55 (9.5%)	1.37 (0.80-2.33)	1.22 (0.64-2.31)
Other	11 (8.7%)	82 (13.2%)		18 (13.0%)	94 (16.2%)		0.67 (0.32-1.42)
Total	126 (100%)	623 (100%)		138 (100%)	579 (100%)		

[a] *IPR (Jumping Injury Proportion / Non-Jumping Injury Proportion)*
[b] *IPR by Sex (Women's Jumping Injury Proportion / Men's Jumping Injury Proportion)*
**$p<0.05$*

Table 3.5d. Throwing Injuries by Sex and Body Region

	Women's Throwing Injuries (%)	Women's Non-Throwing Injuries (%)	IPR[a] (95% CI)	Men's Throwing Injuries (%)	Men's Non-Throwing Injuries (%)	IPR[a] (95% CI)	IPR by Sex[b] (95% CI)
Hip/Thigh	9 (18.8%)	199 (28.4%)	0.66 (0.34-1.29)	10 (18.5%)	225 (33.9%)	0.55 (0.29-1.03)	1.02 (0.41-2.50)
Knee	6 (12.5%)	76 (10.8%)	1.16 (0.50-2.66)	1 (1.9%)	81 (12.2%)	0.16 (0.02-1.11)	6.58 (0.79-54.7)
Foot/Ankle	9 (18.8%)	132 (18.8%)	1.00 (0.51-1.97)	3 (5.6%)	115 (17.4%)	0.32 (0.10-1.01)	3.36 (0.91-12.4)
Wrist/Hand	3 (6.3%)	11 (1.6%)	**3.94 (1.10-14.1)***	10 (18.5%)	11 (1.7%)	**10.9 (4.62-25.6)****	0.34 (0.09-1.24)
Elbow/Forearm	0	4 (0.6%)	-	7 (13.0%)	7 (1.1%)	**11.8 (4.15-33.7)****	-
Shoulder	3 (6.25%)	13 (1.9%)	3.29 (0.94-11.5)	3 (3.7%)	20 (3.0%)	1.23 (0.37-4.15)	1.69 (0.34-8.37)
Spine	13 (27.1%)	74 (10.6%)	**2.56 (1.42-4.61)****	12 (22.2%)	61 (9.2%)	**2.41 (1.30-4.48)****	1.22 (0.56-2.68)
Other	5 (10.4%)	192 (27.4)		9 (16.7%)	143 (21.6%)		
Total	48 (100%)	701 (100%)		54 (100%)	663 (100%)		

[a] *IPR (Throwing Injury Proportion / Non-Throwing Injury Proportion)*
[b] *IPR by Sex (Women's Throwing Injury Proportion / Men's Throwing Injury Proportion)*
**p<0.05; **p<0.01*

CHAPTER 4

INVESTIGATING ADOLESCENT RUNNERS' REPORTING OF OVERUSE INJURIES: AN APPLICATION OF THE DISCLOSURE DECISION-MAKING MODEL

1 INTRODUCTION

Running is one of the most popular forms of physical activity worldwide and presents tremendous health benefits and longevity to its participants (Hespanhol et al 2015, Lee et al 2017, Lee et al 2014). Many adolescents are introduced to the sport of distance running through participation in cross-country. In the United States approzimately 500,000 adolescents compete on high school cross-country teams (NFHS 2019). In the ten-year span from 2008 through 2018 high school participation grew by almost 14%, which was over 250% the growth rate for general sports participation during the same time (NFHS 2009, NFHS 2019). Unfortunately, these high school runners are commonly cited to have high injury rates, which may decrease their sport participation and limit their physical activity and the health benefits it normally provides (Rauh et al 2000, Beachy et al 1997). Furthermore, injuries may negatively affect their mental health and sometimes result in quitting the sport (Chan et al 1988; Koplan et al 1995). Many of the injuries distance runners suffer from are considered overuse injuries caused by repetitive stress on the musculoskeletal system without appropriate preparation and/or recovery (Valovich McLeod et al 2011). These types of injuries tend to have a gradual onset where an ongoing pathological process exists prior to an athlete noticing symptoms (Bahr 2009). In many cases, the initial symptoms of an overuse injury may be minor and seem hardly different than occasional pain associated with sports training (Kox et al 2019). However, if these symptoms are ignored then they may worsen and even result in long-term health concerns (Aicale et al 2018). Instead, early recognition and treatment can provide better outcomes such as a more timely and successful return to pain-free sports and physical activity (*Ohta-Fukushima et al 2002,* Nussbaum et al 2019, Aicale et al 2018).

Therefore, early recognition and treatment for overuse injuries are essential in order for adolescent runners to achieve the best outcomes. However, little is known regarding their ability to identify early symptoms of overuse injuries and athletes' willingness to report them to coaches or athletic trainers. A wealth of evidence exists regarding factors related to athletes' underreporting of concussion symptoms (Baugh et al 2019, Kroshus et al 2014, Register-Mihalik et al 2013). Some studies have successfully employed health behavior theories to illustrate how concepts such as injury knowledge, self-efficacy of reporting injuries, and relational quality with coaches are important in an athlete's decision to report concussion symptoms to others (Cranmer et al 2018, Kroshus et al 2014). Given the progressive and gradual-onset of most overuse injuries, it is important to understand if these or similar factors are associated with athletes' injury reporting when their symptoms first become apparent. The purpose of this study was to assess injury reporting behaviors in adolescent runners and employ the Disclosure Decision-Making Model (DD-MM) to better understand factors related to early reporting. (Greene 2009).

The DD-MM analyzes health disclosure decision-making and posits that disclosures occur based on an individual's assessment of three main factors: information assessment, receiver assessment, and disclosure efficacy (Greene 2009).

Individuals assess information, such as the onset of an overuse injury, in terms of five aspects: stigma, preparation, prognosis, symptoms, and relevance to others. Individuals may evaluate if any *stigma* is associated with a health condition and if so, decide not to disclose their health status. Research on mental illness has revealed strong associations suggesting decreased likelihood of disclosure or help-seeking when individuals perceive stigma surrounding mental illnesses. In the field of sports medicine stigma has been associated with injuries due to a "pain principle" in sports where athletes may be encouraged to suppress bodily awareness and limit their expressions of pain in an effort to prove strength or masculinity (Sabo 2009, Kroshus et al 2017, Cranmer et al 2018). Following this principle, adolescent runners may perceive that reporting an injury will cause others to think they are weak or inferior compared to non-injured teammates. Greene suggests that being *prepared* for a disease or injury gives an individual time to prepare a disclosure strategy rather than being surprised by an injury (Greene 2009). This preparation may be an adolescent runner's awareness of the risk of overuse injuries, readiness to recognize common symptoms, and understand how they may be managed or treated if reported to a coach, parent, or healthcare provider. *Prognosis* is related to an individual's uncertainty of the chronicity of a disease or injury, namely whether the condition is acute, chronic, or terminal. In regards to overuse injuries in adolescent runners, this concept may be extended to a runner's perceptions on how the injury may affect their running participation in the future as well as their continued athletic development. If they are uncertain of how their symptoms will affect their future running then they may have decreased efficacy to disclose their symptoms. Individuals also consider the visibility of *symptoms* as important in regard to disclosure decisions. If an adolescent runner's injury symptoms become more apparent to others or if they perceive the symptoms to be more serious, then their likelihood of reporting them may increase. Lastly, Greene also suggests that individuals will be more likely to disclose their related health information if they perceive it to have *relevance to others*. For instance, if an individual perceives that their illness places their friends or family at risk of becoming ill then they may be more likely to disclose it. However, the opposite effect has been observed in sports concussion where an athlete's injury disclosure may negatively impact their team's performance (Cranmer et al 2018).

The second major assessment in the DD-MM is receiver assessment, which is how an individual perceives the potential recipient of their disclosed information (Greene 2009). The receiver assessment involves evaluating the quality of the relationship between an individual and their recipient and the reaction an individual expects from the information recipient upon disclosure. In short, the DD-MM suggests a better-quality relationship will be associated with greater disclosure intentions. The anticipated response is related to how a receiver may react to the information, whether it is positive and supportive or negative and harmful to their continued relationship. The more confident an individual is in a positive anticipated response, the more likely they will disclose information. For example, if an adolescent runner has a very close relationship with their coach and expects their coach will help provide resources to manage their injury then they may be more likely to report an injury to their coach upon recognition of symptoms.

The last main factor in the DD-MM is disclosure efficacy (Greene 2009). This type of self-efficacy refers to an individual's confidence in their ability to share information with their intended recipient in a manner that results in their intended outcome. If an adolescent runner believes they are capable of sharing their injury-related information with a coach and their personal assessments of the injury and coach favor disclosure then they will report their injury symptoms.

We hypothesized that constructs of the DD-MM would explain injury reporting intentions among adolescent runners presented with an overuse injury scenario. Namely, aspects of information assessment and relationship quality between the participant and their coach would predict participants' anticipated response to reporting an injury and their disclosure-efficacy. In turn, participants' higher disclosure efficacy and more positive anticipated responses would predict a higher likelihood of reporting injury symptoms to their coach. Based on the theoretical rationale of the DD-MM, the following hypotheses were made:

> Hypothesis 1: Adolescent runners' assessment of stigma, prognosis, and relevance to others would negatively predict their disclosure-efficacy (*H1a*) and the response they anticipate from coaches (*H1b*). Adolescent runners' assessment of

preparation and symptom severity would positively predict their disclosure-efficacy (*H1c*) and the response they anticipate from coaches (*H1d*).

Hypothesis 2: Adolescent runners' assessment of the relationship quality with their coach would positively predict their disclosure-efficacy (*H2a*) and the response they anticipate from coaches (*H2b*).

Hypothesis 3: Adolescent runners' anticipated response from coaches would positively predict their disclosure-efficacy (*H3a*) and their intentions to report overuse injury symptomology (*H3b*).

Hypothesis 4: Adolescent runners' disclosure-efficacy would positively predict their intentions to report overuse injury symptomology (*H4*).

This hypothesized model is illustrated in Figure 4.1 and operationalized definitions of DD-MM constructs are listed in Table 4.1.

2 METHODS

2.1 Participant Recruitment & Sampling

Potential participants were recruited using network and purposive sampling beginning with emails to high school cross country coaches known to the research team and coaches found on high school directories. Coaches were encouraged to share study information with members of their cross-country team as well as other known contacts who may be eligible. This study information included a link to an online survey where potential participants were screened for the following eligibility criteria before being able to proceed with the full survey: participants must have participated in the fall 2019 high school cross country season. Participants enrolling in this cross-sectional study were eligible to enter a raffle for 1-in-50 odds of receiving a gift card valued at $100.

2.2 Survey

The survey measured participant demographic factors such as age, grade level, sex, ethnicity, running history, and history of participation in other sports. Age, grade level, sex, ethnicity, and running history were each assessed with single-item measures Coach demographics were also measured using three items assessing their sex, estimated age, and ethnicity.

The survey also measures participants' injury history, including if they sustained any injuries during the fall 2019 cross-country season. In this study an injury was defined as any pain that changed a participant's running, including pain that makes them miss a run or practice, run for less distance, run slower, or change their running form. If participants recorded that they did sustain an injury, then follow up questions included the number of injuries they sustained, how much time (if any) they had to take off from running due to injuries, and whether or not they reported their injury to coaches, athletic trainers, parents, other health care providers, etc.

Participants then progressed to a section of the survey that provided a case scenario and asked them to answer questions in reference to how they would respond to the scenario. The scenario introduced early symptoms of a tibial bone stress injury during the first month of a cross-country season. Upon reading this, participants progressed to sections of the survey that assessed their likelihood to report the symptoms to their coach and the main constructs of the DD-MM: Information assessment, receiver assessment, and disclosure efficacy. For each aspect of the DD-MM, confirmatory factor analyses (CFA) were conducted to ensure they met the criteria of face validity and internal consistency. Scales were considered an acceptable model fit if Likelihood ratio Chi-squared tests (χ^2) failed to reject the null hypothesis, Bentler's (Bentler 1990) comparative fit indexes (CFI) were above .90, Steiger & Lind's (Steiger 1980) root-mean-square error of approximation (RMSEA) was less than .08, or the standard root-mean-square residual (SRMR) was less than .08. Model fit was considered good if CFIs were above .95, RMSEAs were less than .05, and SRMRs were less than .05. Chronbach's Alpha statistic was used to assess the reliability of scales with $\alpha > 0.70$ considered acceptable reliability for this study.

Information assessment was explored using a separate measure for each of the five aspects described previously: stigma, preparation, prognosis, symptoms, and relevance.

Stigma – The stigma of reporting injury symptoms was assessed with a six-item adapted version of the cognitive dimension of the Internalized Stigma Scale (Mak et al 2008).

The items were adapted to refer to running injuries. An example stigma item is "My reputation would be damaged if I told my coach about these symptoms." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that four of the six items formed a latent variable representing stigma, $\chi^2(2) = 2.08$, $p = 0.35$, CFI = 1.00, RMSEA = .01, SRMR = .01. The items were averaged to form a scale ranging from zero to one with a higher score representing greater stigma associated with reporting injury symptoms. Reliability for the four-item scale was acceptable ($\alpha = 0.82$, $M = 0.27$, $SD = 0.16$). Items included in the four-item stigma scale can be found in Appendix 3.

Preparation – Preparedness to recognize symptoms and understand how they may be treated was assessed by a four-item novel measure. An example preparation item is "I know what kind of treatment will be involved for these symptoms." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that the four items formed a latent variable representing participants' preparedness, $\chi^2(2) = 1.72$, $p = 0.42$, CFI = 1.00, RMSEA = .00, SRMR = .01. The items were averaged to form a scale ranging from zero to one with a higher score representing greater preparedness to recognize symptoms and understand their likely management. Reliability for the four-item scale was acceptable ($\alpha = 0.79$, $M = 0.68$, $SD = 0.19$). Items included in the four-item preparation scale can be found in Appendix 3.

Prognosis – Prognosis was assessed using two items measuring participants uncertainty regarding how symptoms may affect their future quality of life and ability to run. Prognosis items included "These symptoms will negatively affect my ability to run when I'm an adult" and "These symptoms will negatively affect my quality of life when I'm an adult." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7) and then re-coded so that the less certain responses (3 – uncertain) would be coded higher than certain responses (1 – strongly agree or disagree. The items were averaged to form a scale ranging from zero to one with a higher score representing greater prognosis uncertainty. Reliability for the two-item scale was acceptable ($\alpha = 0.86$, $M = 0.57$, $SD = 0.30$).

Symptoms – Symptom severity was assessed using six items modified from Cranmer et al 2018 to evaluate participants' perceptions regarding the seriousness and severity of symptoms. An example symptom severity item is "These symptoms are not a big deal." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that four of the six items formed a latent variable representing participants' perceptions of symptom severity, $\chi^2(2) = 6.89$, $p<0.05$, CFI = .99, RMSEA = .078, SRMR = .02. The items were averaged to form a scale ranging from zero to one with a higher score representing greater perceived severity of symptoms. Reliability for the four-item scale was acceptable ($\alpha = 0.72$, $M = 0.53$, $SD = 0.18$). Items included in the four-item symptoms scale can be found in Appendix 3.

Relevance – Participants' perceptions of how symptom reporting would impact their team was assessed with four items adapted from Cranmer et al 2018. These items assessed participants' perceptions regarding whether reporting symptoms would negatively impact their teammates, their coaches, and the team's performance. An example relevance item is "If I were to report these symptoms, it would negatively impact my team's immediate performance." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that the four items formed a latent variable representing participants' perceptions of relevancy, $\chi^2(2) = 21.2$, $p<0.01$, CFI = .98, RMSEA = .15, SRMR = .02. The items were averaged to form a scale ranging from zero to one with a higher score representing greater perceived relevancy to their team. Reliability for the four-item scale was acceptable ($\alpha = 0.89$, $M = 0.37$, $SD = 0.21$). Items included in the four-item relevance scale can be found in Appendix 3.

Relationship Quality – Participants' relationship with their coaches was assessed using seven-items from the Coach-Athlete Relationship Questionnaire (CART-Q) (Jowett et al 2004). The seven-items represent the closeness and commitment domains of CART-Q. An example item of the CART-Q's closeness domain is "I like my coach" and an example from the commitment domain is "I feel committed to my coach." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that five of the seven items formed a latent variable representing the relationship quality participants have with their coach, $\chi^2(2) = 11.8$, $p<0.05$, CFI = .995, RMSEA = .06, SRMR = .02. The items were averaged to form a scale ranging from zero to one with a higher score representing better relationship quality. Reliability for the five-item scale was acceptable ($\alpha = 0.88$, $M = 0.90$, $SD = 0.12$). Items included in the five-item relationship quality scale can be found in Appendix 3.

Anticipated Response – Participants' perceptions of how their coach will respond to reporting symptoms was assessed using ten items. These items were adapted from a measure of perceived-concussion reporting consequences and primarily evaluated participant's perceptions of the positivity and predictability of the coach's response to their disclosure of symptoms (Baugh et al 2014). An example anticipated response item is "If I report these symptoms, my coach would think I made the right decision." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that six of the ten items formed a latent variable representing how participants perceive their coaches would respond to reporting symptoms, $\chi^2(2) = 15.9$, $p=0.07$, CFI = .99, RMSEA = .04, SRMR = .03. The items were averaged to form a scale ranging from zero to one with a higher score representing a more positive response anticipated from coaches. Reliability for the six-item scale was acceptable ($\alpha = 0.78$, $M = 0.85$, $SD = 0.11$). Items included in the six-item anticipated response scale can be found in Appendix 3.

Disclosure Efficacy – Disclosure efficacy was assessed using five items regarding participants' confidence in their ability to recognize and report symptoms of an overuse injury. These items were adapted from Kroshus et al.'s (Kroshus et al, 2014) self-efficacy measure used with junior hockey players' reporting of concussion symptoms. The items were modified to be applicable to the symptoms of a stress fracture. An example disclosure efficacy item is "I am confident in my ability to report specific symptoms, even if I'm not sure if it is a stress fracture." Responses were recorded on a 7-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7). CFA indicated that four of the five items formed a latent variable representing participants' self-efficacy to disclose injury symptoms, $\chi^2(2) = 0.03$, p=0.99, CFI = 1.00, RMSEA = .00, SRMR = .001. The items were averaged to form a scale ranging from zero to one with a higher score representing greater self-efficacy to disclose symptoms. Reliability for the four-item scale was acceptable ($\alpha = 0.86$, $M = 0.74$, $SD = 0.20$). Items included in the four-item disclosure efficacy scale can be found in Appendix 3.

Reporting Intentions – Participants were asked how likely they would report symptoms to their coach: within 1-2 days of experiencing them, within one week of continuing but not worsening symptoms, and after three weeks of worsening symptoms resulting in constant pain. Each response was measured using a scale ranging from 0% to 100% likely to report symptoms to their coach.

2.3 Statistical analysis

Descriptive statistics were reported for measured demographic variables, the prevalence of participants sustaining an injury and missing time due to an injury last season. The likelihood of injury reporting was reported in total and stratified by sex and injury history. For all descriptive statistics reported, means and standard deviation were used to describe normally distributed continuous variables, median and interquartile ranges were used for non-normally distributed continuous variables, and frequencies with percentages were used for categorical variables.

Intercorrelations were calculated for all DD-MM variables to assess relationships between theorized constructs and injury reporting intentions. Maximum likelihood structural equation modeling was used to estimate the overall fit of the hypothesized model and the strength of associations between predictor variables and injury reporting intentions. The standards used to assess acceptable and good model fitness for measurement scales were used to assess the hypothesized model (χ^2, CFI, RMSEA, and SRMR). Structural equation models were calculated for injury reporting intentions after one to two days of symptom duration and after one week of symptom duration. Models were not calculated for three week symptom duration reporting intentions due to participants' overall high likelihood of reporting an injury after three weeks.
If original hypothesized models lacked acceptable or good fit, then modification indices were considered and additional paths were drawn under the condition they had theoretical plausibility. The best fitting models for both periods of symptom duration were also used to analyze and compare parameter estimates by sex and

recent injury history (injured during the previous season). All analyses were performed using Stata 14.2 statistical software (Stata Corp LP, College Station, Texas, USA). Structural equation models were created using the Stata's SEM command.

3 RESULTS

Table 4.2 reports demographic information for the 405 study participants. Most participants were white adolescents in 9th through 11th grades with a mix of males and females (53% male, 47% female). Over 66% (n=269) of participants reported sustaining an injury during the previous cross-country season, 67% (n=180) of which had to miss time away from running due to their injury.

Table 4.3 describes participants' likelihood of reporting injury symptoms to their coach 1-2 days, one week, and three weeks after symptom onset. On average, participants reported they were 49% likely to report injury symptoms after 1-2 days, 69% likely after one week of non-worsening symptoms, and 93% likely after three weeks of worsening symptoms. No differences were calculated between males' and females' likelihood of reporting symptoms after 1-2 days or one week, but females reported a slightly higher likelihood of reporting worsening symptoms after three weeks (96.5% likely vs. 93.4% likely; $p<0.05$). Participants who sustained an injury during the previous cross-country season reported a lower likelihood of telling their coach about symptoms than non-injured participants after both 1-2 days (46.4% likely vs 54.2% likely; $p<0.05$) and one week (66.1% likely vs 74.3% likely; $p<0.05$).

Figures 4.2 and 4.3 represent the hypothesized model tested for injury reporting intentions after 1-2 days and one week of symptoms, respectively. The hypothesized model exhibited a poor fit for 1-2 days of symptom duration ($\chi^2(6)$: 34.6 ($p<0.01$), RMSEA 0.11, CFI .94, SRMR 0.04) and for one week of symptom duration ($\chi^2(6)$: 43.7 ($p<0.01$), RMSEA 0.13, CFI .93, SRMR 0.04). Due to this poor fit, modification indices were considered and direct paths were added for stigma and symptoms to reporting intentions (Figures 4.4 & 4.5). These additional paths resulted in good-fitting models for 1-2 days of symptom duration ($\chi^2(4)$: 4.50 ($p=0.34$), RMSEA 0.02, CFI .999, SRMR 0.01) and one week of symptom duration ($\chi^2(4)$: 2.98 ($p=0.56$), RMSEA 0.00, CFI 1.00, SRMR 0.01).

Intercorrelation coefficients are reported in Table 4.4. Meaningful bivariate relationships were observed between theorized constructs consistent with the hypothesized model and previous sports injury research. Reporting intentions after 1-2 days and after one week were correlated ($r = 0.66$, $p<0.01$), but not identical and showed varied correlations with DD-MM constructs. These differences demonstrate the need to analyze reporting factors at both time points.

Hypothesis 1 was partially supported by the tested models. Stigma and prognosis negatively predicted disclosure-efficacy, but relevance did not (*H1a*). Stigma also negatively predicted anticipated response, but prognosis and relevance did not except among recently injured participants when relevance did negatively predict anticipated response (*H1b*). *H1c* was supported as assessments of preparation and symptom severity each positively predicted disclosure-efficacy during each point of symptom duration and among all groups. Preparation also positively predicted anticipated response but symptom severity did not, so *H1d* was only partially supported. Hypothesis 2 was partially supported as adolescent runners' assessment of the quality of their relationship with their coach positively predicted anticipated response during each point of symptom duration and among all groups (*H2b*), but it only positively predicted disclosure efficacy among females (*H2a*). Hypothesis 3 was partially supported as anticipated response positively predicted reporting intentions among males and recently injured participants, but not females or uninjured participants (*H3b*). Anticipated response was predictive of disclosure efficacy among recently injured participants but not among any other groups (*H3a*). Lastly, hypothesis 4 was supported, revealing that disclosure efficacy positively predicted reporting intentions during each point of symptom duration and among all groups.

Differences in model variables by sex are reported in Table 4.5. Females reported higher preparedness to recognize injury symptoms and understand how symptoms would be treated if reported (19.8 vs 18.4, $p<0.01$). There were no other significant differences between females and males among other model variables or recent injury history. Model 2, which incorporated direct paths for stigma and symptoms to injury reporting fit adequately to report parameter estimates by sex, which are displayed in Figure 4.6 for 1-2 days of symptom duration ($\chi^2(8)$: 11.0 (p=0.20), RMSEA 0.04, CFI .99, SRMR 0.02) and Figure 4.7 for one week of symptom duration ($\chi^2(8)$: 20.3 ($p<0.01$), RMSEA 0.087, CFI .98, SRMR 0.02). The manner in which predictor variables influence reporting intentions were different for females and males at both points of symptom duration. Among the model variables, disclosure efficacy was the strongest predictor of reporting intentions among females and the second strongest among males after 1-2 days of symptom duration. It decreased to the third strongest predictor for females after one-week of symptom duration, but remained the second strongest predictor among males. Anticipated response was the strongest predictor of reporting intentions among males at both points of symptom duration, but it was not a significant predictor among females at either point. Stigma became a more important predictor of reporting intentions from 1-2 days of symptom duration to one-week as it became the strongest predictor among females and also strengthened among males. Lastly, perceived symptom severity became a stronger predictor of reporting intentions among females between the two points of symptom duration, however, it decreased in strength among males.

The other primary sex differences in the model pertained to the importance of pertained to the influences of relationship quality and preparation on disclosure efficacy and anticipated response. Relationship quality with their coach was an important predictor of anticipated response among both sexes, but its positive influence on disclosure efficacy was only observed among females. Preparation was a stronger predictor of disclosure efficacy and anticipated response among males compared to females. The influence of all other model variables on disclosure efficacy and anticipated response were very similar between sexes.

Differences in model variables by recent injury history are reported in Table 4.6. Participants who experienced an injury during the previous cross-country season reported higher preparedness to recognize injury symptoms and understand how they'd be treated if reported (19.6 vs 18.0 on a 28-point scale, $p<0.01$). These recently injured participants also reported higher values of stigma associated with injury reporting compared to other participants (8.0 vs 6.4, $p<0.01$). Lastly, recently injured participants reported lower perceived symptom severity to the case scenario compared to other participants (14.7 vs 15.9, $p<0.05$). There were no other significant differences by recent injury history among other model variables. Model 2, which incorporated direct paths for stigma and symptoms to injury reporting fit adequately to report parameter estimates by recent injury history, which are displayed in Figure 4.8 for 1-2 days of symptom duration ($\chi^2(8)$ 4.95 ($p=0.76$), RMSEA 0.00, CFI 1.00, SRMR 0.01) and Figure 9 for one-week of symptom duration ($\chi^2(8)$ 5.59 ($p=0.69$), RMSEA 0.00, CFI 1.00, SRMR 0.02). The manner in which predictor variables influence reporting intentions were different based on recent injury history status at both 1-2 days and one-week of symptom duration. Among the model variables, disclosure efficacy was the strongest predictor of reporting intentions for both groups after 1-2 days of symptom duration. It decreased to the third strongest predictor for recently injured participants after one-week of symptom duration, but remained the strongest predictor among uninjured participants. Stigma became the most important predictor of reporting intentions after one-week among recently injured participants, but was not a significant predictor among uninjured participants during either point of symptom duration. Anticipated response was the second strongest predictor of reporting intentions among recently injured participants at both points of symptom duration, but it was not a significant predictor among uninjured participants. Lastly, perceived symptom severity was a strong predictor of reporting intentions for both groups after 1-2 days of symptom duration, but only remained a strong predictor after one-week of symptoms among recently injured participants. While this model had adequate fit for participants without recent injury, it did not explain as much variance in reporting intentions compared to participants with a recent injury (adjusted R^2 .130 vs .332). Other differences by injury history included the influence of relevance on anticipated response and the influence of anticipated response on disclosure efficacy. Recently injured participants' perception of information relevance negatively influenced how they anticipated their coaches would respond to their symptom reporting. Additionally, the response they anticipated positively predicted their disclosure efficacy.

4 DISCUSSION

4.1 Overall Model Fit

Initially, the hypothesized model did not fit the data adequately to explain adolescent runners' intentions to report overuse injury symptoms. However, adjusting the model to include direct paths from perceived stigma and symptom severity to reporting intentions resulted in a good model fit and explained 27% and 28% of the observed variance in reporting intentions. These new significant paths suggest that adolescents' perceived stigma and symptom severity directly affect their likelihood to report overuse injury symptoms. These direct relationships are in addition to the influence of perceived stigma and symptom severity on disclosure efficacy and anticipated response. Further testing with this model allowed for observed differences in important factors related to reporting intentions by sex and recent injury history. Important predictors of adolescent runners' symptom reporting intentions are described in more detail below, as well as how they vary by sex and recent injury history.

4.2 Important Predictors of Symptom Reporting Intentions

The most important predictors of reporting intention among adolescent runners in this sample were disclosure efficacy and stigma, although these varied by sex and recent injury history. In the complete sample, disclosure efficacy was the strongest predictor of reporting intention upon recognition of symptoms, however, stigma was the strongest predictor of reporting intention if symptoms lingered for one week. This finding suggests that although disclosure efficacy remains an important predictor of reporting intention, adolescent runners' perceived stigma regarding injury becomes more important as symptom duration increases from 1-2 days to one week.

Stigma has been described to have a moderating effect on disclosing concussion symptoms by negatively influencing how adolescents perceive their coach would respond to their symptom disclosure (Cranmer et al 2018). The current study observed this same effect on the anticipated response from coaches, but it also observed stigma's negative effect on disclosure efficacy and on reporting intentions directly. Previous research has explored the association between sports injury, depression, and psychological stress among athletes and found a decreased likelihood to seek help for psychological health due to a stigma of mental illness (Lebrun et al 2018, Souter et al 2018). However, to our knowledge, stigma associated with reporting overuse injuries among adolescent athletes has not been reported. This stigma is likely associated with adolescent athletes' identity formation. Adolescents with high sport involvement may seek social approval and establish their identity through their athletic accomplishments. These adolescents may be likely to avoid situations that threaten their developing athletic identity, such as injuries that limit their participation in sport (Brewer et al 2017). Adolescent athletes with greater athletic identity experience greater depression following an injury (Manuel et al 2002) and are more likely to play through pain (Weinberg et al 2013). It is possible that adolescent runners in this study who have greater athletic identity perceive greater stigma around reporting an injury as it may threaten their status and identity as an athlete.

Overall, the stigma associated with reporting injury symptoms was low in our sample, however, this suggests that even minor perceptions of stigma have a strong effect on adolescent runners' intentions to report injury symptoms, their confidence to report symptoms, and how they perceive their coach will react if they disclose symptoms.

In addition to perceived stigma's negative association with reporting intentions, adolescent runners' disclosure efficacy, perceived symptom severity, and their anticipated response from coaches are each independent positive predictors of reporting intentions in this study. Disclosure efficacy and anticipated response were both hypothesized predictors of reporting intentions, while symptom severity became a new path based on the study data. At both points of symptom duration and among all sub-groups, perceived symptom severity was positively associated with disclosure efficacy and was also an independent positive predictor of reporting intentions among most groups. This positive influence of perceived symptom severity on reporting intentions is consistent with the Health Belief Model's construct of perceived threat, which is often used to predict or explain preventive health behaviors (Rosenstock 1974). In the context of sports injury research, perceived threat has been observed as a positive predictor of parents encouraging their children to report concussion symptoms, however, this was most evident among parents whose children had already experienced a concussion (Kroshus et al 2018).

4.3 Differences by Sex

The males and females in this study exhibited differences in the important factors surrounding injury reporting intentions. Compared to males, females' reporting intentions were more influenced by the stigma they associate with reporting an injury, while males were more influenced by how they perceived their coaches would respond if symptoms were reported. The perceived severity of symptoms was important for both sexes within 1-2 days of symptom recognition, however, after one week of symptoms the perceived severity remained important predictor of reporting intentions among females but not males. Lastly, disclosure efficacy was an important predictor of reporting intentions among both sexes, but they differed in the observed variables that predicted efficacy. Females' disclosure efficacy was most-informed by perceived stigma and relationship quality, whereas males' disclosure efficacy was most-informed by their preparation to recognize and understand injury symptoms. According to these results, adolescent females' intentions to report overuse injury symptoms could be most improved by reducing the stigma associated with injury. Similarly, adolescent males' intentions to report overuse injury symptoms could be most improved by believing their coach will respond with positivity if presented with a potential injury. Both sexes' injury reporting may be improved by coaches fostering close relationships and instilling confidence in their athletes to recognize symptoms and understand their management. These actions may help negate the stigma that may be associated with overuse injuries.

4.4 Differences by Recent Injury History

Adolescents who experienced an injury in the most recent cross-country season reported a lower likelihood to tell their coaches about overuse injury symptoms than adolescents who had not been injured. Important factors related to these intentions differed greatly between these groups.

Recently injured runners likely developed resiliency through their injury experience and returned to the sport. It is not surprising that they demonstrated greater perceived preparation to recognize and understand symptoms, however, this resiliency may make them take early warning signs of injury with less caution. This might explain why they reported lower symptom severity than non-injured participants. Notably, these results seem to indicate that a part of their personal injury experience results in heightened perceptions of stigma around injury, which negatively effects their disclosure efficacy, perceptions of how their coaches would respond to injury, and ultimately their intention to disclose symptoms to coaches. It is important to note that these recently injured adolescents also place greater importance on their coach's response to inform their disclosure decision. It may be that they desire more support and positivity from their coaches to offset or negate any stigma associated with injury. Or perhaps some of them are concerned about disappointing their coaches by becoming injured again and thus place greater emphasis on their coach's response when deciding whether or not to report symptoms. Either way, qualitative research is needed to provide clarity on the injury experiences of these runners and explore what factors and experiences contribute to changes in their perceived stigma and factors related to reporting intentions.

4.5 Limitations

This study has limitations that should be considered. First, this study uses case scenarios to predict reporting intentions at multiple fictitious time points using a cross-sectional design. The use of case scenarios or vignettes to predict behaviors may result in an over-rationalized thought processes that may not represent how individuals would behave in lived situations. Future research incorporating real experiences should be conducted to add to this topic area. Another caution is the amount of variance of reporting intentions explained by the models studied. As described previously, only 13-19% of the variance associated with injury reporting was explained for non-injured participants. While other groups in this study had greater amounts of variance explained, there was still 67-75% of variance that was unexplained. This unexplained variance may be a potential limitation of the model's scope. While the DD-MM provides a multi-dimensional approach incorporating personal and relational factors there are other external factors that may contribute to adolescent runners' intentions to disclose injury symptoms. For example, social and environmental factors outside the DD-MM may influence intentions. This study focused on relationships and disclosures to coaches only, while adolescents may choose to disclose their symptoms first to a family member, trusted medical provider, or other close relation prior to telling their coach. The advice they receive and interactions they have with these other important individuals would definitely influence their decision to report symptoms to their coach. Additionally, factors regarding access to care were not included in this model. The presence of an athletic trainer who works closely with the team can influence how injuries are recognized and managed. It is also possible that adolescents whose families avoid utilizing the health care system due to financial or other reasons may be less likely to report symptoms. Another limitation of this study is the measures used to assess *relevance*, which did not fit the data as well as other measured variables. This may be responsible for the limited utility of relevance to predict disclosure efficacy or anticipated response in our study. Relevance was only a significant predictor of anticipated response among recently injured adolescents, where greater relevance to others predicted a more negative anticipated response from coaches. Future research may investigate better measures to assess relevance to assess its influence on reporting intentions. Lastly, this study may be limited by selection bias. Our participants received information about the study before actively deciding to complete the survey and share information about their personal experiences with cross-country and injuries. Given their voluntary participation, these individuals may also be more likely to report injuries to their coaches than other eligible individuals who declined to participate. Additionally, the injury prevalence of our participants was higher than what has been reported in other studies with adolescent runners so selection bias among recently injured individuals may have been present. However, we may also speculate that adolescent runners may have underreported injuries in the other studies given the findings of this study.

4.6 Significance of Findings

This study is the first to explore factors related to overuse injury reporting using a theoretical framework. This is an important topic considering the majority of adolescent sports injuries are due to overuse (Cassell et al 2019) and numerous studies cite concerns of underreporting injuries (Baugh et al 2019, Kroshus et al 2014, Yang et al 2012), which bring into question our knowledge of injury burden across sports and the health of young athletes. Further, the theoretical framework used in this study emphasizes the significance of interpersonal relationships as well as many personal factors in determining intentions of injury reporting. This study revealed differences in important factors regarding complex disclosure intentions among adolescent runners by sex and recent injury status. These findings can direct future research to explore salient factors through qualitative and mixed-methods studies and develop strategies to improve adolescent runners' efficacy and overuse injury reporting intentions.

REFERENCES

Aicale, R., Tarantino, D., & Maffulli, N. (2018). Overuse injuries in sport: A comprehensive overview. *Journal of Orthopaedic Surgery and Research, 13*(1), 309-5. doi:10.1186/s13018-018-1017-5 [doi]

Ajzen I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Process, 50(2),* 179-211

Bahr, R. (2009). No injuries, but plenty of pain? on the methodology for recording overuse symptoms in sports. *British Journal of Sports Medicine, 43*(13), 966-972. doi:10.1136/bjsm.2009.066936 [doi]

Baugh, C. M., Kroshus, E., Daneshvar, D. H., & Stern, R. A. (2014). Perceived coach support and concussion symptom-reporting: Differences between freshmen and non-freshmen college football players. *The Journal of Law, Medicine & Ethics : A Journal of the American Society of Law, Medicine & Ethics, 42*(3), 314-322. doi:10.1111/jlme.12148 [doi]

Beachy, G., Akau, C. K., Martinson, M., & Olderr, T. F. (1997). High school sports injuries. A longitudinal study at Punahou School: 1988 to 1996. *The American Journal of Sports Medicine, 25*(5), 675-681. doi:10.1177/036354659702500515 [doi]

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238-246. doi:10.1037/0033-2909.107.2.238 [doi]

Brewer, B. W., & Petitpas, A. J. (2017). Athletic identity foreclosure. *Current Opinion in Psychology, 16*, 118-122. doi:S2352-250X(16)30165-8 [pii]

Cassel, M., Muller, J., Moser, O., Strempler, M. E., Reso, J., & Mayer, F. (2019). Orthopedic injury profiles in adolescent elite athletes: A retrospective analysis from a sports medicine department. *Frontiers in Physiology, 10*, 544. doi:10.3389/fphys.2019.00544 [doi]

Chan, C. S., & Grossman, H. Y. (1988). Psychological effects of running loss on consistent runners. *Perceptual and Motor Skills, 66*(3), 875-883. doi:10.2466/pms.1988.66.3.875 [doi]

Clarsen, B., Myklebust, G., & Bahr, R. (2013). Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: The oslo sports trauma research centre (OSTRC) overuse injury questionnaire. *British Journal of Sports Medicine, 47*(8), 495-502. doi:10.1136/bjsports-2012-091524 [doi]

Cranmer, G., & LaBelle, S. (2018). Using the disclosure decision-making model to understand high school football players' disclosures of concussion symptoms. *International Journal of Sport Communication, 11(2), 241-60.*

Greene, K. (2009). An integrated model of health disclosure decision-making. In T. D. Afifi & W. A. Afifi (Eds.), Uncertainty and information regulation in interpersonal contexts: Theories and applications (pp. 226–253). New York, NY: Routledge.

Hespanhol Junior, L. C., Pillay, J. D., van Mechelen, W., & Verhagen, E. (2015). Meta-analyses of the effects of habitual running on indices of health in physically inactive adults. *Sports Medicine (Auckland, N.Z.), 45*(10), 1455-1468. doi:10.1007/s40279-015-0359-y [doi]

Jowett, S., & Ntoumanis, N. (2004). The coach-athlete relationship questionnaire (CART-Q): Development and initial validation. *Scandinavian Journal of Medicine & Science in Sports, 14*(4), 245-257. doi:10.1111/j.1600-0838.2003.00338.x [doi]

Koplan, J. P., Rothenberg, R. B., & Jones, E. L. (1995). The natural history of exercise: A 10-yr follow-up of a cohort of runners. *Medicine and Science in Sports and Exercise, 27*(8), 1180-1184.

Kox, L. S., Opperman, J., Kuijer, P P F M, Kerkhoffs, G M M J, Maas, M., & Frings-Dresen, M. H. W. (2019). A hidden mismatch between experiences of young athletes with overuse injuries of the wrist and sports physicians' perceptions: A focus group study. *BMC Musculoskeletal Disorders, 20*(1), 235-y. doi:10.1186/s12891-019-2616-y [doi]

Kroshus, E., Babkes Stellino, M., Chrisman, S. P. D., & Rivara, F. P. (2018). Threat, pressure, and communication about concussion safety: Implications for parent concussion education. *Health Education & Behavior : The Official Publication of the Society for Public Health Education, 45*(2), 254-261. doi:10.1177/1090198117715669 [doi]

Kroshus, E., Baugh, C. M., Daneshvar, D. H., & Viswanath, K. (2014). Understanding concussion reporting using a model based on the theory of planned behavior. *The Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine, 54*(3), 269-274.e2. doi:10.1016/j.jadohealth.2013.11.011 [doi]

Kroshus, E., Baugh, C. M., Stein, C. J., Austin, S. B., & Calzo, J. P. (2017). Concussion reporting, sex, and conformity to traditional gender norms in young adults. *Journal of Adolescence, 54*, 110-119. doi:S0140-1971(16)30148-8 [pii]

Lebrun, F., MacNamara, A., Rodgers, S., & Collins, D. (2018). Learning from elite athletes' experience of depression. *Frontiers in Psychology, 9*, 2062. doi:10.3389/fpsyg.2018.02062 [doi]

Lee, D. C., Brellenthin, A. G., Thompson, P. D., Sui, X., Lee, I. M., & Lavie, C. J. (2017). Running as a key lifestyle medicine for longevity. *Progress in Cardiovascular Diseases, 60*(1), 45-55. doi:S0033-0620(17)30048-8 [pii]

Lee, D. C., Pate, R. R., Lavie, C. J., Sui, X., Church, T. S., & Blair, S. N. (2014). Leisure-time running reduces all-cause and cardiovascular mortality risk. *Journal of the American College of Cardiology, 64*(5), 472-481. doi:10.1016/j.jacc.2014.04.058 [doi]

Manuel, J. C., Shilt, J. S., Curl, W. W., Smith, J. A., Durant, R. H., Lester, L., & Sinal, S. H. (2002). Coping with sports injuries: An examination of the adolescent athlete. *The Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine, 31*(5), 391-393. doi:S1054139X02004007 [pii]

Nussbaum, E. D., Gatt, C. J., Epstein, R., Bechler, J. R., Swan, K. G., Tyler, D., & Bjornaraa, J. (2019). Validation of the shin pain scoring system: A novel approach for determining tibial bone stress injuries. *Orthopaedic Journal of Sports Medicine, 7*(10), 2325967119877803. doi:10.1177/2325967119877803 [doi]

Ohta-Fukushima, M., Mutoh, Y., Takasugi, S., Iwata, H., & Ishii, S. (2002). Characteristics of stress fractures in young athletes under 20 years. *The Journal of Sports Medicine and Physical Fitness, 42*(2), 198-206.

Rauh, M. J., Margherita, A. J., Rice, S. G., Koepsell, T. D., & Rivara, F. P. (2000). High school cross country running injuries: A longitudinal study. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine, 10*(2), 110-116. doi:10.1097/00042752-200004000-00005 [doi]

Register-Mihalik, J. K., Guskiewicz, K. M., McLeod, T. C., Linnan, L. A., Mueller, F. O., & Marshall, S. W. (2013). Knowledge, attitude, and concussion-reporting behaviors among high school athletes: A preliminary study. *Journal of Athletic Training, 48*(5), 645-653. doi:10.4085/1062-6050-48.3.20 [doi]

Rosenstock, I. M. (1974). The health belief model and preventive health behavior. *Health Education & Behavior, 2*, 354-386.

Sabo, D. (2009). Sports Injury, the Pain Principle, and the Promise of Reform. *Journal of Intercollegiate Sport*, *2*(1), 145-152.

Souter, G., Lewis, R., & Serrant, L. (2018). Men, mental health and elite sport: A narrative review. *Sports Medicine - Open, 4*(1), 57-7. doi:10.1186/s40798-018-0175-7 [doi]

Steiger, J.H., & Lind, J.C. (1980, May). *Statistically based tests for the number of common factors.* Paper presented at the Annual Spring Meeting of the Psychometric Society, Iowa City, IA.

Valovich McLeod, T. C., Decoster, L. C., Loud, K. J., Micheli, L. J., Parker, J. T., Sandrey, M. A., & White, C. (2011). National athletic trainers' association position statement: Prevention of pediatric overuse injuries. *Journal of Athletic Training, 46*(2), 206-220. doi:10.4085/1062-6050-46.2.206 [doi]

Weinberg R., Vernau D., & Horn T. (2013). Playing through pain and injury: psychosocial considerations. *Journal of Clinical Sport Psychology, 7*, 41-59.

Yang, J., Tibbetts, A. S., Covassin, T., Cheng, G., Nayar, S., & Heiden, E. (2012). Epidemiology of overuse and acute injuries among competitive collegiate athletes. *Journal of Athletic Training, 47*(2), 198-204. doi:10.4085/1062-6050-47.2.198 [doi]

TABLES & FIGURES

Table 4.1 Disclosure Decision-Making Model Operationalized Constructs

DD-MM Construct	Definition	Example Item
Preparation	Perceived ability to recognize symptoms and understand how they may be treated	"I know what kind of treatment will be involved for these symptoms"
Stigma	A mark of shame associated with reporting injury symptoms	"My reputation would be damaged if I told my coach about these symptoms"
Symptom Severity	Perceived severity of symptoms	"These symptoms are not a big deal"*
Prognosis	Participants' uncertainty of the chronicity of an injury	"These symptoms will negatively affect my ability to run when I'm an adult"*
Relevance	Participants' perceptions of how symptom reporting might impact others close to them (e.g. their team's performance)	"If I were to report these symptoms, it would negatively impact my team's immediate performance"
Relationship Quality	Participants' perceptions of the relationship they have with their coach	"I like my coach"
Anticipated Response	Participants' perceptions of how their coach will respond to their symptom reporting, positive or negative	"If I report these symptoms, my coach would think I made the right decision"
Disclosure Efficacy	Participants' confidence in their ability to recognize and report symptoms of an overuse injury	"I am confident in my ability to report specific symptoms, even if I'm not sure if it is a stress fracture"
*Reverse coded for analysis		

Figure 4.1 Proposed DD-MM to Explain Overuse Injury Reporting among Adolescent Runners (n=405)

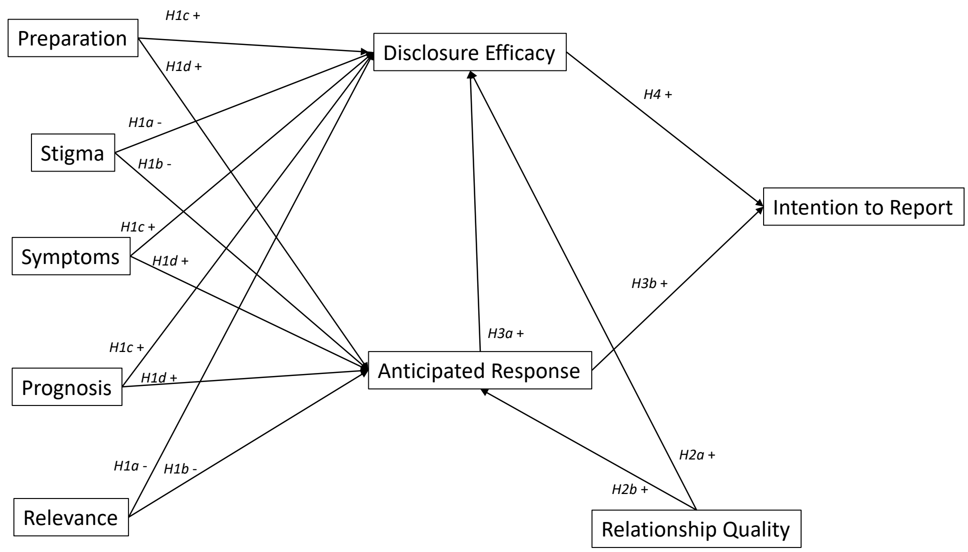


Table 4.2 Participant Demographics (n=405)

Variable	n (%)
Age, mean (SD)	16.1 years (1.3)
Cross-country experience, mean (SD)	2.9 years (1.6)
Sex	
Male	213 (52.6%)
Female	192 (47.4%)
Grade	
7	13 (3.2%)
8	31 (7.7%)
9	104 (25.7%)
10	92 (22.7%)
11	135 (33.3%)
12	30 (7.4%)
Race	
Asian	16 (4.0%)
Black	14 (3.5%)
Hispanic/Latino	42 (10.4%)
White	318 (78.5%)
Other	15 (3.7%)
Injured Last Season (Fall 2019)	269 (66.4%)
Time-Loss Injury Last Season	180 (44.4%)

Table 4.3 Likelihood of Injury Reporting by Symptom Duration, Sex, and Injury History (n=405)

	Symptom Duration		
	1-2 Days	1 Week	3 Weeks
Sex			
Females (n=192)	47.1%	67.0%	96.5%
Males (n =213)	50.8%	70.5%	93.4%*
Injured Last Season			
Yes (n=269)	46.4%	66.1%	94.0%
No (n=136)	54.2%*	74.3%*	96.6%
Total	49.0%	68.8%	94.9%

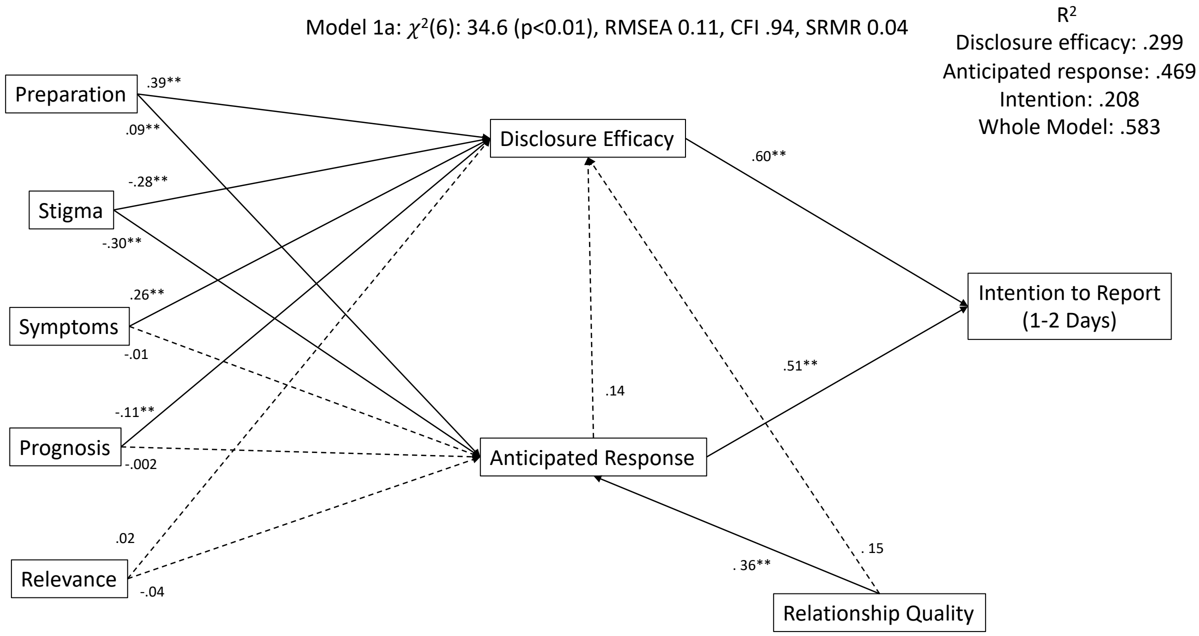
**Significant difference by group (p<0.05)*

Table 4.4 Correlation Matrix for all DD-MM variables (n=405)

	1	2	3	4	5	6	7	8	9	10
1. Stigma	___									
2. Preparation	-.07	___								
3. Prognosis	.13**	-.15**	___							
4. Symptoms	-.15**	-.38**	.12*	___						
5. Relevance	.35**	.09	.19**	-.06	___					
6. Relationship quality	-.28**	.22**	.01	-.03	.02	___				
7. Anticipated response	-.54**	.32**	-.09	-.03	-.19**	.52**	___			
8. Self-efficacy	-.34**	.36**	-.21**	.10	-.07	.25**	.33**	___		
9. 1-2 Day Intention	-.36**	.08	-.08	.22**	-.13*	.25**	.30**	.42**	___	
10. 1 Week Intention	-.43**	.12	-.06	.21**	-.10	.25**	.34**	.39**	.66**	___

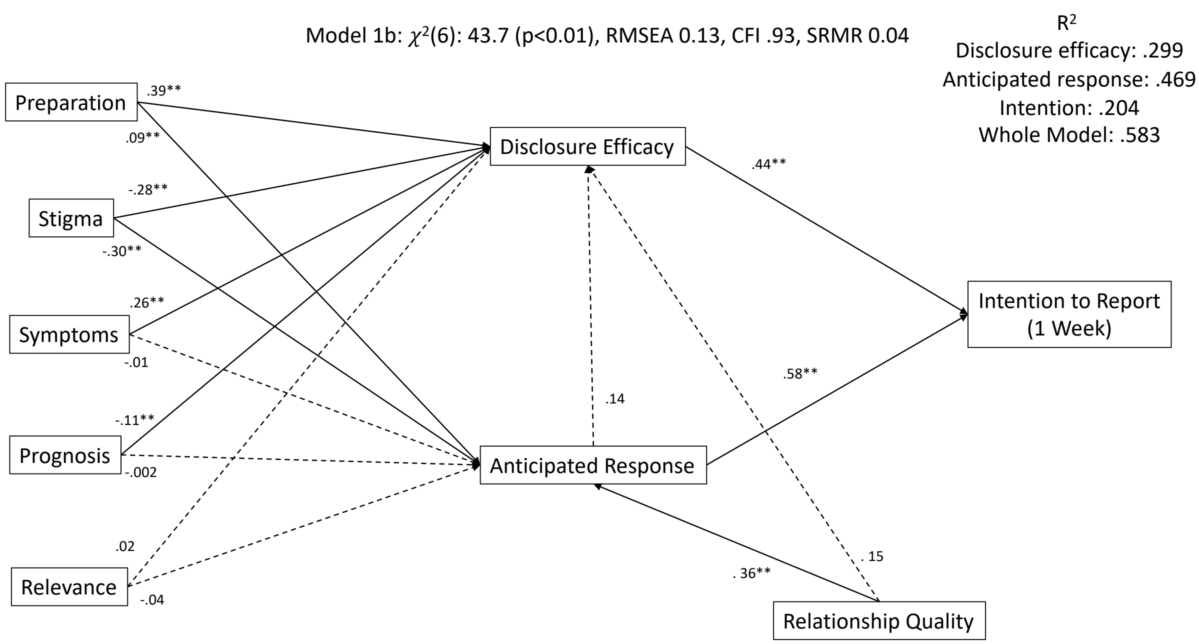
*p<.05; **p<.01

Figure 4.2 Model 1a: DD-MM and Injury Reporting Intentions with 1-2 Days of Symptoms among All Participants (n=405)



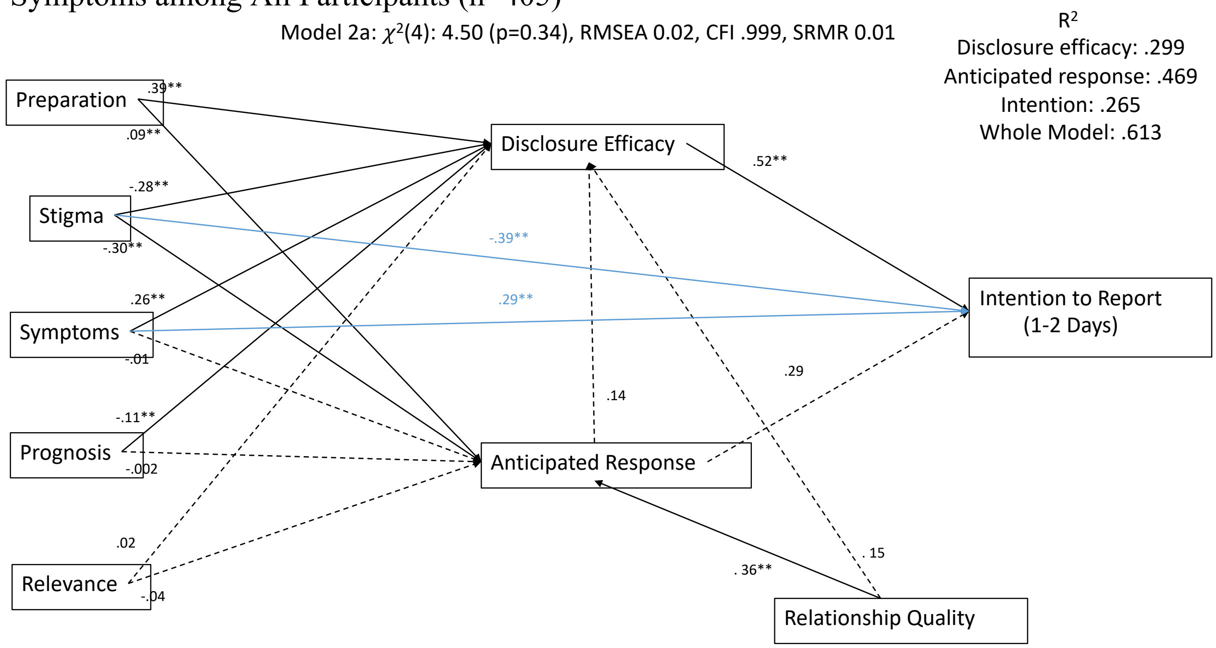
*p<0.05, **p<0.01*

Figure 4.3 Model 1b: DD-MM and Injury Reporting Intentions with 1 Week of Symptoms among All Participants (n=405)



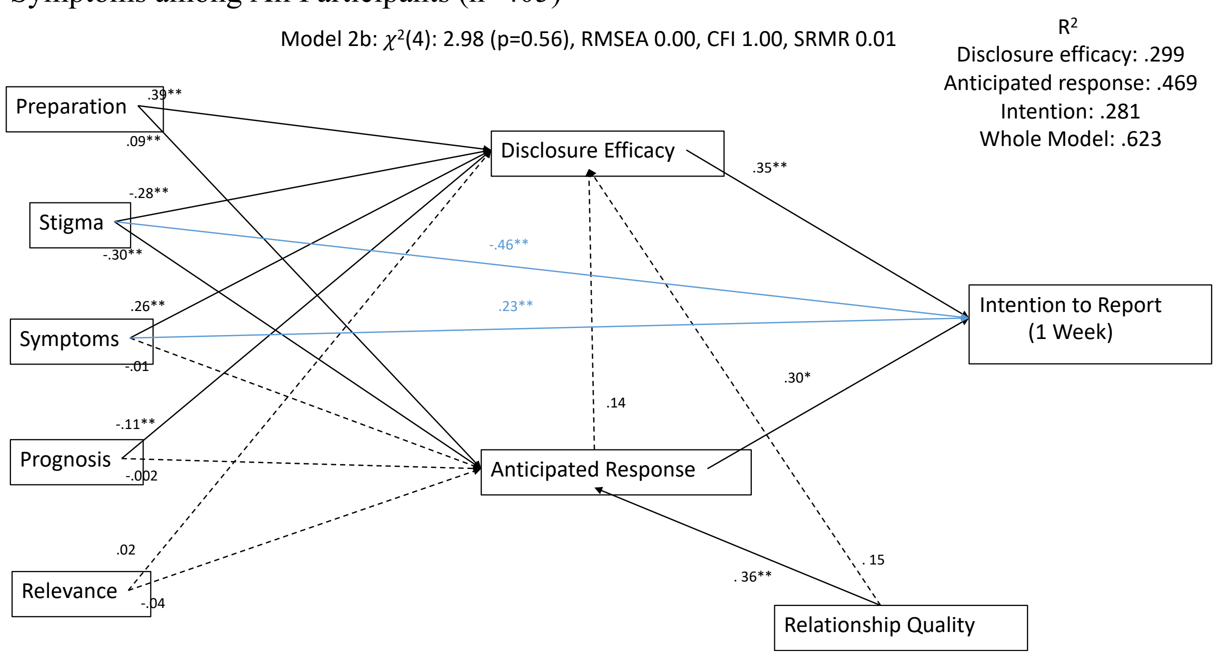
*p<0.05, **p<0.01*

Figure 4.4 Model 2a: DD-MM and Injury Reporting Intentions with 1-2 Days of Symptoms among All Participants (n=405)



^ Blue lines indicate new paths based on modification indices
**p<0.05, **p<0.01*

Figure 4.5 Model 2b: DD-MM and Injury Reporting Intentions with 1 Week of Symptoms among All Participants (n=405)

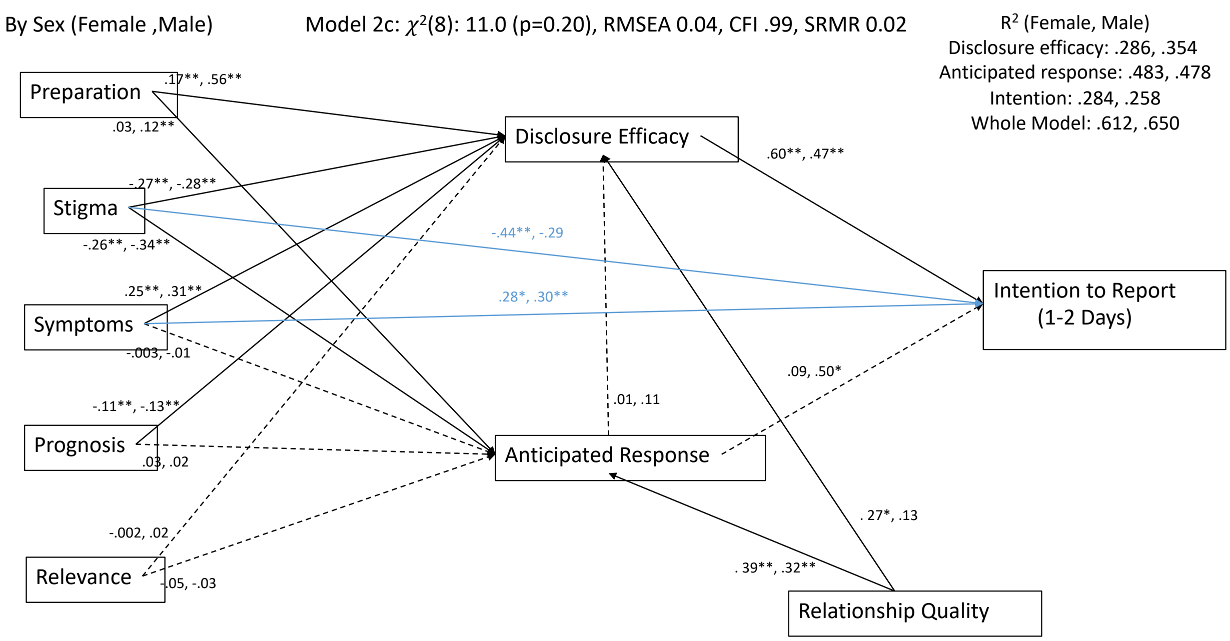


^ Blue lines indicate new paths based on modification indices
**p<0.05, **p<0.01*

Table 4.5 Comparison of Measured Variables by Sex (n=405)

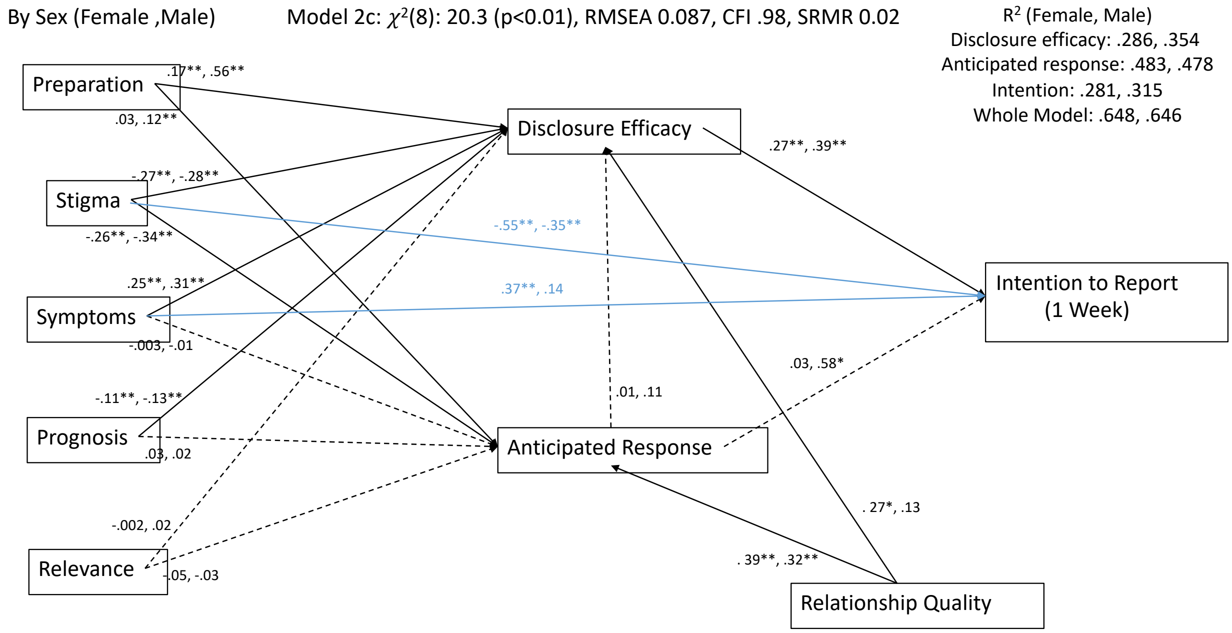
Variable (Max Possible Value)	Female	Male	Difference
Preparation (28)	19.8 (4.9)	18.4 (5.6)	p<0.01
Stigma (28)	7.7 (4.4)	7.3 (4.3)	ns
Symptoms (28)	14.9 (5.0)	15.2 (5.3)	ns
Prognosis (14)	8.0 (4.2)	8.0 (4.3)	ns
Relevance (28)	10.1 (5.6)	10.8 (6.2)	ns
Relationship Quality (35)	31.6 (4.4)	31.7 (4.2)	ns
Anticipated Response (42)	36.0 (4.7)	35.6 (4.9)	ns
Disclosure Efficacy (28)	20.9 (5.2)	20.5 (6.0)	ns
Injured Last Season (n, %)	136 (70.8%)	133 (62.4%)	ns
Injured with Time-lost (n, %)	90 (46.9%)	90 (42.3%)	ns

Figure 4.6 Model 2c: DD-MM on Injury Reporting Intentions with 1-2 Days of Symptoms by Sex (n=405)



^ *Blue lines indicate new paths based on modification indices*
**p<0.05, **p<0.01*

Figure 4.7 Model 2d: DD-MM on Injury Reporting Intentions with 1 Week of Symptoms by Sex (n=405)

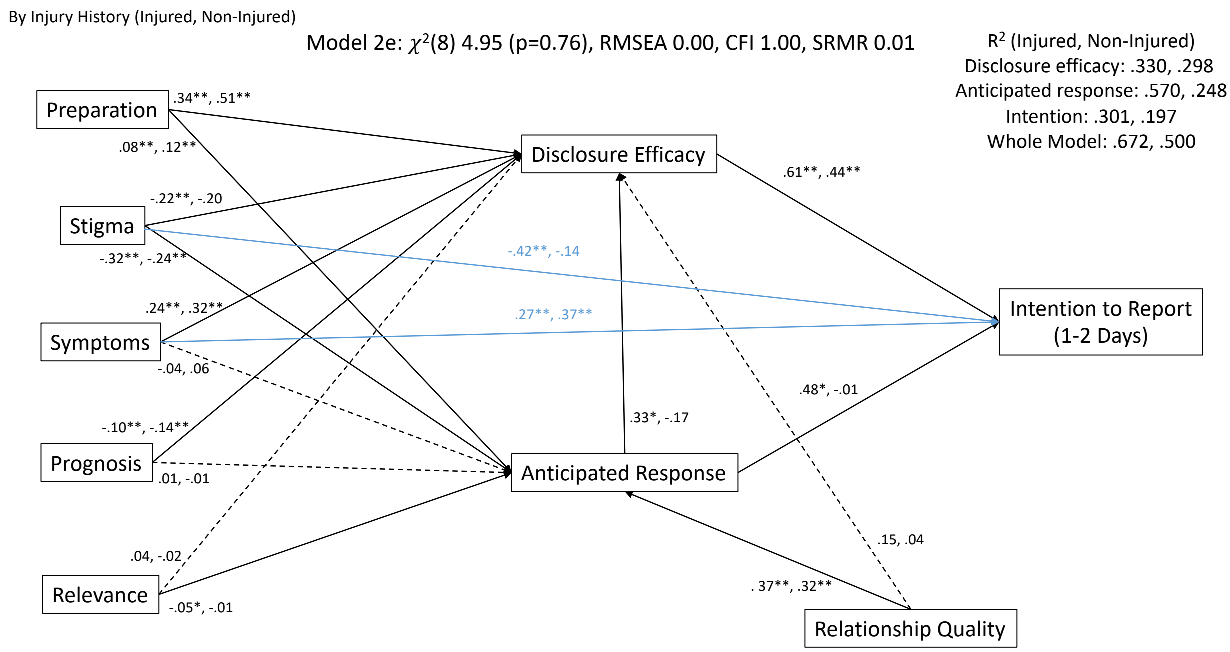


^ Blue lines indicate new paths based on modification indices
**p<0.05, **p<0.01*

Table 4.6 Comparison of Measured Variables by Recent Injury History (n=405)

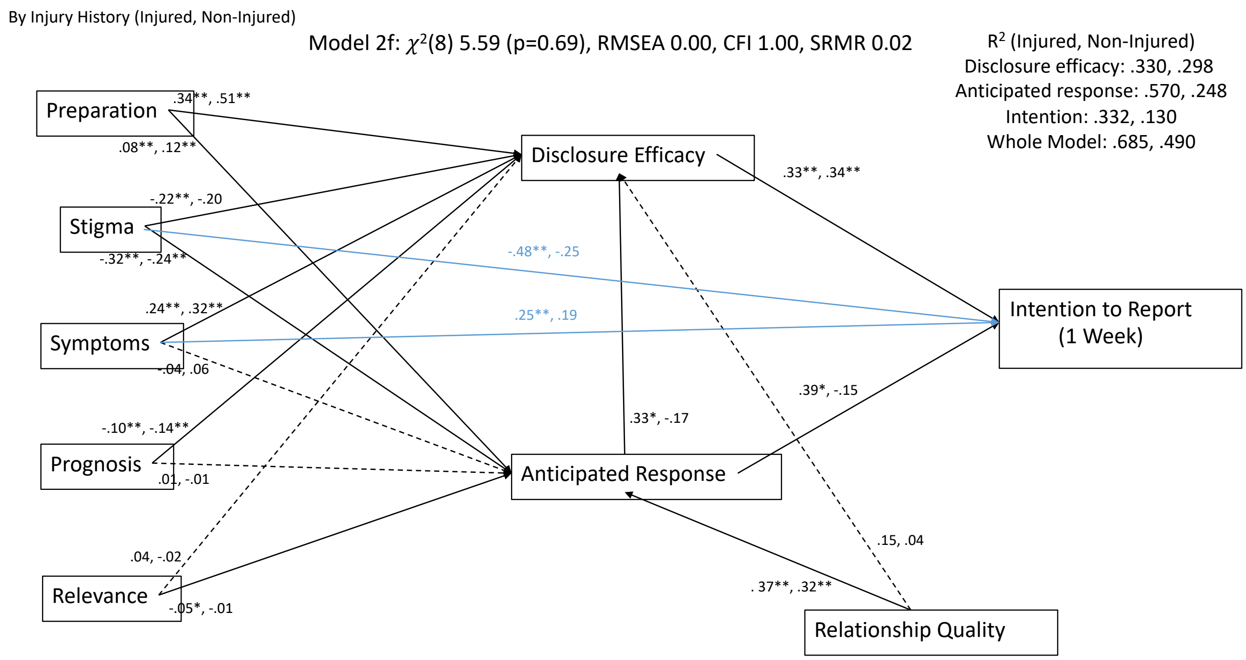
Variable (Max Possible Value)	Injured	Non-Injured	Difference
Preparation (28)	19.6 (5.2)	18.0 (5.4)	p<0.01
Stigma (28)	8.0 (4.6)	6.4 (3.5)	p<0.01
Symptoms (28)	14.7 (5.2)	15.9 (5.0)	p<0.05
Prognosis (14)	7.8 (4.2)	8.3 (4.3)	ns
Relevance (28)	10.8 (6.1)	9.90 (5.6)	ns
Relationship Quality (35)	31.5 (4.6)	31.9 (3.7)	ns
Anticipated Response (42)	35.6 (4.9)	36.2 (4.5)	ns
Disclosure Efficacy (28)	20.4 (5.8)	21.3 (5.3)	ns

Figure 4.8 Model 2e: DD-MM on Injury Reporting Intentions with 1-2 Days of Symptoms by Injury History (n=405)



^ Blue lines indicate new paths based on modification indices
**p<0.05, **p<0.01*

Figure 4.9 Model 2f: DD-MM on Injury Reporting Intentions with 1 Week of Symptoms by Injury History (n=405)



^ *Blue lines indicate new paths based on modification indices*
**p<0.05, **p<0.01*

CHAPTER 5

SUMMARY OF FINDINGS & FUTURE DIRECTIONS

CHAPTER SUMMARIES

Chapter One

The first chapter of this dissertation provided an introduction to the health benefits of sport participation, particularly running athletes in cross-country and track and field. It also highlighted the large numbers of high school and collegiate cross-country and track and field participants, all of whom have great potential for lifelong physical activity, but many of whom experience injuries related to their sport that may decrease their likelihood of continued sport participation, physical activity, and may result in future health consequences (Koplan et al 1995, Carbone et al 2017, Alentorn-Geli et al 2017). Given these injury risks in cross-country and track and field, a prominent injury prevention model was described (van Mechelen 1992). The importance of injury surveillance was highlighted due to its responsibility of defining the extent of injury problems within each sport and its usefulness in evaluating the effectiveness of injury prevention or risk reduction programs. Chapter one also addressed historical problems with estimating injury risk in cross-country and track and field, particularly methodological issues surrounding estimations of injury risk and the problem of athletes under-reporting injuries to coaches or sports medicine staff (Wallace et al 2017, Register-Mihalik et al 2013, Baugh et al 2019). Another problem specifically affecting injury risk estimates in track and field was the heterogeneity of athletes competing in specialized disciplines who likely have very different injury risks and patterns, although this hasn't been appropriately studied in collegiate track and field. Lastly, chapter one defined the purpose of this dissertation and provided an overview of the aims and significance of each subsequent chapter.

Chapter Two

The second chapter of this dissertation was a systematic review and meta-analysis that explored injury risk in high school and collegiate cross-country and track and field. The chapter provided an analysis based on analyzed data from 26 research articles and found no significant difference in injury risk between cross-country and track and field athletes. The meta-analysis pooled 7,603 injuries from eight studies to estimate 5.33 time-loss injuries per 1,000 athletic exposures; 2,689 injuries from 12 studies to estimate 39.5 time-loss injuries per 100 athlete-seasons; and 1,601 injuries from 15 studies to estimate a 25.3% time-loss injury prevalence in a given season. Fewer studies reported non-time loss injuries in addition to time-loss injuries. Pooling total injuries from these studies resulted in 13.1 total injuries per 1,000 athletic exposures, 68.4 total injuries per 100 athlete-seasons, and 49.3% total injury prevalence during cross-country and track and field seasons. The meta-analysis highlighted an increased risk of time-loss injury among females compared to males when accounting for athletic exposures. Additionally, collegiate athletes exhibited a greater prevalence of injury during an entire season, but high school athletes exhibited higher rates of injury per athletic exposure. The systematic review found a lack of studies measuring injury risk in terms of time or distance of sport exposure, which should be included in future studies to better assess injury risk. Lastly, the meta-analysis observed that studies using self-reported injury data may be more sensitive than other mechanisms of injury reporting, which may indicate a problem of athletes under-reporting injuries to their coaches and medical staff. Chapter two closed with a call for future research using qualitative and behavioral science approaches to investigate factors related to injury reporting among these athletes.

Chapter Three

The third chapter of this dissertation aimed to describe and compare injury rates and patterns in collegiate track and field. This study used injury surveillance data from the NCAA Injury Surveillance Program and included 1,466 injuries over the course of five years, including 367,285 unique athletic exposures (AEs). The main findings of this study included an injury rate of 3.99 injuries per 1,000 AEs, which included 1.62 time loss injuries per 1,000 AEs. The rate of injury was higher among women compared to men, during competitions compared to practices, and during the indoor track and field season compared to the outdoor season. In addition to their higher rates of injury, the amount of time missed due to injury was also greater among women and participants who sustained injuries during competition. This study also aimed to compare injury patterns between track and field disciplines, an area that has been underreported among collegiate track and field athletes. Distance running injuries were more often classified as overuse injuries and accounted for greater amounts of time missed due to injury compared to other track and field disciplines. Alternatively, throwing injuries were more often classified as acute injuries compared to other disciplines. The hip and thigh was the most commonly injured body region overall among track and field athletes, but sprinting injuries accounted for the greatest proportion of hip and thigh injuries compared to other disciplines. Distance running accounted for higher proportions of lower leg injuries, women's jumping injuries accounted for higher proportions of foot and ankle injuries, and throwing injuries accounted for higher proportions of upper extremity and back injuries compared to other disciplines. This study found the indoor season and competitions to be unique points of heightened injury risk among collegiate track and field athletes. It also demonstrated a greater injury risk among female participants. Lastly, this study was able to demonstrate different injury patterns between track and field disciplines, but was limited in its ability to compare the rate of injury by disciplines due to the lack of sport exposure for each disciplines or track and field activities.

Chapter Four

The fourth chapter of this dissertation aimed to describe overuse injury reporting behaviors among adolescents and utilized a health communication theory to explore factors related to the timing and likelihood of their symptom reporting to coaches. This study was the first to apply the Disclosure Decision-Making Model to evaluate factors related to adolescent runners' intentions of reporting overuse injury symptoms. This is an important topic given the gradual and progressive nature of overuse injuries that commonly afflict cross-country runners. Further, chapter two of this dissertation and other previous studies have suggested that athletes may underreport injuries, so it is important to investigate factors related to injury reporting. This study revealed important predictors of symptom reporting intentions among adolescent runners. The way in which adolescent runners perceive their symptom reporting efficacy, how they anticipate their coach's response to symptom reporting, their perceptions of stigma associated injury, and the perceived severity of an injury were all important independent predictors of injury reporting intentions. Interestingly, differences existed between male and female runners and also by adolescent runners' recent injury history. Females' reporting intentions were more influenced by the stigma they associated with an injury, while males were most influenced by how they believed their coaches would respond to symptom reporting. The reporting intentions of recently injured adolescent runners were largely influenced by perceived stigma surrounding injury and how they anticipate their coaches would respond. These findings indicate that a part of their personal injury experience may have shifted the significance of these factors, making them more sensitive to stigma and their coach's perception. This study calls for future qualitative research to explore the experiences adolescent runners have reporting and recovering from injuries, specifically how injuries affect the way they perceive their relationships with coaches and teammates.

STRENGTHS AND LIMITATIONS

This dissertation has many strengths to help achieve its stated purpose of exploring injury epidemiology in high school and collegiate cross-country and track and field. First, the systematic review and meta-analysis in chapter two appears to be the first to summarize injury risk in these specific sport populations and quantitatively assesses how certain sports injury research methodologies affect injury risk estimates. Conducting a meta-analysis allows injury and exposure data to be pooled from numerous studies to provide an overall estimate of injury risk within this population, while also assessing how certain measurement and data collection methods may increase or decrease injury risk estimates. However, studies reporting injuries in cross-country and track and field are heterogenous which may affect the pooled estimates of injury risk reported in the meta-analysis. Second, the analysis of NCAA track and field injury surveillance data in chapter three is the most recent epidemiologic study in this population and the only study to compare injury patterns and time loss from injury across collegiate track and field disciplines. To date, the injury surveillance studies on collegiate track and field only compared overall injury rates and the rates of time loss and non-time loss injuries. The previous surveillance studies did not attempt to measure differences by track and field disciplines, which are important considering the very specialized training and unique demands of each discipline likely influence injury patterns and risks in different ways. However, this study was limited by its lack of exposure data specific to each track and field discipline or activity. Thus, injury patterns could be analyzed by the proportions of certain types of injuries between disciplines and their association with the amount of time lost by discipline. If discipline-specific exposure data had been available then it would have been possible to compare injury risks between disciplines, both overall injury risks as well as condition-specific injury risks. This type of exposure data is more difficult to collect within current injury surveillance systems; however, this may change in the future with improvements of injury surveillance systems. Advances in athlete monitoring through the availability of wearable technology and personalized apps should make it easier for athletes to contribute to the research process by sharing their individual training and injury information. Third, the study investigating overuse injury reporting among adolescents was the first to report these findings and was strengthened by the use of a well-established health communications model and measurements previously developed for adolescent athletes, but adapted to runners and overuse injuries. The Disclosure Decision-Making Model (Greene 2009) was developed to explain and predict individuals' disclosure of health-related information, but its application to studying overuse injury symptom reporting among adolescents is novel. This study provided evidence supporting the importance of four factors in predicting adolescent runners' reporting of overuse symptoms: disclosure efficacy, perceived stigma, perceived symptom severity, and anticipated coach's response. This study is limited by its focus only on the disclosure to coaches instead of other important individuals such as parents or athletic trainers. Its findings are also limited solely to adolescent cross-country runners, but may be adapted in the future for other sports or age categories. Other limitations of the injury reporting study were the use of a case scenario instead of truly lived experiences and the potential presence of selection bias. Lastly, while this study provided information regarding which factors were important among males, females, and recent injury status, it does not necessarily provide information regarding why each factor is important or how interventions may influence them to improve reporting. Further research incorporating qualitative approaches should explore the reasons these factors influence particular individuals more than others and how they may be leveraged to improve symptom reporting for earlier injury recognition and management as well as improved injury reporting in epidemiological studies.

SIGNIFICANCE OF FINDINGS FOR SPORTS INJURY RESEARCH

The findings in this dissertation have great significance on sports injury research and practice. The findings of the systematic review and meta-analysis in chapter two provide significant contributions to understanding overall injury risk in high school and collegiate cross country and track and field, while also highlighting inconsistencies and current gaps in epidemiological research within these populations. It observed discrepancies in high school and collegiate injury risk by estimating greater injury prevalence among collegiate athletes, but increased injury risk per athletic exposure among high school athletes. This dual-finding suggests that collegiate athletes are more likely to sustain a time loss injury over the course of a season, but this is likely due to their increased exposure to the sport by practicing and/or competing more often than their high school counterparts. Further research could provide more contextual detail regarding injury risk in this population by assessing sport exposure beyond the number of athletic exposures and instead using estimates of exposure such as time, distance, and/or perceived effort as described in recent scientific commentaries and research articles (Paquette et al, Napier et al, Mann et al).

The results of chapter three have significance for current practice as it reports points of increased injury risk among collegiate track and field athletes and demonstrates increased proportions of certain injury types among particular track and field disciplines. Specifically, the findings in chapter three demonstrate increased risk of injury during the indoor track and field season and during competitions. The heightened injury risk during the indoor season may be related to the time it takes to acclimate to the demands of training and competition, which athletes are likely better acclimated to during the outdoor season starts after they have competed the indoor season. Extra attention may be given to athletes' conditioning and readiness to compete early in the indoor season. Further, chapter three was the first study using injury surveillance data to assess differences in injury proportions among collegiate track and field disciplines. Relative to other disciplines, sprinting had greater proportions of hip and thigh injuries, distance running had greater proportions of lower leg injuries, jumping had greater proportions of foot and ankle injuries, and throwing had greater proportions of upper extremity and back injuries. These injury patterns are likely due to the unique demands of each track and field discipline, however, further exploration into causal factors for these injuries may illuminate better opportunities for injury prevention or risk reduction within each discipline.

Chapter four has great significance for sports injury research as it applied an established health communication model in a novel way among adolescents to discover factors important to adolescent runners' disclosure of overuse injury symptoms. Underreporting of sports injuries in has been established in some cases, so understanding factors related to adolescents' injury reporting is important for their health and well-being. An improved understanding of injury reporting may also improve the measurement of injury occurrence in sports injury research, which can influence where injury prevention and treatment resources may be allocated. For instance, improved injury reporting in traditionally underreported populations may bring increased attention and resources to managing and preventing injuries for those athletes.

DIRECTIONS FOR FUTURE RESEARCH

Accurate injury surveillance detects injury problems and can evaluate injury prevention measures by measuring any changes in injury risk after their implementation. However, this dissertation research highlights a significant flaw in how sport exposure is measured in high school and collegiate cross-country and track and field injury surveillance data. Future research should improve the measurement of sport exposure beyond athlete exposures, or the number of practices and competitions athletes engage in. Instead, more sensitive measures of exposure should be implemented such as the amount of time or distance individuals participate in a sport and the amount of perceived effort they expend while participating. In the sport of track and field, this measurement should focus on each unique track and field discipline instead of pooling all athletes together. Recent evidence demonstrates that the combination of subjective perceived exertion and the duration of a training session can better predict an athlete's training load as opposed to measuring time or distance travelled alone (Napier et al). Surveillance systems that include athletes' perceived ratings of exertion and the duration of their training session should provide more sensitive and accurate measures of training load and improve estimates of injury risk within high school and collegiate cross country and track and field. Additionally, more detailed information about the severity of injuries would benefit future analyses. In chapter three we found that women required more time loss from injuries than men, but were unable to examine whether this was due to women having a higher risk of severe injury or if their injury severities were similar but required more time for recovery due to other factors. Future studies that are able to measure injury severity by assessing pain or loss of function associated with an injury would help elucidate time loss disparities between women and men.

Another important area of future research to expand on the findings of this dissertation is in the area of running injury reporting. Chapter four of this dissertation revealed perceived stigma surrounding injury to be a strong predictor of reporting overuse injury. Notably, the perceived stigma surrounding injury was significantly higher among recently injured participants compared to uninjured participants. This may be indicative of athletes' actual lived experiences with injury altering their perception of how their teammates and coaches view their injury. As described in chapter four, an injury may be perceived as a threat to the *athletic identity* many active adolescents form. Therefore, if they disclose their injury to others then it may result in restricting their participation in sport, disrupting the way they interact with others, and altering how they perceive themselves. This dissertation found that recently injured runners are less likely to report overuse injury symptoms to their coach, perceive greater stigma surrounding injury, and place greater emphasis on how they perceive their coach will react to injury symptoms compared to uninjured participants. Future qualitative research should aim to understand these adolescent runners' lived experiences with injury and how it influences their future likelihood of reporting report an injury. This type of research may provide insight into the cultural norms of reporting and managing injuries as well as specific behaviors of coaches and teammates that may influence an athlete's experience with injury. These experiences may subsequently alter how they perceive injuries and the consequences of reporting injuries in the future. Other opportunities for future research in injury reporting involve organizational and community factors that may influence injury reporting. Future studies may analyze if there are clustering effects on injury reporting by team, school, or region. For instance, studies may consider if there are any differences in injury reporting in schools with full-time athletic trainers or where coaches undergo certain training or certifications. It would also be beneficial for future studies to observe how coaches perceive and respond to injury symptom reporting from their athletes. Future research may explore whether coaches with more training, experience, or closer relationships with athletic trainers or other healthcare providers respond differently to their athletes' reports of injury symptoms. Research in this area may reveal opportunities for intervention to improve early symptom reporting and injury management, which may reduce the risk and severity of injuries and ultimately improve the health and well-being of adolescent runners.

REFERENCES

Alentorn-Geli, E., Samuelsson, K., Musahl, V., Green, C. L., Bhandari, M., & Karlsson, J. (2017). The association of recreational and competitive running with hip and knee osteoarthritis: A systematic review and meta-analysis. *The Journal of Orthopaedic and Sports Physical Therapy, 47*(6), 373-390. doi:10.2519/jospt.2017.7137 [doi]

Baugh, C. M., Meehan, W. P., Kroshus, E., McGuire, T. G., & Hatfield, L. A. (2019). College football players less likely to report concussions and other injuries with increased injury accumulation. *Journal of Neurotrauma, 36*(13), 2065-2072. doi:10.1089/neu.2018.6161 [doi]

Carbone, A., & Rodeo, S. (2017). Review of current understanding of post-traumatic osteoarthritis resulting from sports injuries. *Journal of Orthopaedic Research : Official Publication of the Orthopaedic Research Society, 35*(3), 397-405. doi:10.1002/jor.23341 [doi]

Greene, K. (2009). An integrated model of health disclosure decision-making. In T. D. Afifi & W. A. Afifi (Eds.), Uncertainty and information regulation in interpersonal contexts: Theories and applications (pp. 226–253). New York, NY: Routledge.

Koplan, J. P., Rothenberg, R. B., & Jones, E. L. (1995). The natural history of exercise: A 10-yr follow-up of a cohort of runners. *Medicine and Science in Sports and Exercise, 27*(8), 1180-1184.

Mann, R. H., Williams, C. A., Clift, B. C., & Barker, A. R. (2019). The validation of session rating of perceived exertion for quantifying internal training load in adolescent distance runners. *International Journal of Sports Physiology and Performance, 14*(3), 354-359. doi:10.1123/ijspp.2018-0120 [doi]

Napier, C., BSc, M. R., Menon, C., & Paquette, M. R. (2020). Session rating of perceived exertion combined with training volume for estimating training responses in runners. *Journal of Athletic Training,* doi:10.4085/1062-6050-573-19 [doi]

Paquette, M. R., Napier, C., Willy, R. W., & Stellingwerff, T. (2020). Moving beyond weekly "distance": Optimizing quantification of training load in runners. *The Journal of Orthopaedic and Sports Physical Therapy, 50*(10), 564-569. doi:10.2519/jospt.2020.9533 [doi]

Register-Mihalik, J. K., Guskiewicz, K. M., McLeod, T. C., Linnan, L. A., Mueller, F. O., & Marshall, S. W. (2013). Knowledge, attitude, and concussion-reporting behaviors among high school athletes: A preliminary study. *Journal of Athletic Training, 48*(5), 645-653. doi:10.4085/1062-6050-48.3.20 [doi]

van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine (Auckland, N.Z.), 14*(2), 82-99. doi:10.2165/00007256-199214020-00002 [doi]

Wallace, J., Covassin, T., Nogle, S., Gould, D., & Kovan, J. (2017). Knowledge of concussion and reporting behaviors in high school athletes with or without access to an athletic trainer. *Journal of Athletic Training, 52*(3), 228-235. doi:10.4085/1062-6050-52.1.07 [doi]

APPENDICES

APPENDIX 1: SYSTEMATIC REVIEW EARCH STRATEGY

1. PubMed Search Terms:

("Track and Field/injuries"[Mesh]) OR "Running/injuries"[Mesh] AND (epidemiology[sh]) OR (etiology[sh]) OR (etiology[sh]) AND adolescen* OR school OR college OR university AND “cross-country” OR “cross country” OR track AND injur* NOT (“addresses”[Publication Type] OR “bibliography”[Publication Type] OR “biography”[Publication Type] OR “case reports”[Publication Type] OR “clinical conference”[Publication Type] OR “comment”[Publication Type] OR “congresses”[Publication Type] OR “dictionary”[Publication Type] OR “directory”[Publication Type] OR “editorial”[Publication Type] OR “festschrift”[Publication Type] OR “government publications”[Publication Type] OR “interview”[Publication Type] OR “lectures”[Publication Type] OR “legal cases”[Publication Type] OR “legislation”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type] OR “retracted publication”[Publication Type] OR “retraction of publication”[Publication Type] OR “review”[Publication Type] OR “scientific integrity review”[Publication Type] OR “technical report”[Publication Type] OR “twin study”[Publication Type] OR “validation studies”[Publication Type] OR pregnancy OR rugby OR soccer OR football)

2. SPORTDiscus Search Terms:

("track and field" OR "running" OR "cross country" OR "track") AND (injur*) AND ("colleg*" OR "high school" OR "university") NOT ("review" NOT "systematic review")

3. Web of Science Search Terms:

TS=("track and field" OR "running" OR "cross country" OR "track") AND TS=("injur*") AND "epidemiolog*" OR "etiolog*") REFINE BY ARTICLE OR EARLY ACCESS

APPENDIX 2: RISK OF BIAS ASSESSMENT

8-Item Risk of Bias Assessment:

1. Description of Participants – If the study describes the composition of participants by sex, competition level (high school vs college), and sport (XC and/or T&F) then it receives 1 point.

2. Representativeness of Cohort – If the study participants are representative of the sport(s) then it receives 1 point (ex. Full T&F team, not solely distance runners, pole vaulters, etc.; also representative of XC or T&F community, not solely elite or novice)

3. Definition of Injury – If the study explicitly cites how they defined an injury then it receives 1 point

4. Time-loss – If the study uses a time-loss definition of injury then it receives 1 point

5. Injuries at baseline – If the study explicitly states that participants were not injured at the beginning of the study period then it receives 1 point

6. Injury Assessment – If injuries were evaluated and reported by healthcare providers or study personnel then it receives 1 point (not self-reported)

7. Length of follow-up – If the study period is measured by complete season(s) then it receives 1 point

8. Adequacy of follow-up – If the study cites at least 80% of participants were followed for the entire season then it receives 1 point

APPENDIX 3: INJURY REPORTING QUESTIONNAIRE INSTRUMENTS

Information Assessment

Stigma (4-items)

1) My reputation would be damaged if I told my coach about these symptoms
2) People's attitude towards me would turn sour if I told my coach about these symptoms
3) Telling my coach about these symptoms would have a negative impact on me
4) If I miss time from running because of these symptoms then others will think I'm weak

Preparation (4-items)

1) I am familiar with these symptoms and know how to manage them
2) I have a good understanding of how severe these symptoms are
3) I know what kind of treatment will be involved for these symptoms
4) If I tell my coach about these symptoms, I may be held out of running even if I think it is fine for me to run

Prognosis (2-items)

1) These symptoms will negatively affect my ability to run when I'm an adult
2) These symptoms will negatively affect my quality of life when I'm an adult

Symptom Severity (4-items)

1) These symptoms are common
2) These symptoms are just a part of running
3) These symptoms are not a big deal
4) These symptoms likely will go away

Relevance to Others (4-items)

1) If I were to report these symptoms, it would negatively impact my team's immediate performance
2) If I were to report these symptoms, it would negatively impact my teammates
3) If I were to report these symptoms, it would negatively impact my coaches
4) If I were to report these symptoms, it would negatively impact my team

Receiver Assessment

Relationship Quality (5-items)

1) I feel that my running career is promising with my coach
2) I like my coach
3) I trust my coach
4) I respect my coach
5) I feel appreciation for the sacrifices my coach has experienced in order to improve his/her performance

Appendix 3 (continued)

Anticipated Response (6-items)

1) If I report these symptoms, my coach would think I made the right decision
2) If I report these symptoms, my coach would respond positively
3) If I report these symptoms, my coach would be able to help me
4) My coach would want me to report these symptoms to him/her
5) If I report these symptoms, it could hurt my relationship with my coach
6) If I were to report these symptoms to my coach, I know how he/she would respond

Disclosure Efficacy

Self-Efficacy (4-items)

1) I am confident in my ability to recognize when I have symptoms of a stress fracture
2) I am confident in my ability to report symptoms of a stress fracture, even when I want to keep running
3) I am confident in my ability to report symptoms of a stress fracture, even when I think my teammates want me to continue running
4) I am confident in my ability to report specific symptoms, even if I am not sure it is actually a stress fracture