Exposure to Injury in Sport: High School Football Surveillance System

By

Timothy Alan Tolbert

A dissertation submitted to
The Faculty of the Graduate School at
Middle Tennessee State University
in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy

May 2009

Murfreesboro, TN

UMI Number: 3361588

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI®

UMI Microform 3361588
Copyright 2009 by ProQuest LLC
All rights reserved. This microform edition is protected against unauthorized copying under Title 17, United States Code.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

APPROVAL PAGE

Exposure to Injury in Sport: High School Football Surveillance System

March 23, 2009
Date of Final Defense

Helen M Binkley
Dr. Helen M. Binkley, Committee Chair

Norman L. Weatherby
Dr. Norman L. Weatherby, Committee Member

Lynn C. Parsons
Dr. Lynn Parsons, Committee Member

Dr. Michael G. Miller, Committee Member

Dianne AR Bartley
Dr. Dianne A. R. Bartley, Health and Human Performance Department Chair

Michael D. Allen
Dr. Michael D. Allen, Dean of Graduate Studies

ACKNOWLEDGEMENTS

I would like to thank my mother for all of her support and encouragement. There is no possible way to express my profound gratitude to her and all she has done for me and the understanding she has shown through this process. Anytime things seemed a little too hard and I questioned why I was here, she was always there with one word of advice; persevere.

I would also like to thank all of my friends and family who have offered their support and encouragement while I attained the next step in my career.

Additionally, I would like to thank my committee, Dr. Helen Binkley, Dr. Norman Weatherby, Dr. Lynn Parsons, and Dr. Michael Miller for their support and guidance through this process. I would like to offer thanks and appreciation to Dr. Helen Binkley who has guided my education and professional preparation over the past four years.

Tolbert, Timothy. Exposure to Injury in Sport: High School Football Surveillance System (2009). Directed by Dr. Helen Binkley.

Twenty years ago infectious diseases were the major cause of mortality and morbidity in the world's adolescent population. In this decade, children die worldwide due to unintentional injury more than any other cause. This increase in injury related deaths is also seen in the United States. Recreational and sport related accidents are often reported as the major risk of unintentional injury.

The purpose of this investigation is to answer the following question: What effect does the amount of time spent practicing or participating in competition have on the occurrence of injury to varsity high school football athletes?

The injury surveillance system collected data on 11 varsity high school football injuries during the 2008 football season. The injury surveillance system did not collect data on junior varsity activities, club activities, any in-season individual conditioning or weight-lifting sessions, or most out-of-season or nontraditional season practice, competition, or conditioning activities.

The results suggest that, when controlling for all other variables, the school an athlete attends and the week during which a practice occurs influences the possibility of an injury event. The results suggest that, when controlling for all other variables, the school an athlete attends, classification in school of the athlete, and the week during which a competition occurs influences the possibility of an injury event.

During practice, the school an athlete attends and the week during which the practice occurs are shown to influence the occurrence of injury among varsity high

school football athletes. During competition, the school an athlete attends, the week during which the competition occurs, and the classification of the athlete are shown to influence the occurrence of injury among varsity high school football athletes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Statement of the Problem

Infectious diseases were the major cause of mortality and morbidity in the world's adolescent population twenty years ago (Blum & Nelson-MMari, 2004). In this decade, children die worldwide due to unintentional injury more than any other cause (Blum & Nelson-MMari, 2004; Danesco, Miller, & Spicer, 2000; Kaplan & Thacker, 2000). During the adolescent years, which are defined by the World Health Organization (WHO) as being between the ages of 10 and 19, an increase in the occurrence of injury related traumas are observed (Pickett et al., 2005).

This increase in injury related deaths is also seen in the United States. Three-fourths of all adolescent deaths are due to unintentional injury, homicide, and suicide (Park, Mulye, Adams, Brindis, & Irwin, 2006). Runyan and Gerken (1989) reported that at least one adolescent dies of unintentional injury every hour of every day in the United States. Recreational and sports related accidents are often reported as the major risk of unintentional injury (Blum & Nelson-MMari, 2004).

The Significance of the Study

The development of surveillance systems to prevent unintentional adolescent injuries is crucial in promoting a safe, injury free environment. The data produced by a surveillance system describes the size and characteristic of the health problem, the population at risk, the risk factors, and the trends (Holder et al., 2001). Once this information is gathered and analyzed, it is possible to develop interventions that address the health problem and monitor results of the interventions.

Performing injury surveillance is important because of major health problems that unintentional injury causes. The leading cause of death in children between the newborn and age 18 is unintentional injury (Blum & Nelson-MMari, 2004; Danesco, Miller, & Spicer, 2000; Kaplan & Thacker, 2000). For every child who dies, there are many more who are seriously and permanently disabled, whether the disability is short-term or long term. The knowledge gained form injury surveillance systems allow planners to develop interventions that could significantly reduce the incidence of injury (Holder et al., 2001).

Injuries can be characterized by point epidemics, seasonal variations, long-term trends, and various other distributions (Gordon, 1949). Point epidemics refer to epidemics that indicate single sources of the pathogen. Differences in types of injuries can be observed for due to the season in which they occur (preseason, in-season, post-season, off season). These differences are known as seasonal variations. Observing injuries over the long-term will possibly show differences when compared to short-term surveillance. Haddon (1980) suggested that injury distributions are highly nonrandom in time, place, and person. This argument suggests that injuries are just mere accidents that can occur at any time. Increasing various stresses can cause an increase in the frequency of injury (King, 1949).

Although unintentional injuries to adolescents are discussed throughout literature, few researchers have placed these injuries within the context of a framework (Pryor &

Caruth, 2002). Haddon's Injury Model is one framework based upon the epidemiologic model of host, agent and environment (Haddon, 1968). Injuries, according to Haddon, occur because of an uncontrolled interaction between a host, an agent, and the environment. Forms of energy (energy delivered by an opposing player) serve as the agents of injury transferred to a host (athlete) by a vector (opposing athlete) or vehicle (playing surface).

Haddon stated that factors contributing to injury could be present pre-event, during the injury event, and postevent. All of the factors that increase the likelihood of exposure of a child to a particular environmental hazard are addressed during the pre-event phase. The event phase includes the interaction of the person with the etiologic agent. The postevent phase focuses on whether the severity of the injury consequences can be reduced. Haddon's Injury Model addresses the host, agent, and environmental factors in all three phases. Interactions between the host, agent, and environment during high school athletics is unique because another person, usually a coach, has the responsibility for controlling or supervising the interaction between the host (athlete) and the agent (collision) as transferred by the vector (opposing athlete) or vehicle (playing surface).

Participation in high school athletics is an important factor in developing a healthy lifestyle in adolescents. Although the benefits in participating in high school athletics are undeniable, participation in any sport carries a potential injury risk. As involvement in high school athletics continues to increase, the incidence of sports related injury will also increase.

Currently there are over one million high school male athletes playing football, with a 12.2% increase in the last 10 years (National Federation of State High School Associations, 2006). It is estimated that between 30,000 and 1.2 million high school football athletes sustain a football related injury annually (Shankar, Fields, Collins, Dick, & Comstock, 2007).

The Purpose of the Study

The research problems examined in this investigation were determination of factors causing injuries in varsity football. Although several studies have been conducted (Powell & Barber-Foss, 2000; Agel, Arendt, & Bershadsky, 2005; Cooper, Ferrara, & Broglio, 2006; Dompier, Powell, Barron, & Moore, 2007; Emery, Meeuwisse, & Hartmann, 2005; Mueller, 2001; Nelson, Collins, Yard, Fields, & Comstock, 2007; Shankar, Fields, Collins, Dick, & Comstock, 2007; Weaver, Mueller, Kalsbeek, & Bowling, 1999; Rechel, Yard, & Comstock, 2008) that track injuries that occur to a specific body site, specific diagnosis, and comparisons of competition and practice injuries, few have examined the effect of time on injury occurrence. Rarely examined are the patterns of time distribution in injury settings and how these patterns influence overall risk of injury (Rivara, 2002). Investigating how time distribution between settings influences overall risk differs from questions focusing on how exposure time and other factors influence this occurrence of injury (Breslin, Karmakar, Smith, Etches, & Mustard 2007). The purpose of this investigation is to determine the following: the amount of time spent practicing or participating in competition has an effect on the occurrence of injury in varsity high school football.

Research Questions and Hypotheses

This investigation is based on the following questions and hypotheses:

1. What effect does the amount of time spent practicing have on the occurrence of injury to varsity high school football athletes?
2. What effect does the amount of time spent participating in competition have on the occurrence of injury to varsity high school football athletes?
3. H_{01}-Varsity high school football athletes are more likely to experience an injury event in the final segment of a varsity high school football practice than in all other segments of a varsity high school football practice.
4. H_{02}-Varsity high school football athletes are more likely to experience an injury event in the final quarter of a varsity high school football competition than in all other quarters of a varsity high school football competition.

Assumptions

High school football is a sport that requires contact between athletes, contact between the athlete and the playing surface, and time dedication that can lead to fatigue. Therefore, it is assumed that athletes in this study represent typical athletes in football. It is assumed that injuries will occur to athletes during high school football participation. It is assumed that when injuries are reported to the athletic trainer, these injuries will be properly documented. To properly track the injuries and injury rates the injury surveillance system must be maintained accurately. The information reported by the athletic trainers should be properly entered into the computer. The information entered will correctly correspond to the injury event reported by the athletic trainer.

Operational Definitions of the Study

The injury surveillance system collected data on injuries and exposures that occur in organized practices and competitions from the first day of preseason to the final postseason competition. The injury and exposure variables will be combined to calculate an injury rate. Definitions for reportable injuries, reportable exposures, injury rates, season, time loss, and time of occurrence of injury were used consistently by all participating high schools. Each of these definitions will be examined further in the following paragraphs.

Injury. A reportable injury in the injury surveillance system was defined as one that:

(1) occurred as a result of participation in an organized high school practice or competition,

(2) required medical attention by a team certified athletic trainer or physician, and

(3) resulted in restriction of the student-athlete's participation or performance for one or more calendar days beyond the day of injury (Dick, Agel, & Marshall, 2007).

Exposure. A reportable athlete-exposure (A-E) was defined as one student-athlete participating in one practice or competition in which the athlete was exposed to the possibility of an athletic injury, regardless of the amount of time associated with the participation. Competition exposure was counted for participants who actually participated in the competition. Preseason intrasquad scrimmages were classified as practice, not competition. In some instances multiple teams came together to participate in a joint practice. These joint practices were classified as practice, not competition.

Injury Rate. An injury rate is an assessment of the incidence of injury, defined as the number of injuries in practice or competition divided by the number of A-Es in that category. In the injury surveillance system, this value was expressed in injuries per 1000 A-Es.

Seasons. The traditional high school sport season was used for data collection and was divided into three subcategories: Preseason, In (or regular) season, and postseason. Preseason was defined as all formal team practices and competitions before the first regular season contest. In (or regular) season was defined as all formal team practices and competitions through the last regular season competition. Postseason was defined as all practices and competitions after the last regular season competition through the last postseason competition.

Time Loss. Time loss was defined as the time between the original injury and return to participation at a level that would allow competition participation. This variable is subjective due to the variability that exists among athletic trainers in measuring time loss due to injury. The variable, although susceptible to variability, was used as a basic marker to help isolate the most severe injuries.

Time of Occurrence of Injury. Time occurrence of injury was used to evaluate the time frames during practice and competitions where injuries were more likely to occur. There were five time frames used during both practices and competitions. During the practices, time frames were defined as 0-30 minutes, 31-60 minutes, 61-90 minutes, 91-120 minutes, and greater than 120 minutes. During competition, time frames were defined as first quarter, second quarter, third quarter, fourth quarter, and overtime.

The Limitations of the Study

This investigation has three limitations as follows:

1. The reporting was done by athletic trainers working with participating high schools.
2. The athletic trainers may not properly report all injuries.
3. The athletic trainers may not consistently report injuries to the researcher. Coaches and athletes may be hesitant to report injuries to the athletic trainer in fear that the athlete will be forced to miss time from practice or competition.

The Delimitations of the Study

This investigation has five delimitations as follows:

1. This research only examined varsity high school football.
2. Other interscholastic sports were not investigated.
3. This research used a sample of convenience.
4. The injury data were collected over one sports season.
5. Data was not collected for out-of-season activities.

Chapter II

REVIEW OF LITERATURE

Introduction

A review of the health status of adolescents will show that unintentional injury is a major health concern to children throughout the world (Blum & Nelson-MMari, 2004; Danesco, Miller, & Spicer, 2000; Kaplan & Thacker, 2000). Adolescents often put themselves in a position that may lead to injury due to their increased incidence of risk taking. For injury to occur to an adolescent, an exposure to an injury agent and a vehicle or vector must take place.

The increased risk taking of adolescents and the major health concern of unintentional injury has led to the development of injury surveillance systems (Holder, et al., 2001). For an injury surveillance system to be successful, the researcher must know what is being examining. For this to be possible, certain aspects of the injury surveillance must be defined. Among these definitions are what constitutes an injury, what A-E is, what the injury rate and rate ratio are, specific time of season examined, and time loss due to injuries.

Previous athletic injury surveillance systems have examined many different aspects of injury events. Most often the time of season in which an injury occurs is examined. Other routinely reported data concerns a comparison of competition injuries and practice injuries. Athletic injury surveillance systems often report the descriptive information of injuries, including the position of the injured athlete, the body site and body part injured, characteristic of the injury event, and the time loss due to the injury. Rarely reported is the time of occurrence of an injury.

Finally the review of literature will examine the potential causes of time related injuries. It is widely reported that adolescents do not acquire the needed amount of sleep. Lack of sleep has been shown to increase injuries among adolescents. Participating in athletic competition and practice will cause an athlete to become fatigued over time. Fatigue has been shown to increase the potential for an injury event.

Health Status of Adolescents

The theory of epidemiologic transition developed by Omran (1971) focuses on the complex change in patterns of health and disease. Omran examined the interactions between these patterns and their demographic, economic, and sociologic determinants and consequences. Omran theorized that degenerative and man-made diseases displaced pandemics of infections as the primary cause of morbidity and mortality.

Omran (1971) theorized that there are three different stages in the epidemiologic transition. The first stage is the age of pestilence when mortality is high and fluctuating. This stage saw an average life expectancy at birth as being very low and variable, usually between 20 and 40 years of age. The second stage is the age of receding pandemics. Mortality declines with time, and the rate of decline accelerates as the epidemic peaks become less common or disappear. The average life expectancy increases from about 30 years to approximately 50 years. During this time, population growth is sustained. The final stage is the age of degenerative and man-made diseases. During this stage, mortality continues to decline and eventually approaches a level of stability at a relatively low level. The average life expectancy gradually rises at birth until it exceeds 50 years. The crucial factor in population growth becomes fertility.

The past century has seen a shift in the sources of mortality and morbidity in the world's population, which has been observed in all age groups (Blum & Nelson-MMari, 2004). A generation ago, infectious diseases were the major cause of morbidity and mortality globally; today social, behavioral, and environmental factors are greater contributors to morbidity and mortality (Blum & Nelson-MMari, 2004). Worldwide, unintentional injury is the leading cause of death to children between birth and age 18 (Blum & Nelson-MMari, 2004; Danesco, Miller, & Spicer, 2000; Kaplan & Thacker, 2000). The adolescent years observed peaks in the occurrence of injury related traumas (Pickett et al., 2005). Adolescents comprise twenty percent of the world's population (Blum & Nelson-MMari, 2004).

Injury kills more adolescents in the United States than all diseases combined. Unintentional injury, homicide, and suicide account for three-fourths of all deaths, with the male mortality rate being three times higher than that of females (Park, Mulye, Adams, Brindis, & Irwin, 2006). Major risk of unintentional injury include recreational and sports accidents (Blum & Nelson-MMari, 2004). Sport related injuries are the leading cause of injury among adolescents (Emery, Meeuwisse, & Hartmann, 2005). Injuries during adolescence may have long term effects. Adolescents who are injured may respond to an injury with a reduction in present and future physical activity.

Unintentional injury is recognized as a major public health problem for children, not only as the leading cause of death, but also as the cause of 30,000 permanent disabilities annually (Guyer & Ellers, 1990). Permanent disability due to injury is rare, with most adolescents fully recovering within one year of injury. Of all adolescents injured, a limitation was reported in 26% after 2.5 months, 18% after 5 months, and 8% after nine months (Polinder et al., 2005). Before an adolescent fully recovers, these injuries have the potential for causing a decrease in the quality of life. A reduction in the quality of life can be seen when adolescents are unable to perform routine activities of daily living (ADL). Examples of these tasks are bathing, dressing, or ambulating.

Aitken et al. (2002) studied the effects of unintentional injury on the health status of children ages one to 19 who have been admitted to the hospital. They found that after discharge, 86% of children reported problems with bathing and 82% reported problems with climbing stairs. After one month, 59% of children reported that a disability of some kind still existed. After six months, 37% still reported that disability limited their quality of life.

Aitken, Jaffe, DiScala, and Rivara (1999) studied the functional outcomes in children with multiple traumas. The children were examined after discharge from the hospital. Fractures made up 30% of the injuries. Mild disability was found in 11.2% of the children and 14.5% were found to have had a moderate disability. Fractures to the lower extremity were more likely to have a functional limitation. A rehabilitation evaluation referral was made for 50% of the moderately disabled children and less than

25% for physical therapy. The authors showed that rehabilitation and other services were underused in this population.

Serious injury has been associated with both short and long-term reductions in the quality of life and health status of adolescents (Davey et al., 2005; Aitken et al., 1999; Ding et al., 2006). Holbrook et al. (2007) examined the long-tern deficits in quality of life in adolescents who have been injured. They used the Quality of Well-Being scale to assess the extent to which quality of life was affected by injury. This scale bases the quality of life on three levels of function: mobility, physical activity, and social activity. The most common mechanism of injury was motor vehicle accident (22%) followed by recreational injuries (16%). Recreational injuries include those that occurred while playing sports. Injured adolescents had a significantly lower quality of life outcome after 24 months when compared to uninjured adolescents. They also found that older adolescents (16-19) had a quality of life post injury that was lower than the quality of life to younger adolescents (12-15) who had been injured.

Davey et al. (2005) studied the quality of life of injured children in Australia after two years. A majority of injuries (81%) were categorized as minor, consisting of mainly fractures (47%) and intracranial injury (14%). The injuries were predominately the result of falls (28%) and cycling accidents (14%). Using the Child Health Questionnaire, the researchers found that children who had sustained an injury two years previously had a reduced quality of life when compared to a population of the same age. The reductions in quality of life were seen in increased bodily pain and decreased mental health.

Adolescent Risk Taking

Injuries that are the result of risky behavior are usually preceded by a series of psychologically motivated decisions and behaviors (Schwebel, & Gaines, 2007). Psychologically motivated decisions and behaviors, whether they are emotional, cognitive, or both, can be used to predict the engagement of children in risky behavior (Morrongiello & Matheis, 2004). The cognitive aspects of risk taking are complex. The emotional factors are influenced by social factors, development of cognitive skills, and temperament (Schwebel, & Gaines, 2007). Peterson, Farmer, and Mori (1987) advocated the importance of considering the antecedents, behaviors, and consequences of an injury event to understand the process that causes an injury.

Boys are injured more than girls across all regions and demographics (Matheny, 1991; Rosen & Peterson, 1990; Singh & Yu, 1996). Instinctive differences in the expression of temperament may lead boys to take more risks, to behave more impulsively, and to enjoy sensation seeking to a greater degree (Schwebel, & Gaines, 2007). Boys are more likely to engage in outdoor play, athletics, and agricultural equipment. These activities are more dangerous than the activities that girls participate in, such as indoor play and household chores (Schwebel, & Gaines, 2007). Gender socialization also plays a role in boys being injured more often than girls. Parents encourage boys to take more risks than girls. When boys are injured they are often told to “shake it off” where girls are treated very delicately (Rosen & Peterson, 1990; Morrongiello & Dawber, 1998; Morrongiello & Hogg, 2004).

Haddon's Injury Model

The science of epidemiology is taught and viewed as a collection of methods to be applied to particular problems involving human diseases and health (Krieger, 1994). Contemporary epidemiology has seen an increasing gap develop between its scientific foundations and its contribution to public health (Runyan, 2003). An increased value of using theory and conceptual models to guide research and practice has been argued. Relatively little work has been done to develop the concepts and frameworks of what might be termed epidemiologic theory (Krieger, 1994).

This argument was first started by William Haddon, Jr., over 35 years ago (Runyan, 2003). Haddon argued for a more scientifically driven approach to injury control. Theory helps us structure our ideas so we can explain causal connections between specific phenomena within and across particular domains by using interconnected sets of ideas whose plausibility can be tested by human action and thought (Krieger, 2001).

Multiple causation is the standard of contemporary epidemiology, and its metaphor and model is the web of causation (Krieger, 1994). The web of causation is a visual representation of the belief that population patterns of health and disease can be explained by a complex web of numerous interconnected risks. One step toward developing an ecosocial metaphor would be augmenting the metaphor of the "web" with two spiders: one social, one biologic (Krieger, 1994).

The social ecologic framework created by Urie Bronfenbrenner in the context of understanding human development is very compatible with a broader view of public health (Runyan, 2003). Bronfenbrenner's social ecological theory defines various levels of social environments. These environments depict the nested roles of intrapersonal factors, interpersonal factors, institutional elements, and cultural elements. This theory enhances the standard public health model of agent-host-environment (Runyan, 2003). The intrapersonal factors include the developmental and socio-behavioral features of the host. The results of the interactions between two persons are examples of interpersonal factors. Institutional elements are those that imitate the multiple organizations in which individuals function (e.g., schools, sports teams) and how these institutions encourage or manage activities and environments. Cultural elements include expansive social values and norms as well as the governmental policies that direct or order behaviors of individuals or organizations. The central question to the social ecological theory is who and what is responsible for population patterns of health, disease, and well-being, as manifested in present, past, and changing social inequalities in health (Krieger, 2001).

Haddon (1968) stated that injuries occur because of an uncontrolled interaction between a host, an agent, and the environment. In an athletic setting, these interactions are unique. A coach has the responsibility for controlling and supervising the interaction between host and the agent of injury as transferred by a vector or vehicle. Supervision has been identified as a variable affecting the risk of injury in adolescents in all aspects of their lives, including sport (Laraque, Barlow, & Durkin, 1999).

Injury Surveillance

According to the *International Statistical Classification of Diseases and Related Health Problems* (1994), the term surveillance, as used in the public health field, refers to the ongoing and systematic collection, analysis, interpretation, and dissemination of health information. Surveillance produces data that describe the size and characteristic of the health problem, the population at risk, the risk factors, and the trends (Holder et al., 2001). When this information has been obtained, it is possible to design and apply appropriate interventions and monitor the results and assess the impacts of the interventions (Holder et al., 2001).

Performing injury surveillance is important for many reasons. The cost of injury mortality and morbidity are vast. The costs are measured in the terms of lost economic opportunity and demands on national health budgets, but also in terms of personal suffering (Holder et al., 2001). Without the information obtained by injury surveillance systems, healthcare workers are severely limited. This knowledge would allow planners to allocate resources that could potentially prevent injuries, reducing the harm they do, and treating and rehabilitating injured persons (Holder et al., 2001).

According to the Holder, et al (2001), there are several attributes that a good surveillance system must possess. The attributes are simplicity, flexibility, acceptability, reliability, utility, sustainability, and timeliness. The system will produce the data needed, but in the most simple and straightforward way possible (simplicity). The system should be easy to change (flexible). The system will only work if people are willing to take part in it (accept). People using the data produced by the system should have confidence in the accuracy of that data (reliability). The system should be practical and affordable (utility). The system should function with very little effort and be easy to maintain and update (sustainability). The system should be able to generate current information whenever that information is needed (timeliness).

Definitions

Injury. The review of literature yielded many definitions of what actually constitutes a reportable injury. These definitions are either very broad or very detailed. In one of the first injury surveillance studies conducted, Garrick and Requa (1978) defined a reportable injury as a medical problem resulting from athletic participation necessitating removing the athlete from a practice or competitive event and/or resulting in missing a subsequent practice or competitive event.

Most recent definitions are based on the National Collegiate Athletic Association (NCAA) Injury Surveillance System which has been collecting injury information since 1982 (Dick, Agel, & Marshall, 2007). According to Dick et al., a reportable injury must meet three criteria. First, the injury must have occurred as a result of participation in an organized intercollegiate practice or competition. Second, the injury must have required medical attention by a team athletic trainer or physician. Third, the injury must have resulted in restriction of the student-athlete's participation or performance for one or calendar days beyond the day of injury. Researchers often cite the NCAA Injury Surveillance system when defining an injury. The researchers who use the NCAA Injury Surveillance System definition or definitions which are essentially the same are Rechel, Yard, and Comstock (2008), Nelson, Collins, Yard, Fields, and Comstock (2007), Shankar, Fields, Collins, Dick, and Comstock (2007), Agel, Arendt, and Bershadsky

(2005), Powell and Barber-Foss (2000), and Weaver, Mueller, Kalsbeek, and Bowling (1999).

Dompier, Powell, Barron, and Moore (2007) used a similar definition as the one used by the NCAA Injury Surveillance System. The difference is that Dompier, Powell, Barron, and Moore (2007) lack an exact time loss component to their definition. Their definition was any injury evaluated by the athletic trainer that required removal from the current sessions or subsequent session, or any fracture, dental injury, or other injury requiring physician referral or diagnostic procedures. This definition was similar to the one used previously by Emery, Meeuwisse, and Hartmann (2005). Their definition was the inability of an athlete to complete a full session, missing a subsequent session, or needing to seek medical attention.

In a survey of the injury rate for children, Radelet, Lephart, Rubinstein, and Myers (2002) purposely had a broad injury definition in order to get more detailed information. They defined a reportable injury as an injury that brought a coach onto the field to check the condition of a player, or one in which a player was removed from participation, or one in which a player needed any type of first aid during an event.

There have been several studies conducted through emergency department (ED) visits. The central part of the definition in these studies was that each injured person would have been seen by a physician in an ED (Abernathy & MacAuley, 2003; Cassell, Finch, & Stathakis, 2003; & Conn, Annest, Bossarte, & Gilchrist, 2006). Abernathy and MacAuley (2003) also included that injury could occur at any supervised school sporting event, including school games, physical education classes, and competitive school matches.

Athlete-Exposure. In the review of literature there has been a consensus on the definition of athlete-exposure (A-E). A reportable A-E is defined as one student-athlete participating in one practice or competition in which he or she was exposed to the possibility of athletic injury regardless of the time associated with that participation (Dick et al., 2007; Dompier, Powell, Barron, & Moore, 2007; Nelson, Collins, Yard, Fields, & Comstock, 2007; Rechel, Yard, & Comstock, 2008; & Shankar, Fields, Collins, Dick, & Comstock, 2007). Dick, Agel, and Marshall (2007) included a competition A-E in their definition. A reportable A-E in a competition was only participants with actual playing time in that competition.

Injury rate and rate ratio. Injury rate was defined by Dick, Agel, and Marshall (2007) in the NCAA Injury Surveillance System as a measure of the incidence of injury, defined as the number of injuries in a particular category divided by the number of A-E's in that category. This value was expressed as injuries per 1000 A-Es.

The rate ratios (RR) and proportion ratios (PR) were calculated by Nelson, Collins, Yard, Fields, and Comstock, 2007; Rechel, Yard, and Comstock, 2008; and Shankar, Fields, Collins, Dick, and Comstock, 2007. They calculated RR as [(number of competition injuries / number of competition A-Es) x 1000] ÷ [(number of practice injuries/ number of practice A-Es) x 1000].

Seasons. Dick, Agel, and Marshall (2007) defined the season of athletic participation. They divided the season of athletic participation into three categories;

preseason, in (regular) season, and postseason. Preseason was defined as all formal practices and exhibition games conducted before the first regular season contest. In (regular) season was defined as all practices and competitions from the first regular season competition through the last regular season competition. Postseason was defines as all practices and competitions after the last regular season competition until the last postseason competition.

Time-loss. Dick, Agel, and Marshall (2007) defined time-loss as the time between the original injury and the return to participation at a level that would allow competitive participation. They categorized the injuries into six specific categories; one to two days, three to six days, seven to nine days, 10 days or more, catastrophic (nonfatal), and fatal. Cantu and Mueller (1999) defined catastrophic (nonfatal) as resulting in permanent severe functional brain or spinal cord injury/disability, and catastrophic (serious) as involving transient brain or spinal cord disability. They went on to state that fatalities are either direct or indirect. Direct fatalities are fatalities that result directly from performing the specific activities of a sport. Indirect fatalities are fatalities caused by systemic failure as a result of exertion while participating in a sport.

Dompier, Powell, Barron, and Moore (2007) categorized time loss into three broad categories in their study on youth football injuries. An injury with a time-loss of less than eight days was considered minor. A moderate injury resulted in a time-loss of eight to twenty-one days. Any injury with a time-loss of more than twenty-one days was considered severe.

Descriptive Epidemiology

Season. As defined previously, an athletic season is often divided into three categories; preseason, in (regular) season, or postseason. Dividing the season into these three categories allows researchers the ability to compare injury rates between each category. The NCAA published the findings of their Injury Surveillance System in the *Journal of Athletic Training* (2007) for all collegiate sports. Across all sports preseason injury rates were higher than both in (regular) season and postseason practice injury rates (Hootman, Dick, & Agel, 2007).

There are differences in injury rates for the seasons for collegiate men's sports are as follows. The fall preseason practice injury rates in men's football were three times as high as in (regular) season or postseason practice injury rates (Dick, Ferrara, Agel, Courson, Marshall, Hanley, & Reifsteck, 2007). The in (regular) season game injury rates were approximately 50% higher than postseason game injury rates (Dick, Ferrara, Agel, Courson, Marshall, Hanley, & Reifsteck, 2007). The preseason practice injury rates were almost twice as high in the preseason as in the in (regular) season in men's baseball (Dick, Sauers, Agel, Keuter, Marshall, McCarty, & McFarland, 2007). In men's basketball, the preseason practice injury rates were three times higher than the in (regular) season practice injury rates (Dick, Hertl, Agel, Grossman, & Marshall, 2007). The preseason practice injury rates in men's ice hockey were twice as high as those in the in (regular) season (Agel, Dopier, et al, 2007). The preseason practice injury rates were more than two times as high than in (regular) season men's lacrosse (Dick, Romani, Agel, Case, & Marshall, 2007). Men's soccer had a higher preseason injury rate than did in (regular) season (Agel, Evans, Dick, Putukian, & Marshall, 2007). The preseason practice injury rates for men's wrestling were almost twice as high as in (regular) season practices and preseason match injury rates were higher than in the in (regular) season (Agel, Ransone, Dick, Oppliger, & Marshall, 2007).

The differences in the injury rates between the seasons for women's collegiate sports are as follows. Women's field hockey reported a preseason injury rate three times higher in preseason practice as in regular season practice and four times higher than post season practice (Dick, Hootman, et al, 2007). The preseason injury rates for women's softball were three times higher than the in (regular) season practice injury rates (Marshall, Hamstra-Wright, Dick, Grove, & Agel, 2007). In women's volleyball practice injury rates were three times higher in the preseason when compared to the in (regular) season (Agel, Palmeiri-Smith, Dick, Wojtys, & Marshall, 2007). Women's basketball saw preseason practice injury rates that were twice as high as those reported during regular season practices (Agel, et al, 2007). The preseason practice injury rates for women's ice hockey were almost twice as high as the in (regular) season (Agel, Dick, Nelson, Marshall, & Dompier, 2007). The women's soccer preseason practice injury rates were more than three times greater than the rates for in (regular) season practices (Dick, Putukian, Agel, Evans, & Marshall, 2007).

Competition injuries versus practice injuries. Hootman, Dick, and Agel (2007) reported that among all NCAA sponsored sports; injury rates were significantly higher in competitions than in practices. In football, the injury rate in competitions was nine times higher than in practice (Dick, Ferrara, et al, 2007). In baseball, the injury rate was three times higher in competitions than in practices (Dick, Sauers, et al, 2007). In hockey, the injury rate in competitions was eight times higher than in practice (Agel, Dopier, Dick, & Marshall, 2007). In men's lacrosse, the injury rate in competitions was four times higher than in practice (Dick, Romani, Agel, Case, & Marshall, 2007). In men's soccer, the injury rate in competitions was four times higher than in practice (Agel, Evans, Dick, Putukian, & Marshall, 2007). In men's wrestling, the injury rate for competition was four times higher than the injury rate for practice (Agel, Ransone, Dick, Oppliger, & Marshall, 2007).

In women's volleyball, the injury rate for competitions was slightly higher than in practice (Agel, Palmeiri-Smith, Dick, Wojtys, & Marshall, 2007). In women's basketball, the injury rate was two times higher in competitions than in practice (Agel, Olson, et al, 2007). In gymnastics, the injury rate was two times higher in competitions than in practice (Marshall, Covassin, Dick, Nassar, & Agel, 2007). In women's hockey, the injury rate was five times higher in competitions than in practice (Agel, Dick, Nelson, Marshall, & Dompier, 2007). In women's lacrosse, the injury rate during competition was twice the rate of practice injury rates (Dick, Lincoln, et al, 2007). In women's soccer, the injury rate for competitions was three times higher than the injury rate for practices (Dick, Putukian, Agel, Evans, & Marshall, 2007). In women's field hockey, the injury rate for games was two times higher than the injury rate for practices (Dick, Hootman, et al, 2007).

The higher rate of injury in competition is not only seen in collegiate sporting events, but also in high school sporting events (Shankar, Fields, Collins, Dick, &

Comstock, 2007). Rechel, Yard, and Comstock (2008) compared the high school injury rates of practice to competition. The rate of injury per 1000 A-Es was higher in competition (4.63) than in practice (1.69). When comparing all sports, football had the highest competition and practice injury rates. Nelson, Collins, Yard, Fields, and Comstock (2007) in an epidemiological study of ankle injuries among high school athletes found that the rate of injury to an ankle was higher in competition than in practice.

Injuries by position. To establish which collegiate football positions suffered the most injuries, Dick, Ferrara, et al (2007), weighted the results by position. The percentage of injury by position were calculated, and then divided by the number of players at each position. The number of players at each position used was six offensive linemen, four defensive linemen, four defensive backs, three linebackers, two wide receivers, two running backs, and one quarterback. Dick, Ferrara, et al (2007) found that the running back position was the most injured (20%), followed by the quarterback position (18%).

Shankar, Fields, Collins, Dick, and Comstock (2007) examined the high school football position that is the most common to sustain an injury. Offensive players most likely to sustain an injury were linemen and running backs. Defensively, linebackers were more likely to sustain an injury than other defensive players. Overall, offensive linemen sustain a greater number of injuries; however, running backs sustained the highest percentage of injuries for any one position. In a study of high school ankle injuries, Nelson, Collins, Yard, Fields, and Comstock (2007) also found that running backs suffered ankle injuries more often than any other position.

Body site/part injured. In collegiate athletics, the lower extremity is the most injured area of the body with the ankle ligament sprain being the most common injury (Hootman, Dick, & Agel, 2007). Fifty percent of all injuries were to the lower extremity in collegiate football (Dick, Ferrara, et al, 2007). The most common injuries in competition were knee internal derangement (17.8%), followed by ankle ligament sprain (15.6%), and concussions (6.8%) (Dick, Ferrara, et al, 2007). In practices, knee internal derangement (12.0%) and ankle ligament sprain (11.8%) were the most common injuries, but upper leg muscle tendon strain (10.7%), concussion (5.5%), and heat illness (3.9%) were also very significant injuries (Dick, Ferrara, et al, 2007). The shoulder was another body part injured often in competition and practices. The most common injuries were acromioclavicular joint injuries, ligament sprains, dislocation/subluxations, contusions, muscle tendon strains, and nerve injuries (Dick, Ferrara, et al, 2007).

In a study of high school football injuries, Shankar, Fields, Collins, Dick, and Comstock (2007), saw results similar to the ones found by Dick, Sauers, et al, 2007. Of the injuries reported, 88.2% were newly acquired injuries. The most common injury diagnoses were ligament sprains (31.2%) and muscle/tendon strains (16.5%) The lower extremity was the most common injury site. The knee and the lower leg/ankle/foot were the most injured body parts. The ankle made up 67.9% of all injuries to the lower leg/ankle/foot. Accounting for 96.1% of all injuries to the head, concussions were the most common injury to the head. When comparing high school and collegiate football injuries, Shankar, Fields, Collins, Dick, and Comstock (2007) found that high school athletes sustained a higher proportion of fractures and concussions.

During the 2005-2006 high school academic year, Nelson, Collins, Yard, Fields, & Comstock (2007) reported there was an ankle injury rate of 5.23 injuries per 10,000 A-Es. The rate of injury was higher in competition than in practice. Ligament sprains with incomplete tears accounted for 83.4% of diagnoses, followed by fracture (5.2%), ligament sprains with complete tears (4.0%), and contusions (2.0%). 24.1% of all high school ankle injuries occurred in football.

Head trauma results in more fatalities than any other athletic injury and is the cause of most football fatalities (Mueller, 2001). Traumatic brain injury (TBI) is common in contact sports (Gerberich, Priest, Straub, & Maxwell, 1983). Repeated concussions that occur within a short period can be fatal (Saunders & Harbaugh, 1984). Fatal head injuries include subdural heatomas, brain injury, fractures, and aneurysms.

Mueller (2001) examined catastrophic head injuries in high school and collegiate football. Mueller looked at data from the 1945 through 1999 football seasons. During this time there were 712 football fatalities. Head injuries accounted for 491 (69%) of all of these fatal injuries. Seventy five percent of the head injuries were subdural hematomas (SDH). When compared to college football, high school football produced the greatest number of fatal head injuries. Most often the mechanism of injury was tackling or being tackled. Between 1984 and 1999 there were 69 catastrophic (nonfatal) head injuries. Sixty-three occurred in high school football and 6 occurred in college football. All 69 resulted in incomplete recovery. Incomplete recovery is defined as an inability to return to a pre-injury state.

Concussions represent 8.9% of all high school athletic injuries and 5.8% of all collegiate injuries in a study conducted by Gessel, Fields, Collins, Dick, and Comstock (2007). The sports with the highest incidence were football and soccer. 65.4% of concussions occurred during competition and 34.6% occurred during practice. In football, most concussions occurred during running plays and were the result of contact between players. A majority of concussions (67.6%) occurred while tackling or being tackled.

With the exception of collegiate baseball, all other NCAA sanctioned sports reported lower extremity injuries were more prevalent (Hootman, Dick, & Agel, 2007). As expected, upper extremity injuries accounted for 45% of all injuries in collegiate baseball (Dick, Sauers, et al, 2007). Although the upper extremity was the most often injured area of the body during competition, most collegiate baseball injuries were muscle-tendon strains to the upper leg (11.0%) and ankle ligament sprains (7.4%). During practice, shoulder muscle-tendon sprains were the most frequent injury, accounting for 10.0% of all practice injuries (Dick, Sauers, et al, 2007).

Exertional heat illnesses are a very serious threat to athletes participating in athletic activities during the summer months. Traditionally, heat illness defines three categories: heat cramps, heat exhaustion, and heat stroke (Armstrong, De Luca, & Hubbard, 1990; & Casa, 1999). Binkley, Beckett, Casa, Kleiner, and Plummer (2002) added to this definition by including heat syncope and exertional hyponatremia and other heat and activity related illnesses.

Cooper, Ferrara, and Broglio (2006) in their study of exertional heat illness during a football season found that 88% of all exertional heat illnesses occurred during the month of August. 70% were due to cramps, 23% were due to heat exhaustion, and 7% were due to heat syncope. They concluded that the highest risk of exertional heat illness was during the first three weeks of practice.

Characteristics of injury events. Mechanism of injury is often cited as the cause of an injury. The mechanism of injury may be due to player contact, the playing surface, no contact with rotation about a planted foot, overuse, or many other possibilities. In collegiate athletics, player contact is the leading injury mechanism. Player contact results in 58% of the injuries during competition and 41.6% of the injuries during practice (Hootman, Dick, & Agel, 2007). Athlete contact is a common part of some sports, such as football, thus the reason for the high rate of injury due to this specific mechanism. During collegiate athletic practices 36.8% of injuries are due to noncontact (Hootman, Dick, & Agel, 2007). Most of these noncontact practice injuries would best addressed by identification and modification of risk factors.

In collegiate football, player contact is the reported mechanism of injury for 78% of all game injuries and 57% of all practice injuries (Dick, Ferrara, et al, 2007). Player contact was the primary mechanism of injury for all NCAA sponsored athletics (Dick, Sauers, et al, 2007; Dick, Hertl, Agel, Grossman, & Marshall, 2007; Agel, Dopier, Dick, & Marshall, 2007; Dick, Romani, Agel, Case, & Marshall, 2007; Agel, Evans, Dick, Putukian, & Marshall, 2007; Agel, Ransone, Dick, Oppliger, & Marshall, 2007; Dick, Hootman, et al, 2007; Marshall, Hamstra-Wright, Dick, Grove, & Agel, 2007; Agel, Palmeiri-Smith, Dick, Wojtys, & Marshall, 2007; Agel, Olsonet al, 2007; Agel, Dick, Nelson, Marshall, & Dompier, 2007; & Dick, Putukian, Agel, Evans, & Marshall, 2007).

Shankar, Fields, Collins, Dick, and Comstock (2007) in studying high school football injury patterns, found that the mechanism of injury 67.7% of the time was due to contact with another player. Of these contacts, 28.2% of the mechanisms were contact with another player due to being tackled and 21.8% are due to tackling. The same contact with another player mechanisms are often the cause of ankle injuries (Nelson, Collins, Yard, Fields, & Comstock, 2007). The contact is usually in the form of tackling or blocking.

Anterior cruciate ligament (ACL) strains are often the result of noncontact (rotation about a planted foot). Dick, Ferrara, et al (2007) found that in competitions, 28.6% of ACL strains were due to this mechanism. Being tackled was the mechanism of injury reported for 16.8% of ACL injuries and being blocked was the mechanism of injury reported for 15% of anterior cruciate ligament injuries. In practice, these numbers were very similar; 34.8% noncontact (rotation about a planted foot), 13.2 % blocking, 12.6% being blocked, and 10.7% being tackled).

Time-loss due to injury. Dompier, Powell, Barron, and Moore (2007) examined the time-loss and non-time-loss injuries in youth football. The researchers found that 94.7% of all injuries were classified as either non-time-loss or minor time-loss injuries.

Severe injuries accounted for only 2.7% of all injuries. 63.6% of moderate injuries were sprains.

In collegiate football, 27% of competition injuries and 25% of practice injuries resulted in at least 10 days of time loss (Dick, Ferrara, et al, 2007). Almost half (48.6%) of high school football athletes who sustained an injury were able to return to the team in one to six days with only 9.7% of injuries reported as season ending (Shankar, Fields, Collins, Dick, & Comstock, 2007). Similar time-loss percentages can be observed in ankle injuries. The athletes who sustained an ankle injury, 51.7% missed less than seven days of activity and 33.9% missed between seven and twenty-one days of activity (Nelson, Collins, Yard, Fields, & Comstock, 2007).

Time of injury. Rarely explored are the patterns of time distribution in injury settings and how these patterns influence overall risk of injury (Rivara, 2002). Exploring how time allowance between settings influences overall injury risk differs from questions focusing on how exposure time and other factors control the probability of injury in a single setting (Breslin, Karmakar, Smith, Etches, & Mustard 2007). Time has a zero sum property. Due to the factors that limit time spent in one injury setting lead to time spent somewhere else, with a different injury risk (Robinson & Godbey, 1999). Breslin, Karmakar, Smith, Etches, and Mustard (2007) suggested that injury risk was not a simple function of fatigue and cumulative exposure time. Instead they suggested the importance of considering time of exposure when assessing injury potential.

One area that has seen research into the effects of time on injury is the industrial setting. Most often, researchers are looking how to reduce injury events without production levels decreasing. Researchers have looked at how increasing the amount of time during rest breaks can reduce injuries. It is a consistent view that the repetitive work in the industrial setting fatigues the workers, which predisposes them to injury (Knauth, 2007).

When work hours are increased beyond the typical eight hour work shift significant increases in injury events are noticed. Increasing work shifts to 10 hour shifts were associated with a 13% increased risk and increasing work shifts to 12 hour shifts were associated with a 27% increase in risk (Caruso, 2006; Folkard, Lombardi, & Tucker, 2005; Knauth, 2007).

Many industrial jobs require that employees work beyond a typical 40 hour work week. When the number of hours worked are reduced by between seven and 20 hours per week (down to 50-55 hours per week) an improvement in the quality and quantity of units produced was observed (Harrington, 2001). This reduction of work hours also has a positive effect on the incidence of injuries. Extended hours at work increase the possibility of an injury (Savery & Luks, 2000).

Injury rates have been shown to increase during longer periods of work. Tucker, Folkard, and Macdonald (2003) examined the impact of rest breaks and accident risks in a United Kingdom automotive plant. They divided the work day into two hour blocks. Each block was separated by a break. They found that the risk of accident rose significantly over the four half-hour segments that made up each two hour period of continuous work. When comparing different two hour segments, they found that the risk immediately after a break was reduced to a rate close to that recorded at the start of a preceding period of work.

Dababneh, Swanson, and Shell (2001) examined the impact of added rest breaks on the productivity and well being of workers in a meat processing plant. They increased the amount of rest time given to the workers. They compared two different rest break schedules to see how the discomfort and production rates were affected. Both rest break schedule increased the rest time by 36 minutes. The first did so by given nine, three minute breaks. The second gave four, nine minute breaks. Neither rest break schedule negatively effected production. When comparing the two break schedules, the nine minute break schedule improved the discomfort rating among the workers are a higher level. One interesting note on production levels was that when given the frequent rest breaks, production rates improved in the latter hours of the work day. Breaks of 10 minutes have been shown in other studies to increase production by between five and 12% (Harrington, 2001).

In a study conducted in transport operations (truck drivers, bus operators, etc.), conclusions were made that contradicted current theories of time on task (Folkard, 1997). Current theories of time on task effects would predict a straightforward trend over time in performance capabilities or relative risk. The researcher found that accident risk in transport operations vary over time. The greatest risk occurred during the first four hours of a shift, unless the driver had been worker for greater than 12 hours. A reduction of 30% was seen from the first four hours of a shift to the second four hours of a shift.

The findings of research in the industrial setting could possibly parallel that of research done in the athletic setting. This is especially true when time on task is compared between the two settings. It is easy to forget that athletes have been in the school setting for up to eight hours before they begin their athletic practice. It is very probable that when athletes begin practice, they are already physically and mentally fatigued.

Causes of Time Related Injuries

The purpose of this investigation is to study the effects of time on injury events. As described previously, there are many mechanisms that may cause an injury, but none are related to time. Instead, they are single episodes that can cause an injury without regard to time. Since this study will look at time of occurrence, it is proper to examine factors that may increase an athlete's susceptibility to injury over time.

There are many causes of injury, but all potential causes can be categorized into two groups; either intrinsic or extrinsic. Intrinsic is person related. The individual genetic or psychosocial characteristics of a person, such as joint flexibility, functional instability, previous injuries, and insufficient rehabilitation are all examples of intrinsic causes of injury (Dvorak, et al, 2000). Extrinsic is environment related. Examples of extrinsic related causes of injury are the amount of training and number of games played, climatic factors, surface, playing field conditions, and equipment (Dvorak, et al, 2000).

Intrinsic risk factors are predisposing factors that act from within, and that may be necessary, but rarely sufficient, to produce injury (Bahr & Holme, 2003). Extrinsic risk factors act on the predisposed athlete from the outside and are classified as enabling factors in that they facilitate the manifestation of injury (Meeuwisse, 1994). The presence of both intrinsic and extrinsic risk factors makes the athlete susceptible to injury. According to Meeuwisse (1994), an inciting event (usually termed the mechanism of injury) is the final link in the chain that causes an injury.

Sleep patterns. Sleep problems in children and adolescents are common (Stein, Mendelsohn, Obermeyer, Amromin, & Benca, 2001). Megdal and Schernhammer (2007) in a study of adolescents in Los Angeles found that 69% of girls and 58% of boys are poor sleepers. Poor sleep is measure by the total amount of sleep, the degree of awakening during the night, and most importantly, how long it takes to get to sleep. Circadian rhythms and biological sleep patterns among adolescents are thought to be different from those of preadolescents or adults (Carskadon, 1990). Adolescents have a predisposition to go to sleep later at night and also wake up later in the morning (Carskadon, 1990). This is the result of several factors, including social factors that may promote and perpetuate the delayed bedtime and wakening (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). The combination of postponed circadian sleep phase and early start times at high schools in the United States causes adolescents to lose sleep during the school week (Carskadon, 1990; Wolfson & Carskadon, 1998). This loss of sleep by adolescents exhibits sleep habits that are in line with an unhealthy pattern (Megdal and Schernhammer, 2007).

Hansen, Janssen, Schiff, Zee, and Dubocovich (2005) studied high school students' sleep patterns over a forty five day period. The forty five day period began while school was on summer break and concluded while school was in session. This was done to compare the sleep an adolescent obtains while school is not in session and the sleep obtained while school is in session. They found that the mean sleep on weekdays while school was not in session was 8.7 hours of sleep a night. When school started this amount decreased to seven hours of sleep per night. This loss of sleep was highly significant, ($p<.0001$). Also highly significant ($p<.0001$) was that on weekends, adolescents slept 30 minutes longer during the school year than they did during the summer. What Hansen, Janssen, Schiff, Zee, and Dubocovich (2005) were able to show was that adolescents lost up to two hours of sleep per night on the weekdays during the school year as compared to the summer. The increase amount of sleep during the weekends of the school year was due to this loss during the week.

Daytime sleepiness may affect several factors, including mood, behavior, and academic performance, and even put adolescents at risk for accidents and injury (Hansen, Janssen, Schiff, & Dubocovich, 2005). Several studies have shown that sleep deprivation impairs physical functioning and emotional well-being (Tynjala, Kannas, Levalahti, & Valimaa, 1999; Chen, Wang, & Jeng, 2006).

Sleep disturbances have been studied as a risk factor for injuries because it may compromise daytime performance due to sleepiness, fatigue, and cognitive impairment. Choi et al (2006) studied the effects of sleep deprivation on injuries in a rural population in Iowa. During their study they found that 316 injuries occurred during the 2677.6 person-years. The overall injury rate was 11.8 cases per 100 person-years. They were able to conclude that sleeping less than seven and a half hours increases the risk for injuries 1.61 times that of sleeping for seven and a half to eight and a half hours (95% CI, 1.21-2.15).

The same conclusions were made by Lam and Yang (2007) and Edmonds and Vinson (2007). Lam and Yang (2007) studied adolescents in China between the ages of 13 and 17. They found a significant association between nightly duration of sleep and injury, particularly with multiple injuries (OR=2.4, 95% CI, 1.2-4.9). Adolescents who slept less than seven hours per night during a normal school week were approximately two times more likely to have experiences multiple episodes of unintentional injury when compared to adolescents who slept seven hours or more. Edmonds and Vinson (2007), through ED interviews, were able to show that better sleep quality during the past seven days was associated with a lower risk of injury (OR=0.88, 95% CI 0.80-0.97).

As shown previously, insufficient sleep can lead to the occurrence of injury. This is due to the impairment of reaction time, vigilance, and alertness (Carskadon, 2005). Adolescents generally perform better early in the day than late in the afternoon and evening. Performance in adolescents benefits from adequate sleep obtained routinely on a regular basis (Carskadon, 2005). Significant performance improvements in speed and accuracy can be caused by a nigh of sleep. This was supported by research done by Walker, Brakefield, Morgan, Hobson, and Stickgold (2002).

Walker, Brakefield, Morgan, Hobson, and Stickgold (2002) conducted a study where participants were taught a finger tapping exercise. After sleeping, participants were able to improve their speed and average of 20% and their accuracy by 39%. This is significant for the athletic world in that it is not unusual to train athletes consistently across the day, only to return the athlete to practice early the next morning. Based on the current evidence of how the brain consolidates task, such a schedule could be potentially harmful (Walker & Stickgold, 2005). Building sufficient sleep patterns into training programs may offer the biologically necessary periods of sleep required to maximize skill potential (Walker & Stickgold, 2005).

Morad, et al (2007) found that sleep deprivation causes a reduction in stability. Postural stability shows a significant peak of destabilization between 5:00 p.m. and 8:00 a.m. ($p<.05$). This is significant to athletics due to the fact that practices are within their second hour or competitions are either about to begin or have already begun. A decrease in stability and proprioception has been shown to be a risk factor for injury (Nyland, Shapiro, Stine, Horn, & Ireland, 1994; Nyland, Shapiro, Carbon, Nitz & Malone, 1997).

During a 24-hour period, cognitive and metabolic processes that affect mental and physical activities vary. Morad, et al examined the relationship that sleep deprivation has on postural stability throughout the day. Barenboim (2007), Gribble, Tucker, and White (2007), in the only study of its kind, examined the influences of time-of-day on static and dynamic postural control. They were able to show that the time of day seems to influence measure of postural control. The subjects in their study had more postural control in the morning than they did in the afternoon and evening. This is of importance to athletics due to the fact that many athletic practices and competitions take place in the afternoon and evening hours.

In one of the only studies of its kind, Samuels (2008) examined the relationship between sleep, recovery, and performance in athletics. Samuels states that critical metabolic, immunologic, and restorative physiologic processes are negatively affected by sleep restriction, sleep disturbances, and forced desynchrony of the human circadian (rhythm) sleep/wake phase. Sleep deprivation directly affects cognitive performance. He was able to show that a casual relationship exists among sleep, memory, and performance. These results validate the importance of adequate sleep for athletes to ensure optimal performance when cognitive tasks and psychomotor vigilance are required.

Fatigue. Fatigue is an extrinsic factor affecting the musculoskeletal systems (Chappell, et al, 2005). There have been many studies published that examined the effect of fatigue on muscle strain injury, knee kinetics and kinematics, neuromuscular function, joint laxity, and sport specific techniques. Sports medicine personnel widely agree that fatigue may be a predisposing factor in the occurrence of injury (Heiser, Weber, Sullivan, Clare, & Jacobs, 1984). Dornan (1971) stated that muscle strains usually occurred early or in the latter stages of practices or matches. The early injuries were more commonly due to improper warm-up, where the latter injuries were more commonly due to fatigue.

In two epidemiological studies of injuries that occurred in rugby league matches, Gabbett (2000; 2002) found that muscular injuries are more often sustained in the latter stages of the season and during the second half of matches. These finding suggest that fatigue or accumulative microtrauma, or both, may contribute to injuries in amateur rugby league players (Gabbett, 2000). In his epidemiological study of rugby league sevens tournaments, Gabbett (2002) was able to make the same conclusions. He observed an increasing incidence of injury over the first (99.2 injuries per 1000 hours), second (198.4 injuries per 1000 hours), third (347.2 injuries per 1000 hours), and fourth (694.4 injuries per 1000 hours) matches played during the tournament. The results of his study suggest that amateur rugby league sevens tournaments, which require players to compete repeatedly on the same day, may hasten the onset of fatigue and predispose athletes to injury.

In a study using rabbit models, Mair, Seaber, Glisson, and Garrett (1996) examined the role of fatigue in susceptibility to acute muscle strain. The researchers chose to use the extensor digitorum longus muscle of a rabbit because the characteristics of that muscle are very similar to muscles athletes commonly strain in athletic participation. After fatiguing muscle through electrical stimulation, the researchers found that muscles are injured at the same length of stretch, regardless of the effects of fatigue. However, the fatigued muscles are able to absorb less energy before reaching the degree of stretch that causes injury.

The maintenance and control of posture and balance, whether under static or dynamic conditions, are essential requirements for physical and daily activities. Lepers, Bigard, Diard, Gouteyron, and Guezennec (1997) conducted a study in order to evaluate and quantify the equilibrium performance before and after long distance (24 km) running on well-trained athletes. The equilibrium score, which reflected the subjects' ability to maintain his balance, decreased after the run. These results show that the ability to maintain balance in a dynamic environment was altered by prolonged exercise.

The effects of fatigue has been associated with decreases in knee proprioception and increased joint laxity compared to baseline values (Nyland, Shapiro, Stine, Horn, &

Ireland, 1994; Nyland, Shapiro, Carbon, Nitz & Malone, 1997). Athletes exhibit decreases in proprioceptive ability and changes in muscular activity following muscular fatigue. Rozzi, Lephart, and Fu (1999) showed that subjects demonstrated an overall decrease in the ability to detect joint motion moving into the direction of extension, an increase in the onset of contraction time for the medial hamstring, lateral gastrocnemius muscles, and an increase in the first contraction area of the vastus medialis and vastus lateralis muscles.

Mechanomyography is a new technique that records and quantifies the low-frequency lateral oscillations produced by active skeletal muscles fibers (Beck, et al, 2004). Using mechanomyography, Ebersole and Malek (2008), examined the electromechanical efficiency of the vastus medialis and vastus lateralis muscles when fatigued. They were able to report a linear decrease in torque, vastus medialis electromechanical efficiency, and vastus lateralis electromechanical efficiency across 75 repetitions at 180° per second. A 58% decrease in the electromechanical efficiency of the vastus medialis and a 66% decrease in the electromechanical efficiency of the vastus lateralis occurred concurrently with a 47% decline in torque production when the participants were fatigued. The researchers feel that the electromechanical efficiency measurements may provide a unique insight into the influence of fatigue on the contractile properties of skeletal muscle, including alterations that occur to the intrinsic electric and mechanical components.

Wilkins, Valovich McLeod, Perrin, and Gansneder (2004) used the Balance Error Scoring System to measure the effects of fatigue on balance. The Balance Error scoring

System measures the athlete's postural stability through a clinical assessment battery and is scored by counting the number of errors the athlete commits during the test. In the study conducted by Wilkins, Valovich McLeod, Perrin, and Gansneder (2004), the fatigue group scored significantly more total errors on the posttest than on the pretest. They also scored significantly more errors than the control group at the posttest. Although the Balance Error Scoring System is designed to study mild brain injury, the results from this research strengthens the argument that fatigue decreases postural stability.

Chappell, et al (2005) examined the effect of fatigue on knee kinetics and kinematics in stop-jump tasks. There subjects were 20 recreational athletes. The recreational athletes showed a significant decrease in jumping height after fatigued. An increase of 21% peak proximal tibial anterior shear force was found when the recreational athletes were fatigued. Knee flexion angle at the peak proximal tibial anterior shear force in the post-fatigue exercise test was significantly decreased in comparison to that in the pre-fatigued exercise test. These results show that when fatigued, an athlete is more susceptible to the mechanisms that may cause a knee injury.

The results of Chappell, et al (2005) were similar to the results of Wojtys, Wylie, and Huston (1996). Wojtys, Wylie, and Huston (1996) studied the effects of muscle fatigue on neuromuscular function and anterior tibial translation in healthy knees. The researchers were able to show an increase of 32.5% in the anterior tibial translation after fatigue. The researchers believed that muscle fatigue affected the dynamic stability of the knee, which caused an alteration in the neuromuscular response to anterior tibial translation. Fatigue may play a significant role in the pathomechanics of knee injuries in physically challenging sports.

In a recent study, Gabbett (2008) examined the effect of fatigue on tackling technique in rugby league players. His research is one of the first to examine the effects of fatigue on tackling technique. Gabbett found that fatigue resulted in progressive reductions in tackling technique. The greatest decrease in tackling technique under fatigued conditions was seen among players with the best form in a non-fatigued state.

In a pilot study conducted prior to this dissertation, injury events were shown to increase as time increased during practice (Tolbert, Binkley, Miller, Weatherby, 2008). A majority of injuries occurred in the final quarter of practice. This study used the NCAA Injury Surveillance System as a guide, but expanded the questionnaire to include specific time sensitive information concerning the injury event.

Unintentional injury is a growing health concern throughout the world. An increase in the occurrence of injury related traumas are observed in adolescents (Pickett, et al, 2005). Injury, in the United States, results in death to more adolescents than all diseases combined (Park, Mulye, Adams, Brindis, & Irwin, 2006). Not only is unintentional injury a major health problem due to the fact that it is the leading cause of death, but also due to the fact that unintentional injury causes 30,000 permanent disabilities annually (CDC, 1990; Guyer & Ellers, 1990). Participating in sports has been shown to be a major risk for unintentional injury (Blum & Nelson-MMari, 2004).

Data produced by injury surveillance systems describe the size and characteristic of the health problem, the population at risk, the risk factors, and the trends (Holder, et al, 2001). The information obtained by injury surveillance systems makes it possible to design and apply appropriate interventions and monitor the results and assess the impacts of the interventions (Holder, et al, 2001).

To develop interventions to combat the growing concern of unintentional injury, injury surveillance systems must be developed that can report appropriate, useful information. Current injury surveillance systems report almost identical information. Injury events are reported due to the injury site, mechanism, and whether they occur during a competition or practice. This information, although very useful, does not show the entire picture of an injury event. Seldom examined are the specific time frames in which an injury occurs. The pilot study for this dissertation showed that athletes are more likely to be injured later in practice. The ability to show when, specifically, athletes are injured will be a valuable asset in developing interventions to reduce the occurrence of injuries.

CHAPTER III

METHODOLOGY

Sampling and Data Collection

Sport Sampled. The injury surveillance system collected data on 11 varsity high school football teams during the 2008 football season. The injury surveillance system did not collect data on junior varsity activities, club activities, any in-season individual conditioning or weight-lifting sessions, or most out-of-season or nontraditional season practice, competition, or conditioning activities.

Data Collection. During the 2008 varsity football season, twelve different schools were invited to participate in the injury surveillance system data collection through their certified athletic trainer. Participation in the injury surveillance system was voluntary. During the summer prior to the football season, a letter was sent requesting participation and approval to conduct research to the superintendent of the selected school systems and the principal of the selected schools. A letter requesting participation was sent to the head athletic trainer of the selected schools. Attached to the letters were the instruments that were used.

Athletic trainers at participating schools were provided data collection instructions and a packet of injury and exposure forms. The instructions defined reportable injuries and exposure and specifically described each exposure and injury question. Participating athletic trainers were asked to submit data from the first day of official preseason practice to the final day of any postseason competition.

Protection of Human Subjects

All information collected during the research is stored on a password protected computer. The researcher is the only individual with access to the information obtained during the research. A coding system was used to differentiate between schools. Only the researcher has access to the codes. The athletic trainer submitting information included their individual school code on all submitted injury forms and exposure forms.

Power Analysis

Two models were examined using Cox regression. The first model tested whether the amount of time exposure during a varsity football practice increased the risk of an injury event. The second model tested whether the amount of time exposure during a varsity football competition increased the risk of an injury event. The α for the test of these models was set at .05. To achieve power of .85 and a medium effect size (f^2=.15), 96 injury events are required to detect a significant model.

Instrumentation

Injury Form. A two page injury form, based on the NCAA Injury Surveillance System injury form, was completed for each reportable injury. This form contains twelve questions relating to basic injury mechanism, when the injury occurred, body part injured, type of injury, measure of severity (time loss), sport-specific questions (e.g. position played and specific injury mechanism), and the type of surface the injury occurred on. The difference between the NCAA Injury Surveillance injury form and the one used in this research is that the form used in this research asked an additional question regarding the time in which an injury occurred during a practice or competition. Practice injuries were categorized as injuries occurring between 0 and 30 minutes, 31 and 60 minutes, 61 and 90 minutes, 91 and 120 minutes, and greater that 120 minutes. Competition injuries were categorized as injuries occurring during the 1st quarter, 2nd quarter, 3rd quarter, or 4th quarter. If more than one body part was injured in the same injury event, a separate form was completed for each injury. No name or personal identification was collected by the researcher. Each week a spreadsheet, which contains all reportable injuries that occurred that week, was sent electronically to the researcher. The researcher sent emails to participating athletic trainers every Thursday reminding the participating athletic trainer to submit their data. A second email was sent every Sunday to remind the participating athletic trainers who had not yet submitted their data to do so.

Exposure Form. A one page exposure form was submitted electronically weekly to the researcher by each participating athletic trainer. This form summarized the number of practices and/or competitions; the number of participants for each activity; the season (preseason, regular season, or postseason); the types of playing surface for each activity; the day the activity occurred; and the length of the practice. As discussed before, competition participants were counted only if they officially participated in some part of the competition. Exposure forms were submitted weekly, even if there were no reportable injuries that occurred during that time period. This participation information was used to analyze the injury rates.

Pilot Study

IRB exempt approval (08-294) was obtained to use the test instruments in a pilot study. The pilot study was conducted during spring football practices with four high schools in Rutherford County, TN. During the fifteen day spring football practices there were sixteen injury events. The fourth segment of practice (91-120 minutes) saw the greatest occurrence of injuries (50%). The third segment of practice (61-90 minutes) contained 18.8% of the injuries. Both the first segment of practice (0-30 minutes) and the second segment of practice (31-60 minutes) contained 12.5% of the injuries. One injury occurred during the fifth segment of practice. Based on the results of the pilot study, injury events increased over time during a high school football practice.

Data Aggregation and Participation Incentive

Forms received by the researcher were entered into a database via hand entry by the investigator. Other than the unique school code number, no identifiers were present on either the injury or exposure forms. Each participating school received a hard copy of its own data.

Inclusion Criteria

Following the guidelines set by Dick et al. (2007) in the NCAA Injury Surveillance System, for a school's data to be included in the injury surveillance system, the athletic trainer was required to send data covering 70% of the possible weeks. If 70% of a school's information was not submitted, then the school was eliminated before the statistical analysis takes place.

Eliminated School. One school was eliminated from the injury surveillance system due to not submitting the required information. This school was a large classification school with approximately 95 varsity football athletes at the beginning of the season.

Data Analysis and Presentation

Statistical Analysis. Injury rates (number of injuries divided by number of A-Es) were computed per 1000 A-Es. Rates were reported using competition and practice exposures. Rate ratios comparing the competition rate to the practice rates were computed by dividing the competitions rate by the practice rate. Rate ratios indicate the increased rate of injury associated with competition participation relative to practice participation. Rate differences were also used.

Ninety-five percent confidence intervals (95% CIs) were computed for all rates, rate ratios, and rate differences. The 95% CIs provide information about the accuracy of each rate and can be used to conclude if two rates differ statistically from one another.

Cox Regression was used to evaluate trends in the injury rates over time. The dependent variable in a Cox Regression is made up of two parts: an event indicator and a measure of time from baseline to the event. In this investigation, an event indicator is defined as the occurrence of an injury. A measure of time in this investigation is the specific time of the practice or competition during which the injury occurred. Hazard rates measure the risk of event occurrence within a specified time interval. This measure is conditional on survival to the beginning of that time interval. Survival is defined as not yet having experiences the injury event. Specifically, Cox Regression was used to predict an injury event based on the predictor variables. The time variable measures time to the event as defined by the status variable. Since time was measured by a counter variable in units of time, the Cox model assumed that the hazard rate increases linearly with time. Analysis time was a time variable where t=0 is the time of onset of risk. Onset of risk is defined as the time when injury first becomes possible. All data was processed using SPSS statistical software (Version 16.0, SPSS Inc., Chicago, Illinois).

Chapter IV

RESULTS

The purpose of this dissertation was to examine the effect of the amount of time spent practicing or competing in varsity football on the incidence of injury. The first hypothesis stated that varsity high school football athletes are more likely to experience an injury event in the final segment of a varsity football practice than in all other segments of a varsity high school practice. The second hypothesis stated that varsity high school football athletes are more likely to experience an injury event in the final quarter of a varsity high school football competition than in all other quarters of a varsity high school football competition.

The participants who took part in this investigation were taken from a sample of convenience. The schools selected were done so because of their previous relationship with the investigator. The fact that the participating schools were not randomly assigned causes the investigator to believe that these results may not be generalizable.

Descriptive Statistics

Practice. There were a total of 732 varsity football athletes from 11 participating schools who participated in the injury surveillance system. This number differs from the total number of participants in competitions due to the fact that when athletes were injured multiple times, they were counted as a new athlete to better achieve an understanding of when athletes are injured. Table 1 shows the descriptive statistics for the participating schools, player positions, classification of the participants, and the number of injuries by week of practice. These variables were entered into the Cox regression as possible predictors of injury. TR-5 was the school with the fewest participants (n=34). TR-8 was the school with the most participants (n=96). The average number of participants per school was 67.

A large percentage of varsity football athletes reported playing more than one position during practice (49.45%). Table 1 shows the descriptive statistics for each position as well as the combination of positions that athletes play. Most of the participants were offensive linemen (n=122). Other positions reporting high levels of participants were the combination of offensive linemen and defensive linemen (n=109) and flanker/wide receiver and defensive back (n=117). Two groups were combined into one group due to the low numbers in the respective groups. Running backs and defensive linemen were combined with flanker/wide receivers and linebackers to give a total of 11 participants in that group.

Table 2 shows the descriptive statistics for the number injures based on position. An overall percentage as well as a weighted percentage is reported. Overall, offensive linemen sustained the greatest percentage of injuries in practice (23.89%). Other positions sustaining high percentages of injury events were defensive linemen (21.24%), linebackers (15.04%), defensive backs (13.27%), and running backs (12.39%).

To achieve a proper understanding of injuries by position, positions were weighted according to the number of athletes playing that position at one time. The percentages of injury by position were calculated and then divided by the number of players at each position as follows: offensive line=6, wide receiver/flanker=2, quarterback=1, running back=2, defensive line=4, linebacker=3 and defensive back=4. The offensive players with the highest number of injuries by weighted position were running backs (6.19%), wide receivers/flankers (5.31%), and offensive linemen (3.98%). The defensive players with the highest number of injuries by weighted position were defensive linemen (5.31%), linebackers (5.01%), and defensive backs (3.32%).

Table 1 shows the descriptive statistics for the classification of the participating athletes. A majority of participants (n=252) were sophomores. The classification with the smallest amount of participants were freshmen (n=75). This is due to the fact that freshmen often do not participate on varsity football teams at larger schools. Instead, they participate in freshmen football. Smaller schools, where the overall number of participants is limited, see increased numbers of freshmen on the varsity football team.

Table 1 also shows the week of injury. A majority of the injuries occurred within the first 6 weeks of practice (n=94). The number of injuries during practice steadily declined from week 1 through week 15.

The characteristics of injury times during practice are shown in Table 3. The third section of practice (61-90 minutes) reported the highest number of injury event (n=36). This time frame saw 31.86% of all injuries. The first time frame (0-30 minutes) saw the least amount of injuries. This time frame accounted for only 6.19% of all injuries.

Table 1

Participant Characteristics (Practice), Exposure to Injury in Sport ($N = 732$)

Characteristic	*n*	%
Participating Schools		
TR-1	72	9.84
TR-2	49	6.69
AE-1	50	6.83
AE-2	76	10.38
AE-3	47	6.42
TR-3	81	11.07
TR-5	34	4.64
TR-6	91	12.43
TR-7	74	10.11
TR-8	96	13.11
AE-4	62	8.47
Total	732	100.00
Player Position		
Players with Multiple Positions		
Offensive Lineman and Defensive Lineman	109	14.89
Quarterback and Defensive Back	24	3.28
Running Back and Linebacker	49	6.69
Flanker/Wide Receiver and Defensive Back	117	15.98
Offensive Lineman and Linebacker	20	2.73
Running Back and Defensive Back	32	4.37
Running Back and Defensive Lineman or Flanker/Wide Receiver & Linebacker	11	1.50
Players with Single Positions		
Offensive Lineman	122	16.67
Quarterback	15	2.05
Running Back	45	6.15

Flanker/Wide Receiver	60	8.20
Defensive Lineman	63	8.61
Linebacker	24	3.28
Defensive Back	32	4.37
Kicker	9	1.23
Total	732	100.00
Classification		
Freshman	75	10.25
Sophomore	252	34.43
Junior	230	31.42
Senior	175	23.91
Total	732	100.00
Week of Injury		
Week 1	31	27.68
Week 2	17	15.18
Week 3	15	13.39
Week 4	11	9.82
Week 5	10	8.93
Week 6	10	8.93
Week 7	4	3.57
Week 8	3	2.68
Week 9	3	2.68
Week 10	2	1.79
Week 11	2	1.79
Week 12	0	0.00
Week 13	1	0.89
Week 14	2	1.79
Week 15	1	0.89
Total	112	100.00

Table 2

Position when Injured (Practice), Exposure to Injury in Sport ($N = 113$)

Characteristic	*n injured*	*n of players at position*	*% of total injuries*	*% of players injured in season*	*Odds of being injured in season*	*Weighted %*
Position when Injured						
Offensive linemen	27	251	23.89	10.76	0.12	3.98
Quarterback	3	39	2.65	7.69	0.08	2.65
Running back	14	137	12.39	10.22	0.11	6.19
Flanker/Wide receiver	12	188	10.62	6.38	0.07	5.31
Defensive Linemen	24	183	21.24	13.11	0.15	5.31
Linebacker	17	104	15.04	16.35	0.20	5.01
Defensive back	15	205	13.27	7.32	0.08	3.32
Kicker	1	9	0.88	11.11	0.13	0.88
Total	113	1,116	100.00			

Note: The weighted percent of injuries by position is divided by the number of players at that position.

Table 3

Injury Time Characteristics (Practice), Exposure to Injury in Sport (N = 113)

Characteristic	*n*	%
Injury Time Frames		
0-30 minutes	7	6.19
31-60 minutes	30	26.55
61-90 minutes	36	31.86
91-120 minutes	26	23.01
Greater than 120 minutes	14	12.39
Total	113	100.00

Competitions. There were a total of 749 varsity football athletes who participated in the injury surveillance system. This number differs from the total number of participants in practice due to the fact that when athletes were injured multiple times, they were counted as a new athlete to better achieve an understanding of when athletes are injured. Table 4 shows the descriptive statistics for the participating schools, player positions, classification of the participants, and the number of injuries by week. These variables were entered into the Cox regression as possible predictors of injury. TR-5 was the school with the fewest participants (n=34). TR-8 was the school with the most participants (n=104). The average number of participants per school was 68.

A large percentage of athletes reported playing more than one position during competitions. Table 4 shows the descriptive statistics for each position as well as the combination of positions that athletes play. Most of the participants were offensive linemen (n=127). Other positions reporting high levels of participants were flanker/wide receiver and defensive back (n=118) and offensive linemen and defensive linemen (n=114). Two groups were combined into one group due to the low numbers in the respective groups. Running backs and defensive linemen were combined with flanker/wide receivers and linebackers to give a total of 9 participants in that group.

Table 5 shows the descriptive statistics for the number of injuries based on position. An overall percentage as well as a weighted percentage is reported. Overall, defensive backs sustained the greatest percentage of injuries during competition (23.08%). Other positions sustaining high percentages of injury events were linebackers (17.09%), defensive linemen (16.24%), and running backs (16.24%).

To achieve a proper understanding of injuries by position, positions were weighted according to the number of athletes playing that position at one time. The percentages of injury by position were calculated and then divided by the number of players at each position as follows: offensive line=6, wide receiver/flanker=2, quarterback=1, running back=2, defensive line=4, linebacker=3 and defensive back=4. The offensive players with the highest number of injuries by weighted position were quarterbacks (8.55%) and running backs (8.12%). The defensive players with the highest number of injuries by weighted position were defensive backs (5.77%) and linebackers (5.70%).

Table 4 shows the descriptive statistics for the classification of the participating athletes. A majority of participants (n=250) were sophomores. The classification with the smallest amount of participants were freshmen (n=76). This is due to the fact that freshmen often do not participate on varsity football teams at larger schools. Instead, they participate in freshmen football. Smaller schools, where the overall number of participants is limited, see increased numbers of freshmen on the varsity football team.

Table 4 also shows the week of injury. A majority of injuries occurred between preseason and week 5 of the season (59.83%). Week 8 saw the highest total of injuries during any one week. A majority of the participating teams were off during week 7, which is a possible reason for the low numbers.

The characteristics of injury times during competitions are shown in Table 6. The fourth quarter of the competition saw the greatest number of injuries (n=34). This quarter saw 29.06% of all injuries. Injuries during warm ups were relatively few (n=3). This time frame saw only 2.56% of all injuries.

Table 4

Participant Characteristics (Competition), Exposure to Injury in Sport ($N = 749$)

Characteristic	*n*	%
Participating Schools		
TR-1	71	9.48
TR-2	50	6.68
AE-1	50	6.68
AE-2	76	10.15
AE-3	48	6.41
TR-3	81	10.81
TR-5	34	4.54
TR-6	91	12.15
TR-7	76	10.15
TR-8	104	13.89
AE-4	68	9.08
Total	749	100.00
Player Position		
Players with Multiple Positions		
Offensive Lineman and Defensive Lineman	114	15.22
Quarterback and Defensive Back	24	3.20
Running Back and Linebacker	55	7.34
Flanker/Wide Receiver and Defensive Back	118	15.75
Offensive Lineman and Linebacker	23	3.07
Running Back and Defensive Back	34	4.54
Running Back and Defensive Lineman or Flanker/Wide Receiver & Linebacker	9	1.20
Players with Single Positions		
Offensive Lineman	127	16.96
Quarterback	18	2.40
Running Back	44	5.87

Flanker/Wide Receiver	62	8.28
Defensive Lineman	58	7.74
Linebacker	23	3.07
Defensive Back	31	4.14
Kicker	9	1.20
Total	749	100.00
Classification		
Freshman	76	10.15
Sophomore	250	33.38
Junior	236	31.51
Senior	187	24.97
Total	749	100.00
Week of Injury		
Preseason	3	2.56
Week 0	14	11.97
Week 1	5	4.27
Week 2	14	11.97
Week 3	12	10.26
Week 4	12	10.26
Week 5	10	8.55
Week 6	8	6.84
Week 7	2	1.71
Week 8	16	13.68
Week 9	7	5.98
Week 10	7	5.98
Week 11	7	5.98
Total	117	100.00

Table 5

Position when Injured (Competition), Exposure to Injury in Sport ($N = 117$)

Characteristic	*n injured*	*n of players at position*	*% of total injuries*	*% of players injured in season*	*Odds of being injured in season*	*Weighted %*
Position when Injured						
Offensive linemen	12	264	10.26	4.55	0.05	1.71
Quarterback	10	42	8.55	23.81	0.31	8.55
Running back	19	135	16.24	14.07	0.16	8.12
Flanker/Wide receiver	9	187	7.69	4.81	0.05	3.85
Defensive Linemen	19	174	16.24	10.92	0.12	4.06
Linebacker	20	108	17.09	18.52	0.23	5.70
Defensive back	27	207	23.08	13.04	0.15	5.77
Kicker	1	9	0.85	11.11	0.13	0.85
Total	117	1,126	100.00			

Note: The weighted percent of injuries by position is divided by the number of players at that position.

Table 6

Injury Time Characteristics (Competition), Exposure to Injury in Sport (*N* = 177)

Characteristic	*n*	%
Injury Time Frames		
Warm-up	3	2.56
First Quarter	22	18.80
Second Quarter	28	23.93
Third Quarter	30	25.64
Fourth Quarter	34	29.06
Total	117	100.00

Injury Rates and Athlete Exposures

Practice. There were a total of 113 practice injury events during 42,328 athlete exposures, for an injury rate of 2.67 injury events per 1000 athlete exposures.

Competitions. There were a total of 117 competition injury events during 4,595 athlete exposures, for an injury rate of 25.46 injury events per 1000 athlete exposures.

Rate Ratio. The rate ratio was 9.54 (95% CI 7.36 to 12.35, $p<.001$). Overall injury rates were higher in competitions than in practices.

Survival Analysis

Practice. The original Cox regression model (Table 7) included the following main effects: school attended, position of athlete, classification in school of the athlete, and the week of practice that the injury occurred. The position of athlete and classification in school of the athlete were removed from the model due to the fact that each category lacked any significance. The model was analyzed again with the following main effects: school attended and the week of practice that the injury occurred.

Cox regression results (Table 8) suggest that, when controlling for all other variables, the school an athlete attends and the week during which a practice occurs influences the possibility of an injury event. Athletes at school TR-1 are less likely to sustain an injury than athletes at school AE-4 (Odds Ratio 0.31, 95% CI 0.12 to 0.78, $p=.012$). As the weeks of the season progress, the odds of an athlete sustaining an injury decrease (Odds Ratio 0.95, 95% CI 0.95 to 0.96, $p<.001$).

Table 7

Summary of Cox Regression Analysis Predicting Time of Injury During Practice (N = 732)

Variable	*b*	*SE*	Odds ratio	95% Confidence Interval Lower	Upper	Wald statistic	*p*
Main Effects:							
AE-4 (reference)						13.01	0.223
TR-1	-1.05	0.54	0.35	0.12	1.00	3.84	0.05
TR-2	0.03	0.52	1.03	0.37	2.83	0.00	0.96
AE-1	-0.38	0.68	0.68	0.18	2.60	0.32	0.574
AE-2	-0.67	0.68	0.51	0.13	1.96	0.95	0.329
AE-3	0.22	0.44	1.24	0.53	2.91	0.25	0.618
TR-3	0.14	0.43	1.15	0.50	2.68	0.11	0.744
TR-5	0.16	0.63	1.17	0.34	4.04	0.06	0.806
TR-6	0.72	0.66	2.06	0.57	7.46	1.20	0.273
TR-7	0.55	0.42	1.74	0.77	3.92	1.76	0.185
TR-8	-0.07	0.43	0.93	0.40	2.15	0.03	0.863

Kicker (reference)						13.09	0.52
Offensive Lineman and Defensive Lineman	-0.57	1.05	0.56	0.07	4.41	0.30	0.585
Quarterback and Defensive Back	-0.75	1.22	0.47	0.04	5.19	0.38	0.539
Running Back and Linebacker	-0.30	1.07	0.74	0.09	5.96	0.08	0.776
Flanker/Wide Receiver and Defensive Back	-0.94	1.08	0.39	0.05	3.24	0.75	0.386
Offensive Lineman and Linebacker	-0.08	1.46	0.92	0.05	16.22	0.00	0.957
Running Back and Defensive Back	-0.19	1.25	0.83	0.07	9.55	0.02	0.879
Running Back and Defensive Lineman or Flanker/Wide Receiver & Linebacker	-0.16	1.48	0.86	0.05	15.58	0.01	0.916
Offensive Lineman	-0.93	1.10	0.39	0.05	3.39	0.72	0.396
Quarterback	0.40	1.48	1.49	0.08	26.84	0.07	0.787
Running Back	0.24	1.15	1.27	0.13	12.10	0.04	0.835
Flanker/Wide Receiver	-0.26	1.20	0.77	0.07	8.02	0.05	0.827
Defensive Lineman	-0.12	1.11	0.88	0.10	7.71	0.01	0.911
Linebacker	0.01	1.20	1.01	0.10	10.56	0.00	0.996
Defensive Back	0.85	1.22	2.34	0.22	25.48	0.49	0.484

Senior (reference)						0.97	0.809
Freshman	0.02	0.46	1.02	0.41	2.50	0.00	0.971
Sophomore	-0.26	0.29	0.78	0.44	1.36	0.80	0.371
Junior	-0.12	0.27	0.89	0.53	1.50	0.19	0.662
Week of Injury	-0.05	0.00	0.95	0.94	0.96	192.03	0.00

Note: Model Chi Square = 989.13, $df = 28$, ($p < .001$); -2 Log Likelihood =991.780

Table 8

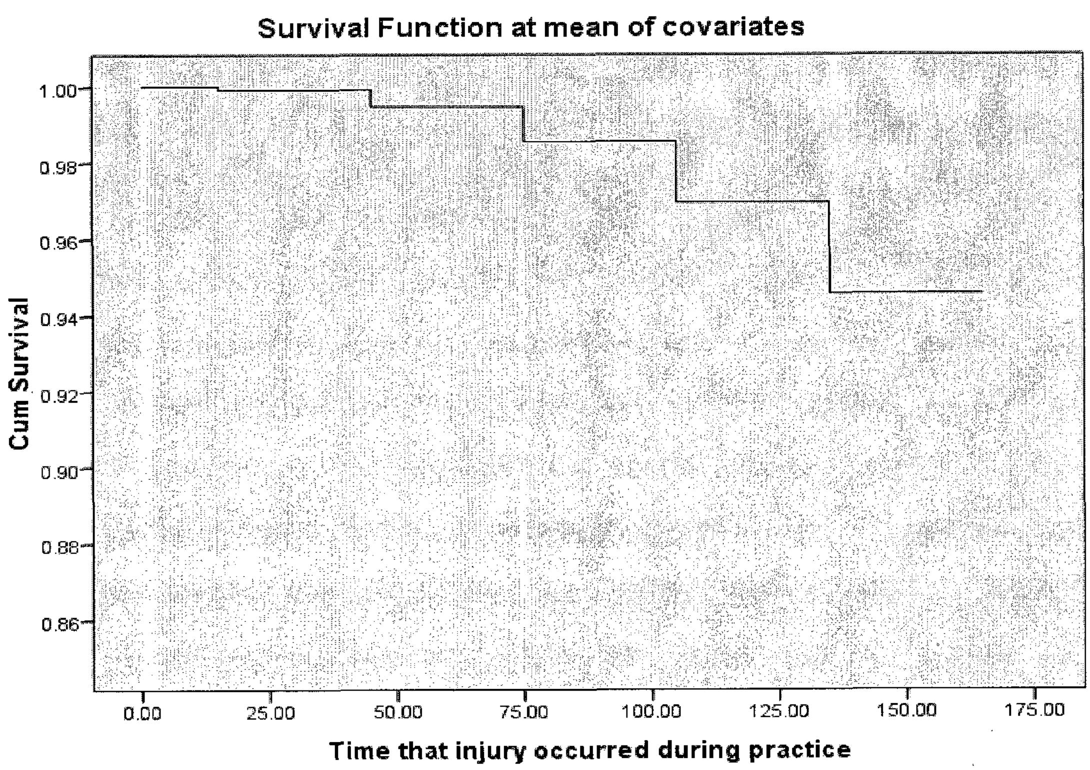
Summary of Cox Regression Analysis Predicting Time of Injury During Practice (N = 732)

Variable	*b*	*SE*	Odds ratio	95% Confidence Interval Lower	Upper	Wald statistic	*p*
Main Effects:							
AE-4 (reference)						11.01	0.357
TR-1	-1.17	0.47	0.31	0.12	0.78	6.25	0.012
TR-2	-0.26	0.45	0.77	0.32	1.87	0.33	0.563
AE-1	-0.37	0.57	0.69	0.23	2.10	0.43	0.512
AE-2	-0.31	0.65	0.73	0.21	2.60	0.23	0.631
AE-3	-0.06	0.38	0.95	0.45	1.98	0.02	0.883
TR-3	0.20	0.41	1.22	0.55	2.69	0.23	0.629
TR-5	-0.15	0.53	0.86	0.30	2.44	0.08	0.777
TR-6	0.29	0.54	1.33	0.46	3.83	0.29	0.593
TR-7	0.12	0.37	1.12	0.54	2.32	0.10	0.752
TR-8	-0.22	0.35	0.80	0.41	1.59	0.40	0.526
Week of Injury	-0.05	0.00	0.95	0.95	0.96	229.43	0.000

Note: Model Chi Square = 985.63, $df = 11$, ($p < .001$); -2 Log Likelihood = 1476.80

Figure 1 shows the survival function as it changes during the course of the practice. During the first two time segments of practice there is very little change in the survival function. During the third segment (61-90 minutes), the survival function is 0.99. The likelihood of not sustaining and injury continues to decrease throughout the practice. The chance of survival during the final segment of practice (greater than 120 minutes) is 0.95. This figure shows that as practice times are increased, the likelihood of survival decreases.

Figure 1: Injury Survival During Practice



Competition. The original Cox regression model (Table 9) included the following main effects: school attended, position of athlete, classification in school of the athlete, and the week of competition that the injury occurred. The position of athlete was removed from the model due to the fact that each category lacked any significance. The model was analyzed again with the following main effects: school attended, classification in school of the athlete, and the week of competition that the injury occurred.

Cox regression results (Table 10) suggest that, when controlling for all other variables, the school an athlete attends, classification in school of the athlete, and the week during which a competition occurs influences the possibility of an injury event. Athletes at school TR-6 are less likely to sustain an injury than athletes at school AE-4 (Odds Ratio 0.11, 95% CI 0.01 to 0.84, $p=.034$). Sophomores were less likely to sustain an injury than seniors (Odds Ratio 0.48, 95% CI 0.25 to 0.83, $p=.008$). As the weeks of the season progress, the odds of an athlete sustaining an injury decrease (Odds Ratio 0.71, 95% CI 0.68 to 0.74, $p<.001$).

Table 9

Summary of Cox Regression Analysis Predicting Time of Injury During Competition (N = 749)

Variable	*b*	*SE*	Odds ratio	95% Confidence Interval Lower	95% Confidence Interval Upper	Wald statistic	*p*
Main Effects:							
AE-4 (reference)						16.79	0.079
TR-1	-0.92	0.62	0.40	0.12	1.33	2.23	0.135
TR-2	-0.04	0.50	0.96	0.36	2.55	0.01	0.93
AE-1	-0.27	0.67	0.76	0.21	2.80	0.17	0.68
AE-2	0.17	0.61	1.19	0.36	3.88	0.08	0.779
AE-3	0.30	0.51	1.36	0.50	3.67	0.36	0.551
TR-3	-0.17	0.55	0.85	0.29	2.51	0.09	0.766
TR-5	-0.32	0.55	0.73	0.25	2.13	0.34	0.56
TR-6	-2.64	1.06	0.07	0.01	0.57	6.24	0.013
TR-7	-0.10	0.40	0.90	0.41	1.99	0.06	0.8
TR-8	-0.81	0.38	0.45	0.21	0.95	4.41	0.036

Kicker (reference)						13.94	0.454
Offensive Lineman and Defensive Lineman	0.25	1.11	1.28	0.15	11.29	0.05	0.823
Quarterback and Defensive Back	0.81	1.15	2.25	0.24	21.45	0.50	0.48
Running Back and Linebacker	0.54	1.12	1.72	0.19	15.30	0.24	0.627
Flanker/Wide Receiver and Defensive Back	0.51	1.11	1.66	0.19	14.66	0.21	0.648
Offensive Lineman and Linebacker	1.51	1.23	4.52	0.41	50.31	1.51	0.22
Running Back and Defensive Back	0.31	1.13	1.36	0.15	12.50	0.08	0.784
Running Back and Defensive Lineman or Flanker/Wide Receiver & Linebacker	1.23	1.48	3.42	0.19	61.70	0.70	0.404
Offensive Lineman	-0.99	1.16	0.37	0.04	3.59	0.74	0.391
Quarterback	-0.17	1.20	0.84	0.08	8.85	0.02	0.886
Running Back	-0.36	1.07	0.70	0.09	5.73	0.11	0.737
Flanker/Wide Receiver	-0.44	1.14	0.65	0.07	6.01	0.15	0.702
Defensive Lineman	0.47	1.10	1.59	0.19	13.74	0.18	0.672
Linebacker	-0.33	1.24	0.72	0.06	8.23	0.07	0.794
Defensive Back	-0.38	1.18	0.68	0.07	6.89	0.10	0.747

Senior (reference)						7.19	0.066
Freshman	-0.32	0.57	0.73	0.24	2.24	0.31	0.578
Sophomore	-0.76	0.28	0.47	0.27	0.82	7.12	0.008
Junior	-0.25	0.26	0.78	0.47	1.31	0.86	0.354
Week of Injury	-0.34	0.02	0.72	0.68	0.75	218.23	0.00

Note: Model Chi Square = 978.57, $df = 28$, ($p < .001$); -2 Log Likelihood =1107.05

Table 10

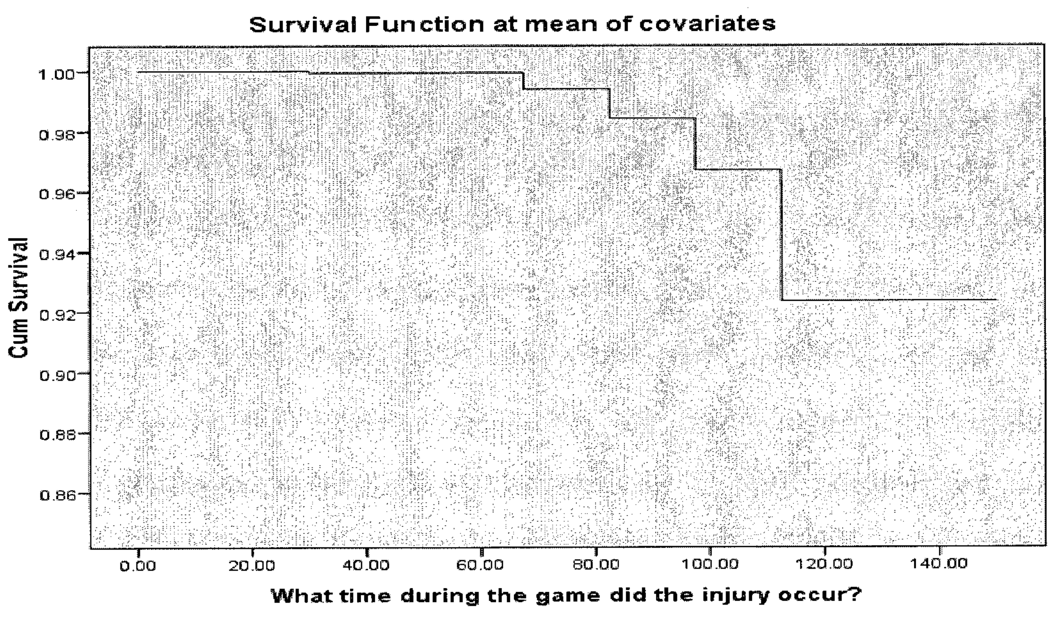
Summary of Cox Regression Analysis Predicting Time of Injury During Competition (N = 749)

Variable	*b*	*SE*	Odds ratio	95% Confidence Interval Lower	95% Confidence Interval Upper	Wald statistic	*p*
Main Effects:							
AE-4 (reference)						15.63	0.111
TR-1	-0.32	0.55	0.73	0.25	2.12	0.34	0.562
TR-2	0.29	0.48	1.34	0.53	3.39	0.37	0.543
AE-1	-0.95	0.58	0.39	0.13	1.19	2.75	0.097
AE-2	-0.26	0.49	0.77	0.30	2.02	0.28	0.600
AE-3	0.03	0.44	1.03	0.44	2.43	0.00	0.947
TR-3	-0.63	0.41	0.53	0.24	1.20	2.33	0.127
TR-5	0.11	0.51	1.12	0.41	3.04	0.05	0.830
TR-6	-2.21	1.04	0.11	0.01	0.84	4.51	0.034
TR-7	0.07	0.37	1.08	0.52	2.22	0.04	0.845
TR-8	-0.56	0.36	0.57	0.28	1.15	2.46	0.117
Senior (reference)						7.31	0.063
Freshman	-0.45	0.56	0.64	0.21	1.92	0.64	0.425
Sophomore	-0.73	0.28	0.48	0.28	0.83	6.93	0.008
Junior	-0.09	0.24	0.92	0.58	1.46	0.14	0.712
Week of Injury	-0.34	0.02	0.71	0.68	0.74	261.94	0.000

Note: Model Chi Square = 971.84, *df* = 14, ($p < .001$); -2 Log Likelihood = 1121.913

Figure 2 shows the survival function as it changes during the course of a competition. During the warm-ups, first quarter, and second quarter, the survival function decreases very slightly. During the third quarter, the survival function is 0.97. The likelihood of not sustaining and injury continues to decrease throughout the competition. The chance of survival during the fourth quarter of competition is 0.92. This figure shows that as competition progresses over time, the likelihood of survival decreases.

Figure 2: Injury Survival During Competition



Chapter V

DISCUSSION

The major findings of this dissertation were the possible isolation of some of the variables that contribute to the incidence of injury among varsity high school football athletes. During practice, the school an athlete attends and the week during which the practice occurs are shown to influence the occurrence of injury among varsity high school football athletes. During competition, the school an athlete attends, the week during which the competition occurs, and the classification of the athlete are shown to influence the occurrence of injury among varsity high school football athletes. There are several possible explanations why each of these variables may influence injury.

When putting the findings of this investigation in the context of Haddon's Injury Model (Haddon, 1968), it becomes evident that injury is a result of an uncontrolled interact between host, agent, and environment. The varsity athlete lacks control over the circumstances of a football practice or competition. But athletics tend to be defined differently. Although the athlete lacks control, the coaching staff exerts almost complete control during the practice. The coaching staff controls the length of practice, the drills performed, and the intensity level at which athletes perform (Dick, Ferrara, et al, 2007).

Injuries are due to both intrinsic and extrinsic factors (Dvorak, et al, 2000). The extrinsic causes of injury are influenced by the coaching staff at a high school. The coaching staff controls the amount and type of training, the surface that the practice occurs on, and the equipment the athletes use. Due to this control of the coaching staff over a varsity high school football practice, the argument can be made that they may influence the potential for injury among their athletes. This partially explains the reason that the school an athlete attends predicts their probability of injury. Another reason for the school as a predictor of injury is the athletic trainer.

Injury evaluation and the return to play standards after injury differ among athletic trainers. This could be due to the differences in education or differences in the mentality of the various athletic trainers. The participating athletic trainers were given a very strict injury definition. But there are variations among what athletic trainers consider a reportable injury. It is possible that some athletic trainers are very radical in their treatment of injuries as compared to others, who may be more conservative. What one constitutes as an injury another athletic trainer may not.

There were several factors not taken into account when analyzing the results of this investigation. Among these results are environment, playing surface, and number of practices within one day. In a study conducted by Cooper, Ferrara, and Broglio (2006), it was observed that during the first three weeks of preseason practice, athletes are more likely to sustain an exertional heat illness. A majority of the extertional heat illness occurred during this time (88%).

Participating schools in this investigation practiced and competed on multiple surfaces. Only one of the participating schools had artificial turf on their home field. Research conducted on elite soccer athletes has shown that there is no increase in injury rates between athletes who compete and artificial turf when compared to athletes who compete on natural turf (Ekstrand, Timpka, & Hagglund, 2006). Although Ekstrand, Timpka, and Hagglund were able to show there is no difference in injury rates between the surfaces, surface should be considered when evaluating causes of injury to athletes. The causes of injury in football are multifactorial with many confounding variables to be considered when designing future research.

The NCAA has strict rules when it comes to the number and length of practices collegiate teams can require an athlete to participate in. These rules are not seen in high school athletics. The NCAA has a five day acclimatization period for preseason football. During this time, athletes can not engage in more than one on field practice per day, not to exceed three hours in length (Dick, Ferrara, et al, 2007). This rule change went into effect during the 2002-2003 season. The limited data has not allowed the NCAA to compare injury rates before and after the rule change (Dick, Ferrara, et al, 2007).

The major goal of this dissertation was to evaluate how exposure influenced injury in sport. This is a task that is seldom undertaken in the realm of sport. Exposure can be examined as something that occurs during a single practice or over the course of a season. It was suggested by Breslin, Karmakar, Smith, Etches, and Mustard (2007) that time of exposure be considered when assessing injury potential. One area that has seen research into the time of exposure is industry. It is a consistent view that the continuous work in the industrial setting fatigues the workers, which predisposes them to injury (Knauth, 2007).

When examining the number of injuries per time frame in a varsity football practice, it becomes evident that injuries increase over time for the first three time frames. The fourth and fifth time frames saw a decline in injuries. Most practices ended during the fourth time frame, which explains the decreased number of injuries during the fifth time frame. The low numbers of injuries during the first time frame are explained by the fact that this segment is often focused on individual drills. The intensity of the practice increases through the second and third time frames. Conditioning often occurs during the fourth time frame, which results in fewer injuries as compared to other drills which may include player-to-player contact.

It is widely agreed by sports medicine personnel that fatigue may be a predisposing factor in the occurrence of injury (Heiser, Weber, Sullivan, Clare, & Jacobs, 1984). Muscle strains that occur later in practice are often the result of fatigue while muscle strain injuries early in practice are often the result improper warm-up (Dornan, 1971). When a muscle becomes fatigued, the proprioceptive ability of the athlete is diminished, which in turn can lead to injury (Rozzi, Lephart, & Fu, 1999).

Fatigue in the later stages of practice has been shown to effect tackling technique in rugby league players (Gabbett, 2008). Tackling technique progressively reduced over time. The same assumption can be made about varsity high school football athletes. Contact drills that occur in the later stages of practice may predispose an athlete to injury due to improper form in tackling as well as other essential functions that a football player must be able to perform.

As reported earlier, Figure 1 shows the survival function as it changes throughout a practice. The probability of sustaining an injury continually increases throughout a practice. The first two time frames of practice, which saw very few injuries, had a very high survival function. But as the practice progressed, the survival function steadily decreased. As athletes continue to practice, the possibility of them sustaining an injury increases until practice is terminated.

The injury events were very high the first week of the season, but steadily decreased throughout the first six weeks. One possible explanation for this is that athletes are beginning the season unconditioned for the sport which they are participating in. This lack of conditioning results in numerous injuries during the first several weeks of practice.

Another explanation is the intensity of the practices as dictated by the coaching staff. It is generally accepted that most contact between players occurs during preseason practices (Dick, Ferrara, et al, 2007). In seeing large numbers of injuries during the first several weeks of practice and the fear of losing other athletes at the end of the season, many coaches make the conscious effort to reduce the intensity of the practices. Instead of focusing on the physical aspect of the competition (i.e., blocking), they focus on the mental aspect of the competition (i.e., performing plays correctly).

These findings contradict findings made in other research which showed an increase in injuries as the season progresses (Gabbett, 2000). Although this research was performed on amateur rugby league athletes, the results could also pertain to varsity high school football. Gabbett suggested that the increase of injury throughout the season may be due to fatigue and accumulative microtrauma.

The variables that influence injury during competition, the school an athlete attends, the week during which the competition occurs, and the classification of the athlete are very similar to the variables that influence injury during practice. The exception is the classification of the athlete.

Less control is exerted by the coaching staff during competition as compared to practice (Dick, Ferrara, et al, 2007). The coaching staff can not control the intensity level of a competition they way they control the intensity level of a practice. The control of the coaching staff instead focuses on who plays and for how long.

The relationship between an athletic trainer and coach may also have an effect on an injured athlete. It has been shown that coaches have limited knowledge on the training, preparation, and experience of athletic trainers (Mensch, Crews, & Mitchell, 2005). This limited knowledge of the coaching staff towards athletic trainers may result in injured athletes being allowed play. Mensch, Crews, and Mitchell were able to show that coaches expected the athletic trainers to compliment the role of the coaching staff.

The results of this study have shown that sophomores have a decreased chance of sustaining an injury when compared to seniors. The starting positions on a varsity football team are often filled by upper-classmen (juniors and seniors). Under-classmen are often placed in reserve roles, which see very little playing time. This limited exposure is the reason sophomores have a decreased chance of sustaining an injury when compared to seniors.

As seen with practice, the school an athlete attends may influence the occurrence of injury. This result could be due to several factors including coaching staff, athletic trainer, and physical condition of the athletes. Coaching staffs tend to keep the same players in the competition regardless of the score. Schools whose records are below .500 will often keep the better athletes in the competition in hopes of remaining competitive.

When athletes are left in competitions for extended periods, often playing offensive and defensive positions, fatigue will develop. Fatigue has been shown to lead to injury among athletes in competition (Gabbett, 2002). To reduce the occurrence of injury, the advisement could be made that increasing rest time of fatigued athletes during competition would be beneficial. Athletic trainers and coaches should pay careful attention to athletes showing increased signs of fatigue. To reduce the risk of injury to these athletes, they should be removed from the competition. Removing an athlete from competition for a short period of time would be more beneficial than losing the athlete for extended periods due to injury.

The athletic trainer is the person who is responsible for deciding if an injured athlete is able to continue participating. Part of the definition of a reportable injury of this dissertation was that the injury resulted in restriction of the student-athlete's participation or performance for one or more calendar days beyond the day of injury. If the athletic trainer decides an athlete is able to return to the competition, even if an injury has occurred, they may not report the injury based on this part of the definition. Other athletic trainers may manage the same injury in a different way and not allow the athlete to return to competition. This athletic trainer would then report the injury. This difference in the management of injury may have influenced the perception that athletes attending certain schools were less likely to be injured than athletes attending other schools.

The week of the season during which a competition occurred was shown to be an influence on the occurrence of injury. More injuries occurred during the first have of the season as compared to the second half. These findings contradicted findings made by Gabbett (2000, 2002) when he examined the injury rates of amateur rugby athletes. In his research, Gabbett found that the number of injuries were higher in the second half of the season as compared to the first half. He suggested that fatigue or accumulative microtrauma, or both, may contribute to injury.

The number of injuries tends to decrease throughout the season. Although this was the overall tendency, there were two weeks where this was not evident. Week seven being an off week for all of the participating schools in Tennessee, saw the fewest number of injuries. With only four Alabama school competing during week 7; it is only logical that the overall number of injuries would decrease.

The other abnormality in the data occurred in week 8. Week 8 saw the largest number of injuries when compared to all other weeks. Week 8 was the week following the off week of the Tennessee schools. Practice during the off week was reduced to only a couple of sessions. While this is often done to allow injured athletes the time to recuperate, it appears that it may have a negative impact on the occurrence of injury in the following week. Following week 8, the number of injuries decreased dramatically, which fell within the tendencies that had been observed.

When examining the Survival Function in figure 2, it is obvious that as the competition progresses the likelihood of sustaining an injury increases. There is very little change in the survival function from the start of warm-ups until the end of the second quarter. The third quarter and the fourth quarter saw the most dramatic drops in the survival function. This information shows that the chances of sustaining an injury increase as the competition progresses.

Conclusions and Recommendations

The main focus of this dissertation was to examine the relationship between time of exposure and the incidence of injury among varsity high school football athletes. This research has shown the patterns of injuries that occur during both practice and competition. Additionally, other variables that may influence the incidence of injury have been identified.

The authors would like to make several recommendations to persons associated with varsity high school football based on this investigation.

1. Governing bodies should allow for a longer conditioning phase to be included in preseason.
2. The intensity of practices should be slowly increased over the first several weeks to accommodate the changing conditioning level of the athlete.
3. Injured athletes should be withheld from practice and competition until they are physically able to return to play as determined by a certified athletic trainer.
4. Additional attention should be paid to the positions that see higher incidences of injury.
5. Athletic trainers should pay additional attention to their athletes during the final stages of both practice and competition.
6. Further epidemiological research should be undertaken that not only focuses on the type and cause of injury, but also the time during practice and competition these injuries are occurring.

The results of this dissertation have shown the trends of injury events across both practice and competition. A thorough review of literature revealed very few studies that examined athletic injury in the context that it has been examined here. A deeper understanding of athletic injury can be made by examining the relationship between exposure and injury. This understanding can lead to the development of preventative strategies that may decrease the occurrence of injury among athletes.

REFERENCES

Abernathy, L., & MacAuley, D. (2003). Impact of school sports injury. *British Journal of Sports Medicine,* 37, 354-355.

Agel, J., Arendt, E. A., & Bershadsky, B. (2005). Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: a 13-year review. *American Journal of Sports Medicine*, 33, 524-530.

Agel, J., Dick, R., Nelson, B., Marshall, S. W., & Dompier, T. P. (2007). Descriptive epidemiology of collegiate women's ice hockey injuries: national collegiate athletic association injury surveillance system, 2000-2001 through 2003-2004. *Journal of Athletic Training,* 42, 249-254.

Agel, J., Dopier, T. P., Dick, R., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's ice hockey injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training,* 42, 241-248.

Agel, J., Evans, T. A., Dick, R., Putukian, M., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's soccer injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2002-2003. *Journal of Athletic Training*, 42, 270-277.

Agel, J., Olson, D. E., Dick, R., Arendt, E. A., Marshall, S.W., & Sikka, R. S. (2007). Descriptive epidemiology of collegiate women's basketball injuries: National collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42, 202-210.

Agel, J., Palmeiri-Smith, R. M., Dick, R., Wojtys, E. M., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate women's volleyball injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42, 295-302.

Agel, J., Ransone, J., Dick, R., Oppliger, R., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's wrestling injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training,* 42, 303-310.

Aitken, M. E., Jaffe, K. M., DiScala, C., & Rivara, F. P. (1999). Functional outcomes in children with multiple trauma without significant head injury. *Archives of Physical Medicine Rehabilitation*, 80, 889-895.

Aitken, M. E., Tilford, J. M., Barrett, K. W., Parker, J. G., Sinpson, P., Landgraf, J., & Robbins, J. M. (2002). Health status of children after admission for injury. *Pediatrics*, 110, 337-342.

Armstrong, L. E., De Luca, J. P., & Hubbard, R. W. (1990). Time course of recovery and heat acclimation ability of prior exertional heatstroke patients, *Medicine and Science in Sports and Exercise,* 22, 36-48.

Bahr, R. & Holme, I. (2003). Risk factors for sports injuries: a methodological approach. *British Journal of Sports Medicine*, 37, 384-393.

Beck, T.W., Housh, T. J., Johnson, G. O., Weir, J. P., Cramer, J. T., Coburn, J. W., & Malek, M. H. (2004). Mechanomyographic and electromyographic amplitude and frequency responses during fatiguing isokinetic muscle actions of the biceps brachii. *Electromyography and Clinical Neurophysiology,* 44, 431-441.

Binkley, H. M., Beckett, J., Casa, D. J., Kleiner, D. M., & Plummer, P. E. (2002). National athletic trainers' association position statement: exertional heat illnesses. *Journal of Athletic Training*, 37, 329-343.

Blum, R. W., & Nelson-MMari, K. (2004). The health of young people in a global context. *Journal of Adolescent Health*, 35, 402-418.

Breslin, F. C., Karmakar, S. D., Smith, P., Etches, J., & Mustard, C. (2007). Time allocation between work and recreation and the associated injury risks among young people. *Journal of Safety Research*, 38, 373-379.

Cantu, R. C., & Mueller, F. O. (1999). Fatalities and catastrophic injuries in high school and collegiate sports, 1982-1997: lessons for improving safety. *The Physician and Sportsmedicine,* 27, 35-48.

Carskadon, M. A. (1990). Patterns of sleep and sleepiness in adolescents. *Pediatrician,* 17, 5-12.

Carskadon, M. A. (2005). Sleep and circadian rhythms in children and adolescents: relevance for athletic performance of young people. *Clinics in Sports Medicine,* 24, 319-328.

Carskadon, M. A., Wolfson, A. R., Acebo, C., Tzischinsky, O., & Seifer, R. (1998). Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep,* 21, 871-881.

Caruso, C. C. (2006). Possible broad impacts of long work hours. *Industrial Health*, 44, 531-536.

Casa, D. J. (1999).Exercise in the heat, II: critical concepts in rehydration, exertional heat illnesses, and maximizing athletic performance. *Journal of Athletic Training,* 34, 253-262.

Cassell, E. P., Finch, C. F., & Stathakis, V. Z. (2003). Epidemiology of medically treated sport and active recreation injuries in the Latrobe Valley, Victoria, Australia. *British Journal of Sports Medicine,* 37, 405-509.

Chappell, J. D., Herman, D. C., Knight, B. S., Kirkendall, D. T., Garrett, W. E., & Yu, B. (2005). Effect of fatigue on knee kinetics and kinematics in stop-jump tasks. *American Journal of Sports Medicine,* 33, 1022-1029.

Chen, M. Y., Wang, E. K., & Jeng, Y. J. (2006). Adequate sleep among adolescents is positively associated with health status and health-related behaviors. *BMC Public Health,* 6, 1-8.

Choi, S. W., Peek-Asa, C., Sprince, N. L., Rautiainen, R., Flamme, G., Whitten, P, & Zwerling, C. (2006). Sleep quantity and quality as a predictor of injuries in a rural population. *American Journal of Emergency Medicine,* 24, 189-196.

Conn, J. M., Annest, J. L., Bossarte, R. M., & Gilchrist, J. (2006). Non-fatal sports and recreational violent injuries among children and teenagers, United States, 2001-2003. *Journal of Science and Medicine in Sport*, 9, 479-489.

Cooper, E. R., Ferrara, M. S., & Broglio, S. P. (2006). Exertional heat illness and environmental conditions during a single football season in the southeast. *Journal of Athletic Training,* 41, 332-336.

Dababneh, A. J., Swanson, N., & Shell, R. L. (2001). Impact of added rest breaks on the productivity and well being of workers. *Ergonomics*, 44, 164-174.

Danesco, E. R., Miller, T. R., & Spicer, R. S. (2000). Incidence and cost of 1987-1994 childhood injuries: demographic breakdowns. *Pediatrics*, 105, 27-37.

Davey, T. M., Aitken, L. M., Kassulke, D., Bellamy, N., Ambrose, J., Gee, T., & Clark, M. (2005). Long-term outcomes of seriously injured children: A study using the child health questionnaire. *Journal of Pediatric Child Health*, 41, 278-283.

Dick, R., Agel, J., & Marshall, S. W. (2007). National Collegiate Athletic Association Injury Surveillance System commentaries: introduction and methods. *Journal of Athletic Training,* 42, 173-182.

Dick, R., Ferrara, M. S., Agel, J., Courson, R., Marshall, S. W., Hanley, M. J., & Reifsteck, F. (2007). Descriptive epidemiology of collegiate men's football injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*. 42, 221-233.

Dick, R., Hertl, J., Agel, J., Grossman, J., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's basketball injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training,* 42, 194-201.

Dick, R., Hootman, J. M., Agel, J., Vela, L., Marshall, S. W., & Messina, R. (2007). Descriptive epidemiology of collegiate women's field hockey injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2002-2003. *Journal of Athletic Training,* 42, 211-220.

Dick, R., Lincoln, A. E., Agel, J., Carter, E. A., Marshall, S. W., & Hinton, R. Y. (2007). Descriptive epidemiology of collegiate women's lacrosse injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42, 262-269.

Dick, R., Putukian, M., Agel, J., Evans, T. A., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate women's soccer injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2002-2003. *Journal of Athletic Training*, 42, 278-285.

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, 255-261.

Dick, R., Sauers, E. L., Agel, J., Keuter, G., Marshall, S. W., McCarty, K., & McFarland, E. (2007). Descriptive epidemiology of collegiate men's baseball injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42, 183-193.

Ding, R. U., McCarthy, M. L., Houseknecht, E., Ziegfeld, S., Knight, V. M., Korehbandi, P., et al. (2006). The health-related quality of life of children with an extremity fracture: a one-year follow-up study. *Journal of Pediatric Orthopedics*, 26, 157-163.

Division of Injury Control, Center for Environmental Health and Injury Control, Centers for Disease Control. (1990). Childhood injuries in the United States. *American Journal of Disabled Children*, 144, 627-646.

Dompier, T. P., Powell, J. W., Barron, M. J., & Moore, M. T. (2007). Time-loss and non-time-loss injuries in youth football players. *Journal of Athletic Training,* 42, 395-402.

Dornan, P. (1971). A report on 140 hamstring injuries. *Australian Journal of Sports Medicine,* 4, 30-36.

Dvorak, J., Junge, A., Chomiak, J., Graf-Baumann, T., Perterson, L., Rosch, D., & Hodgson, R. (2000). Risk factor analysis for injuries in football players: possibilities for a prevention program. *The American Journal of Sports Medicine,* 28, 69-74.

Ebersole, K. T., & Malek, D. M. (2008). Fatigue and the electromechanical efficiency of the vastus medialis and vastus lateralis muscles. *Journal of Athletic Training,* 42, 152-156.

Edmonds, J. N., & Vinson, D. C. (2007). Three measures of sleep, sleepiness, and sleep deprivation and the risk of injury: a case-control and case-crossover study. *Journal of the American Board of Family Medicine,* 20, 16-22.

Ekstrand, J., Timpka, T., & Hagglund, M. (2006). Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study. *British Journal of Sports Medicine,* 40, 975-980.

Emery, C. A., Meeuwisse, W. H., & Hartmann, S. E. (2005). Evaluation of risk factors for injury in adolescent soccer; implementation and validation of an injury surveillance system. *The American Journal of Sports Medicine*, 33, 1882-1892.

Folkard, S. (1997). Black times: temporal determinants of transport safety. *Accident Analysis and Prevention Journal,* 29, 417-430.

Folkard, S., Lombardi, D. A., & Tucker, P. T. (2005). Shiftwork: Safety, Sleepiness, and Sleep. *Industrial Health*, 43, 20-23.

Gabbett, T. J. (2000). Incidence, site, and nature of injuries in amateur rugby league over three consecutive seasons. *British Journal of Sports Medicine,* 34, 98-103.

Gabbett, T. J. (2002). Incidence of injury in amateur rugby league sevens. *British Journal of Sports Medicine,* 36, 23-26.

Gabbett, T. J. (2008). Influence of fatigue on tackling technique in rugby league players. *The Journal of Strength and Conditioning Research,* 22, 625-632.

Garrick, J. G. & Requa, R. K. (1978). Injuries in high school sports. *Pediatrics*, 61, 465-469.

Gerberich, S. G., Priest, J. D., Straub, C. P., & Maxwell, R. E. (1983). Concussion incidences and severity in secondary school varsity football players. *American Journal of Public Health*, 73, 1370-1375.

Gessel, L. M., Fields, S. K., Collins, C. L., Dick, R. W., & Comstock, R. D. (2007). Concussions among United States high school and collegiate athletes. *Journal of Athletic Training*, 42, 495-504.

Gordon, J. E. (1949). The epidemiology of accidents. *American Journal of Public Health,* 39, 504-515.

Gribble, P. A., Tucker, W. S., & White, P. A. (2007). Time-of-day influences on static and dynamic postural control. Journal of Athletic Training, *42, 35-41.*

Guyer, B., & Ellers, B. (1990). Childhood injuries in the United States: mortality, morbidity, and cost. *American Journal of Disabled Children*, 144, 649-652.

Haddon, W. (1968). The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. *American Journal of Public Health,* 58, 1431-1438.

Haddon, W. (1980). Advances in the epidemiology of injuries as a basis for public policy. *Public Health Reports*, 95, 411-421.

Hansen, M., Janssen, I., Schiff, A., Zee, P., & Dubocovich, M. (2005). The impact of school daily schedule on adolescent sleep. *Pediatrics*, 115, 1555-1561.

Harrington, J. M. (2001). Health effects of shift work and extended hours of work. *Occupational and Environmental Medicine*, 58, 68-72.

Heiser, T. M., Weber, J., Sullivan, G., Clare, P., & Jacobs, R. R. (1984). Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. *American Journal of Sports Medicine,* 12, 368-370.

Holbrook, T. L., Hoyt, D. B., Coimbra, R., Potenza, B., Sise, M. J., Sack, D. I., & Anderson, J. P. (2007). Trauma in adolescents causes long-term marked deficits in quality of life: adolescent children do not recover preinjury quality of life or function up to two years postinjury compared to national norms. *Journal of Trauma*. 62, 577-583.

Holder, Y., Peden, M., Krug, E., Lund, J., Gururaj, G., & Kobusingye, O. (Eds.) (2001). *Injury Surveillance Guidelines*. Geneva: World Health Organization.

Hootman, J. M., Dick, R., & Agel, J. (2007). Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *Journal of Athletic Training*, 42, 311-319.

International Statistical Classification of Diseases and Related Health Problems, (10th revision). (1994). Geneva, World Health Organization.

Kaplan J., & Thacker, S. B. (2000). Working to prevent and control injuries in the year 2000. The injury fact book for the year 2000. Atlanta: National Center for Injury Prevention and Control, CDC.

King, B. G. (1949). Accident prevention research. *Public Health Report,* 64, 373-382.

Knauth, P. (2007). Extended work periods. *Industrial Health,* 45, 125-136.

Krieger, N. (1994). Epidemiology and the web of causation: has anyone seen the spider? *Social Science in Medicine,* 39,887-903.

Krieger, N. (2001). Theories for social epidemiology in the 21st century: an ecosocial perspective. *International Journal of Epidemiology*, 30, 668-677.

Lam, L. T., Yang, L. (2007). Short duration of sleep and unintentional injuries among adolescents in China. *American Journal of Epidemiology,* 166, 1053-1058.

Laraque, D., Barlow, B., Durkin, M. (1999). Prevention of youth injuries. *Journal of the National Medical Association,* 91, 557-571.

Lepers, R., Bigard, A. X., Diard, J. P., Gouteyron, J. F., & Guezennec, C. Y. (1997). Posture control after prolonged exercise. *European Journal of Applied Physiology and Occupational Physiology,* 76, 55-61.

Mair, D., Seaber, A. V., Glisson, R. R., & Garrett, W. E. (1996). The role of fatigue in susceptibility to acute muscle strain injury. *The American Journal of Sports Medicine,* 24, 137-143.

Marshall, S. W., Covassin, T., Dick, R., Nassar, L. G., & Agel, J. (2007). Descriptive epidemiology of collegiate women's gymnastic injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42, 234-240.

Marshall, S. W., Hamstra-Wright, K. L., Dick, R., Grove, K. A., & Agel, J. (2007). Descriptive epidemiology of collegiate women's softball injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42, 286-294.

Matheny A.P. (1991). Children's unintentional injuries and gender: differentiation by environment and psychosocial aspects. *Child Environ Quarterly*. 8, 51-61.

Meeuwisse, W. H. (1994). Assessing causation in sport injury: a multifactorial model. *Clinical Journal of Sports Medicine,* 4, 166-170.

Megdal, S. P., & Schernhammer, E. S. (2007). Correlates for poor sleepers in a Los Angeles high school. *Sleep Medicine*, 9, 60-63.

Mensch, J., Crews, C., & Mitchell, M. (2005). Competing perspectives during organizational socialization on the role of certified athletic trainers in high school settings. *Journal of Athletic Training,* 40. 333-340.

Morad, Y., Azaria, B., Avni, I., Barkana, Y., Zadok, D., Kohen-Raz, R., & Barenboim, E. (2007). Posturography as an indicator of fatigue due to sleep deprivation. *Aviation, Space, and Environmental Medicine,* 78, 859-863.

Morrongiello B. A., & Hogg, K. (2004). Mother's reaction to children misbehaving in ways that can lead to injury: implications for gender differences in children's risk taking and injuries. *Sex Roles*, 50, 103-118.

Morrongiello, B. A., & Dawber, T. (1998). Toddlers' and mothers' behavior in an injury-risk situation: implications for sex differences in childhood injuries. *Journal of Applied Developmental Psychology*, 19, 625-639.

Morrongiello, B. A., & Matheis, S. (2004). Determinants of children's risk-taking in different social-situational contexts: the role of cognitions and emotions in predicting children's decisions. *Journal of Applied Developmental Psychology*, 253, 303-326.

National Federation of State High School Associations. 2005-06 High school athletics participation survey. http://www.nfhs.org/web/2004/01/the_case_for_high_ school_activities.aspx. Accessed May 1, 2008.

Mueller, F. O. (2001). Catastrophic head injuries in high school and collegiate sports. *Journal of Athletic Training,* 36, 312-315.

Nelson, A. J., Collins, C. L., Yard, E. E., Fields, S. K., & Comstock, R. D. (2007). Ankle injuries among United States high school sports athletes, 2005-200. *Journal of Athletic Training*, 42, 381-387

Nyland, J. A., Shapiro, R., Carbon, D. N. M., Nitz, A. J., & Malone, T. R. (1997). The effect of quadriceps femoris, hamstring, and placebo eccentric fatigue on knee and ankle dynamics during crossover cutting. *Journal of Orthopedic Sports Physical Therapy,* 25, 171-184.

Nyland, J. A., Shapiro, R., Stine, R. L., Horn, T. S., & Ireland, M. L. (1994). Relationship of fatigued run and rapid stop to ground reaction forces, lower extremity kinematics, and muscle activation. *Journal of Orthopedic Sports Physical Therapy,* 20, 132-137.

Omran, A. R. (1971). The epidemiologic transition: a theory of the epidemiology of population change. *Milbank Memorial Fund Quarterly*, 49, 509-538.

Park, M.J., Mulye, T. P., Adams, S. H., Brindis, C. D., & Irwin, C. E. (2006). The health status of young adults in the United States. *Journal of Adolescent Health*, 39, 305-317.

Peterson, L., Farmer, J., & Mori, L. (1987). Process analysis of injury situations: a complement to epidemiological methods. *Journal of Societal Issues*, 43, 33-44.

Pickett, W., Molcho, M., Simpson, K., Janssen, I., Kuntsche, E., Mazur, J., Harel, Y., & Boyce, W. F. (2005). Cross national study of injury and social determinants in adolescents. *Injury Prevention*, 11, 213-218.

Polinder, S., Meerding, W. J., Toet, H., Mulder, S., Essink-Bot, M. L., & van Beeck, E. F. (2005). Prevalence and prognostic factors of disability after childhood injury. *Pediatrics, 116, 810-817.*

Powell, J. W., & Barber-Foss, K. D. (2000). Sex-related injury patterns among selected high school sports. *American Journal of Sports Medicine,* 28, 385-391.

Pryor, S. K., & Caruth, A. K. (2002). Children's injuries in agriculture related events: the effect of supervision on the injury experience. *Issues in Comprehensive Pediatric Nursing,* 25 189-205.

Radelet, M. A., Lephart, S. M., Rubinstein, E. N., & Myers, J. B. (2002). Survey of the injury rate for children in community sports. *Pediatrics,* 110, 28-39.

Rechel, J. A., Yard, E. E., & Comstock, R. D. (2008). An epidemiologic comparison of high school sports injuries sustained in practice and competition. *Journal of Athletic Training*, 43, 197-204.

Rivara, F. P. (2002). Prevention of injuries to children and adolescents. *Injury Prevention*, 8, IV5-IV8.

Robinson, J., & Godbey, G. (1999). Time for Life. University Park, PA: Pennsylvania State University Press.

Rosen, B. N., & Peterson, L. (1990). Gender differences in children's outdoor play injuries: a review and an integration. *Clinical Psychology Review*, 10, 187-205.

Rozzi, S. L., Lephart, S. M., & Fu, F.H. (1999). Effects of muscular fatigue on knee joint laxity and neuromuscular characteristics of male and female athletes. *Journal of Athletic Training,* 34, 106-114.

Runyan, C. W. (2003). Introduction: back to the future-revisiting Haddon's conceptualization of injury epidemiology and prevention. *Epidemiologic Reviews*, 25, 60-64.

Runyan, C. W., & Gerken, F. A. (1989). Epidemiology and prevention of adolescent injury: a review and research agenda. *Journal of the American Medical Association*, 262, 2273-2278.

Samuels, C. (2008). Sleep, recovery, and performance: the new frontier in high-performance athletics. *Neurologic Clinics,* 26, 169-180.

Saunders, R. L., & Harbaugh, R. E. (1984). The second impact in catastrophic contact sports head trauma. *Journal of the American Medical Association*, 252, 538-539.

Savery, L. K. & Luks, A. J. (2000). Long hours at work: are they dangerous and do people consent to them? *Leadership and Organization Development Journal*, 21, 307-310.

Schwebel, D. C., & Gaines, J. (2007). Pediatric unintentional injury: behavioral risk factors and implications for prevention. *Journal of Developmental and Behavioral Pediatrics*, 28, 245-254.

Shankar, P. R., Fields, S. K., Collins, C. L., Dick, R. W., & Comstock, R. D. (2007). Epidemiology of high school and collegiate football injuries in the United States, 2005-2006. *American Journal of Sports Medicine,* 35, 1295-1303.

Singh, G. K., & Yu, S. M. (1996). US childhood mortality, 1950 through 1993: trends and socioeconomic differentials. *American Journal of Public Health*, 86, 505-512.

Stein, M. A., Mendelsohn, J., Obermeyer, W. H., Amromin, J., & Benca, R. (2001). Sleep behavior problems in school-aged children. *Pediatrics,* 107, 60-69.

Thacker, S. B., & Berkelman, R. L. (1988). Public health surveillance in the United States. *Epidemiology Review,* 10, 164-190.

Tucker, P., Foljard, S., & Macdonald, I. (2003). Rest breaks and accident risk. *Lancet*, 361, 680.

Tolbert, T. A., Binkley, H. M., Miller, & Weatherby, N. (2008). [Injuries as a function of time]. Unpublished raw data.

Tynjala, J., Kannas, L., Levalahti, E., & Valimaa, R. (1999). Perceived sleep quality and its precursors in adolescents. *Health Promotion International,* 14, 155-165.

Walker, M. P., Brakefield, T., Morgan, A. Hobson, J., & Stickgold, R. (2002). Practice with sleep makes perfect: sleep dependent motor skill learning. *Neuron*, 35, 205-211.

Walker, M., & Stickgold, R. (2005). It's practice, with sleep, that makes perfect: implications of sleep-dependent learning and plasticity for skill performance. *Clinics in Sports Medicine,* 24, 310-317.

Weaver, N. L, Mueller, F. O., Kalsbeek, W. D., & Bowling, J. M. (1999). The North Carolina high school injury study: design and methodology. *Medicine and Science in Sports and Exercise,* 31, 176-182.

Wilkins, J. C., Valovich McLeod, T. C., Perrin, D. H., & Gansneder, B. M. (2004). Performance on the balance error scoring system decreases after fatigue. *Journal of Athletic Training,* 39, 156-161.

Wojtys, E. M., Wylie, B. B., & Huston, L. J. (1996). The effects of muscle fatigue on neuromuscular function and anterior tibial translation in healthy knees. *American Journal of Sports Medicine,* 24, 615-621.

Wolfson, A. R., & Carskadon M. A. (1998). Schedules and daytime functioning in adolescents. *Child Development,* 69, 875-887.

APPENDICES

APPENDIX A

INJURY FORM

Exposure to Injury in Sport: High School Football Surveillance System

Injury Definition: A reportable injury in the HSFSS is defined as one that:
1. Occurs as a result of participation in an organized practice or contest;
2. Requires medical attention by a team athletic trainer or physician; and
3. Results in any restriction of the athlete's participation or performance for one or more days beyond the day of injury.

Name:__________________ **Athlete ID:**______________ **School ID:**__________________

1. Yearly Classification: (circle one)
Fr So Jr Sr

2. Date of Injury:__________

3. Position: (circle one)
1) Offensive Lineman
2) Quarterback
3) Running Back
4) Flanker/Wide Receiver
5) Defensive Lineman
6) Linebacker
7) Defensive Back

4. The injury occurred during: (circle one)

Practice (circle one):	Game (circle one):
1) 0-30 minutes	6) warm-up
2) 31-60 minutes	7) 1st quarter
3) 61-90 minutes	8) 2nd quarter
4) 91-120 minutes	9) 3rd quarter
5) More than 120 minutes	10) 4th quarter
	11) Overtime

5. Injury occurred during: (circle one)
1) Preseason (before first regular-season game)
2) Regular season
3) Postseason (after final regular-season game)
99) Other:

6. This injury is: (circle one)
1) New injury
2) Recurrence of injury to the same body part from this season
3) Recurrence of injury to the same body part from prior history

7. How long did this injury restrict the student-athlete from participating in the sport? (If end of season, give best estimate.)
1) Number of days out: __________
2) Date of return: __________
3) Catastrophic, non fatal: __________
4) Fatal __________

8. Injury occurred during: (circle one)
1) Offensive play
2) Defensive play
3) Special teams
4) Individual drills
5) Conditioning during practice

9. Type of surface: (circle one)
1) Grass
2) Artificial turf
3) Indoor (gymnasium)

Continue on next page

10. Principal body part injured: (Circle One)
1) Ankle
2) Buttocks
3) Cervical Spine
4) Cheek
5) Chin
6) Clavicle
7) Coccyx
8) Ears
9) Elbow
10) External genitalia
11) Eyes
12) Finger(s)
13) Foot
14) Forearm
15) Hand
16) Head
17) Heel/Achilles' tendon
18) Jaw
19) Kidney
20) Knee
21) Liver
22) Lower back
23) Lower leg
24) Lumbar Spine
25) Mouth
26) Neck
27) Nose
28) Patella
29) Pelvis, hips, groin
30) Ribs
31) Scalp
32) Scapula
33) Shoulder
34) Spleen
35) Sternum
36) Stomach
37) Teeth
38) Thoracic Spine
39) Thumb
40) Toe(s)
41) Tongue
42) Upper arm
43) Upper back
44) Upper leg
45) Wrist
99) Other: ______

11. Primary type of injury: (circle one)
1) Abrasion
2) AC separation
3) Avulsion (tooth)
4) Blisters
5) Boil(s)
6) Burn
7) Bursitis
8) Concussion
9) Contusion
10) Dislocation (complete)
11) Dislocation (partial)
12) Foreign object in body orifice
13) Fracture
14) Heat Cramps
15) Heat exhaustion
16) Heatstroke
17) Hemorrhage
18) Hernia
19) Hyperextension
20) Infection
21) Inflammation
22) Internal Injury (nonhemorrhage)
23) Laceration
24) Ligament sprain (complete tear)
25) Ligament sprain (incomplete tear)
26) Muscle-tendon strain (complete tear)
27) Muscle-tendon strain (incomplete tear)
28) Nerve Injury
29) Puncture wound
30) Stress Fracture
31) Tendonitis
32) Torn cartilage
99) Other: ______

12. This injury involved: (circle one)
1) Blocked below waist
2) Being blocked
3) Being tackled
4) Blocking
5) Blocking a kick/punt
6) Catching/blocking pass
7) Clipped
8) Clipped by an offensive lineman in legal clip zone
9) Impact with padded cast
10) Impact with playing surface
11) Noncontact (rotation about a planted foot)
12) Noncontact other
13) Overuse
14) Sprints/running
15) Stepped on/fallen on/kicked
16) Tackling
99) Other: ______

APPENDIX B

EXPOSURE FORM

Time Specific Athletic Injuries Surveillance System

School Code:__________ **Week of:**__________

Number of Practices this Week:________________

Season (Circle one): Preseason Regular Season Post Season

Practice Number	**Day of Practice (Circle One):**	**Length of Practice (Circle One):**	**Number of Participants:**
1	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
2	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
3	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
4	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
5	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
6	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
7	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
8	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
9	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
10	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
11	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
12	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
13	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
14	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________
15	M, T, W, Th, F, Sa, Su	0-30, 31-60, 61-90, 91-120, Greater than 120 min.	__________

Was a varsity contest played (circle one)? Yes No

If yes, total number of participants with actual playing time. __________

Type of surface during game (circle one). Grass Artificial

APPENDIX C

IRB APPROVAL

July 15, 2008

Timothy A. Tolbert
Protocol Title: Time Component of Athletic Injuries
Protocol Number: 09-006

Dear Investigators,

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above, and has determined that the study poses minimal risk to participants and qualifies for an exempt review under 45 CFR 46.101(b)(4). This is based on the fact that the research is involving the collection or study of existing data, documents, records, or specimens and information will be recorded in such a manner that the subjects cannot be identified directly or through identifiers linked to the subjects.

Approval is granted, pending permission letters from the principals and superintendents of all schools data will be collected from. Approval will expire three (3) years from the date of this letter.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Tara Prairie, Box 134) before they begin to work on the project. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting and analyzing data. Should you not finish your research within the three (3) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Your study will expire on **July 15, 2011.**

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

Sincerely,

Lisa Pritchett, Assistant to
Tara Prairie, Compliance Officer
MTSU Institutional Review Board