An epidemiological study of lower extremity injury rates based on age sex, and timing of injury

Jessica Suzzanne Moss
The University of Toledo

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Entitled

An Epidemiological Study of Lower Extremity Injury Rates Based on Age, Sex, and Timing of Injury

By

Jessica Suzzanne Moss

Submitted to the Graduate Faculty as a partial fulfillment of the requirement for the Masters of Science Degree in Exercise Science

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The University of Toledo
August 2010
An Abstract of
An Epidemiological Study of Lower Extremity Injury Rates Based on Age, Sex, and Timing of Injury

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Objective: To examine acute lower extremity injury rates of the secondary school athlete; specifically considering what age group is more inclined to injury, and at what time during competition the athlete is more at risk.

Design, Setting, and Data Source: Data on high school age athletes were collected from eleven Toledo Ohio and Southern Michigan area high schools in the sports of football, volleyball, boy’s and girl’s soccer, and boy’s and girl’s basketball. Middle school age data were collected from Toledo area youth leagues in the sports of girls and boys basketball, football, and girls and boys soccer. Athletes’ ages ranged from 10-19 years of age. All data were collected by certified Athletic Trainers and provided to the primary investigator. The number of each type of injury served as the dependant variables. The independent variables were age (middle school age, high school age), timing of injury, (1st quarter, 2nd quarter, 3rd quarter, 4th quarter) sex, and
competition/practice. For each dependant variable, frequency descriptives are represented according to each independent variable. **Measurements:** An exposure was defined by any player that participated on each day. The following injuries were tracked: lateral and medial ankle sprains, peroneal tendon sprains, achilles tendon strains, fracture or dislocation of the ankle and knee joint, hamstring and quadriiceps strains, anterior and posterior cruciate ligament injuries, medial and lateral collateral ligament injuries, patellar dislocation, and medial and lateral meniscus injuries. **Results:** Middle school age athletes had a higher injury rate (4.03 injuries per 1000 exposures) compared to high school age athletes. Overall, in the breakdown of a competition, athletes were most likely to get injured during the 3rd quarter. Middle school age and high school age athletes recorded 0.51 injuries per 1000 in the 1st quarter, 1.22 injuries per 1000 in the 2nd quarter, 2.08 injuries per 1000 in the 3rd quarter, and 1.28 injuries per 1000 in the 4th quarter. When comparing practice injuries versus competition injuries, there were more injuries in practice. There were 1.70 injuries recorded for every 1000 practice exposures; while there were 1.50 injuries for every 1000 games exposures. When comparing males versus female injury rates, males overall had a larger injury rate (5.82 injuries/1000 exposures) compared with females (1.34 injuries/1000). **Conclusions:** On the whole middle school aged males in the 3rd quarter are the most at risk group, with high school males closely behind.
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Chapter 1

Introduction

Nationwide in high schools there are 110,583 football players, 715,631 boy’s and girl’s soccer players, 452,056 volleyball players, 1,013,236 boy’s and girl’s basketball players and countless other boys and girls in other sports; amounting to close to 8 million high school athletes. High school athletes puts their bodies at risk and exposes themselves to injury daily, either by accident or predisposition. As the rate of high school athletic participation increases, the rate of injuries in the high school setting also increases. Injury rate in athletics has risen 21% percent in the last decade. With over four million injuries annually, researchers are exploring trends in injury epidemiology in the middle school and high school age ranges in the hope of identifying definitive risk factors. Lower extremity injury makes up more than three fourths of all athletic injury; with the ankle and the knee being the most commonly injured joints. Ankle and knee injuries do not seem
to discriminate between age, sex, race or sport, amounting nearly two million each year. 17 10-30% Of musculoskeletal injuries happen at the ankle. 15, 5 While this is a large percentage of injuries the knee is more commonly injured in the adolescent population. 16

Injury rate or epidemiology studies are not uncommon. The parameters that the researchers typically examine include sex, injury, injury mechanism, or other external factors. 9, 11 Age (middle school age vs. high school age) and fatigue (associated with timing of injury) have rarely if at all been studied specifically in high school injury epidemiology. 1-3, 7-8, 10

Age is a significant factor because it not only looks at risk of injury across the lifespan and development, but also sees specific injuries are more prevalent in certain age groups. 10 Many researchers have looked at the difference between male and female injuries about the ankle and the knee, but there is no research identifying injury rates when accounting for sex and age, or differentiating boney and soft tissue injuries. 9

Timing of the injury, such as which quarter the injury happened in during an athletic event, is essential to examine as it addresses potential deficiencies and declines in the body’s muscle firing mechanisms, and subsequent stabilization of muscles around the joints that are being injured. Considering the effects of fatigue on injury rate and type will hopefully enlighten the risk factors of competing during prolonged activity. While there
is an abundant amount of research demonstrating fatigue as a factor on performance, there is a limited amount of research addressing effects of timing of injury.

**Statement of the Problem**

Epidemiological studies about high school injury rates exist but are not abundant, above all not for athletes participating in northwest Ohio and southeast Michigan. In particular, the studies that exist have not included the variables of age (middle school age vs. high school age) as well as the timing of injury during the activity as an index of fatigue.

**Statement of the Purpose**

The purpose of this study was to examine acute lower extremity injury rates of the secondary school athlete; specifically considering what age group is more inclined to injury, and at what time during competition the athlete is more at risk. Both these factors will help medical professionals discover the implications behind injury rates and in the long run how to manage them more effectively.
Significance of the Study

Many studies have been completed on high school injury rates, but never injury rates specifically looking at age, and timing during competition. Hopefully these two specific variables will help the clinician develop a strategy that will successfully identify at-risk individuals for ankle and knee injuries.
Hypothesis

H1: Middle school age athletes will have a lower rate or frequency of overall injury compared with the high school age athletes.

H2: High school age athletes will have a higher occurrence of injury during the end of competition as compared to the beginning because of fatigue factors.

H3: There will be a higher rate of injury in competition versus practice.

H4: There will be a higher rate of injury in high school age males as compared to middle school age males, and all female ages.
Chapter 2

Literature Review

Anatomy

Ankle

The ankle is a unique joint, as it is actually comprised of two joints; the subtalar joint, and the talocrural joint. The two joints work together to compose the ankle complex. The inferior and superior tibiofibular articulations also contribute to ankle complex function. The joints are comprised of five individual bones, the calcaneus, talus, navicular, tibia, and fibula. The fibula and tibia articulate superior to the talus, this articulation is intertwined with an interosseous membrane of the two bones. This broad fibrous connective tissue is what is responsible for providing stability between the two bones together, and is implicated in “high” ankle sprains.
The inferior tibiofibular joint makes a concave gap for the dome of the talus to fit in. When doing this it also allows for the bony projections of the malleoli, medial and lateral. The subtalar joint is the more superior of the two joints, which is an articulation of the talus, the tibia, and the fibula. This joint is a hinge joint with one degree of freedom with the motions of plantar and dorsiflexion. The subtalar joint, inferior to the talocrural, joint, contains the calcaneus, talus, and navicular. This joint is more of a gliding joint with also one degree of freedom; pronation and supination.\textsuperscript{19, 23}

Each of the joints has fibrous ligaments that hold the articulations together. Medially the deltoid ligament originates on the medial malleolus and inserts on the talus and calcaneus. This ligament is triangular in shape with four refined superficial and deep parts. Laterally, there is a complex of three separate ligaments that stabilize this side. The anterior talofibular, the posterior talofibular, and the calcaneofibular, more commonly referred to as the ATF, PTF, and CF, respectively. These three ligaments are the most commonly sprained in the order listed above. They are also graded in severity as to how many ligaments are disturbed and ruptured. The ATF originates on the anterior lateral malleolus and inserts on the body of the talus. The PTF originates on the lateral malleolus and inserts on the posterior talus. Finally, the CF originates on the anterior inferior malleolus and inserts on the tubercle of the calcaneus.\textsuperscript{19, 22}
The ligaments give the bones a unified joint; muscles give the bones motion. The ankle moves in four directions, each direction being associated with a group of muscles. Dorsiflexion can be largely elicited via the tibialis anterior, extensor hallucis longus, and the extensor digitorium longus. The tibialis anterior originates on the lateral condyle, tibia, and interosseous membrane, and inserts on the first cuneiform. The extensor hallucis longus originates mid-fibula and interosseous membrane, while inserting on the distal big toe. The extensor digitorum longus originates lateral condyle, fibula, and interosseous membrane, and inserts on the distal toe phalanges. Working opposite from the dorsiflexors are the plantarflexors, the gastrocnemius, soleus, plantaris, flexor hallucis longus, and flexor digitorum longus. The gastrocnemius originates on the medial and lateral condyles of the femur, and inserts on the calcaneus. The soleus originates on the mid-tibia and fibula, while inserting on the calcaneus. The plantaris originates on the lateral supraciliary ride of the femur, and inserts on the calcaneus. The flexor hallucis longus originates on the tibia while inserting on the big toe. The flexor digitorum longus originates on the tibia, and inserts on the toe phalanges. Moving the ankle laterally or pronation involves chiefly three muscles, peroneus tertius, peroneus longus, and peroneus brevis. The peroneus tertius originates on the fibula and interosseous membrane while inserting on the fifth metatarsal. The peroneus longus originates on the fibula, and inserts on the medial cuneiform. Opposing pronation is
supination, or moving the ankle medially which involves the tibialis posterior. The tibialis posterior originates on the tibia, fibula, and interosseous membrane, while inserting on the majority of the forefoot bones.\textsuperscript{19, 22}

There is an abundant vascular and nervous supply to the ankle complex. The descending aorta supplies the vascular supply for the lower extremity. From there the femoral artery breaks off into the popliteal and finally the posterior tibial and anterior tibial. From the posterior tibial the dorsalis pedis splits off, which is the main artery for which pulse is taken in the lower extremity. The greater and lesser saphenous veins are responsible for venous return and empty into the femoral and iliac veins, and lastly the inferior vena cava. There are four main innervations of the ankle: the sural, posterior tibial, deep peroneal, and common peroneal nerves. These nerves can be traced back to branches of the large sciatic and femoral nerves. The nerve roots associated with the spine that innervate the ankle directly are L4, L5, S1, and S2\textsuperscript{19, 22}

**Knee**

The knee is far more complex than it may seem. It is a modified hinge joint that flexes and extends, but also has rotational capabilities. The knee is comprised of three bones: the femur which sits superiorly to the tibia, and
fibula. In between these, shifting and gliding occur with a system of ligaments and cartilage that work together to prevent the condyles of the femur from grinding on the tibia and fibula. The tibia and fibula are held together by a thick connective tissue called the interosseus membrane. The fibula is also articulated with the tibia via the lateral collateral ligament.19, 22

The knee structures can either be intracapsular or extracapsular. All the muscles that in are involved in the knee joint are extracapsular. Anteriorly a group of four muscles called the quadriceps come together to form the patellar/quadriceps tendon and insert on the tibial tuberosity. The rectus femoris originates on the ilium; the vastus medialis originates on the linea aspera; the vastus intermedialis originate from the antero-lateral femur; and the vastus lateralis originates on the greater trochantner. These muscles work together to extend the lower leg at the knee joint. Counteracting the extensors are the flexors located on the posterior knee. The flexor complex as a whole is referred to as the hamstrings which consist of three muscles, the biceps femoris, originating on the ischium and inserting on the lateral tibial condyle, the semitendinosis, originating on the ischium and inserting on the pes anserinus, and the semimembranosus which originates on the ischial tuberosity and inserts on the medial tibia. The flexor and extensor muscles make up the majority of the muscles that cross the knee and are primary movers. The adductors sit on the inside of the thighare consisting of only two muscles, the sartorius and the gracilis. The sartorius
originates on the iliac spine and the garcilis originates on the ischiopubiuc ramus; both insert on the pes anserius.¹⁹,²²

The other three structures that lie extracapsularly are the patellar complex, medial collateral ligament and the lateral collateral ligament. The patella is the largest sesamoid bone in the body. A sesamoid bone is one that does not articulate with any other bones, but rather only has tendon attachments. The quadriceps muscles come together superior to the joint space to form the patellar tendon, which encloses the patella bone, then attaches inferior to the joint space at the tibial tuberosity. The patellar complex is used to create leverage in extension of the knee. The collateral ligaments of the knee work to stabilize and translate forces medially and laterally. The medial collateral ligament runs from the medial femoral condyle to the medial tibial condyle. It chiefly protects the knee against valgus forces. The lateral collateral ligament stretches from lateral femoral condyle to the head of the fibula on the lateral tibial condyle. The lateral collateral ligament largely protects against varus forces to the knee.¹⁹,²²

The intracapsular structures of the knee are surrounded by a joint capsule, particularly a synovial joint capsule. The synovial capsule is filled with synovial fluid which provides nutrition to its structures. There are two main ligaments and the meniscus which sit inside the capsule. The anterior cruciate ligament and the posterior cruciate ligament are two ligaments that translate anterior and posterior forces, respectively. The anterior cruciate
ligament extends from the lateral condyle of the femur to the anterior intercondyloid eminence. The posterior cruciate ligament runs from the posterior intercondyler area to the medial femoral condyle. The meniscus is a cartilaginous structure that sits upon the tibial plateau in two “c” and “o” shaped rings. The coronary ligaments not only attach the meniscus to the tibia but provide nutrients and blood supply also. The medial meniscus is larger and “c” shaped, while the lateral meniscus is smaller and “o” shaped. They connect anteriorly via the transverse ligament. The meniscus is a semi solid fibrocartilage connective tissue that provides not only structural integrity but cushioning when forces are transmitted through the knee.¹⁹

The bones, muscles, and structures of the knee have a network of genicular arterries that supply the blood. There are five genicular arteries; decending, superior medial, superior lateral, inferior medial, and inferior lateral. The genicular arteries are supplied by the femoral and popliteal arteries. The saphenous and femoral veins are responsible for venous return from the knee.¹⁹

The nerve supply for the knee complex originates in the lumbar and sacral plexis. The obturator nerve runs medially, femoral nerve runs anteriorly and the sciatic runs posteriorly.¹⁹
Injury Definitions

Injury as a whole can be defined by a bodily chief complaint that has caused pain or damage to the individual, in which the individual seeks help from medical personnel.\textsuperscript{12, 11} For the purposes of this study the injury definitions will be derived from The Fundamentals of Athletic Training by Arnheim.\textsuperscript{19} These definitions will help characterize the injuries tracked in the study and provide insight to the severity of each injury experienced.

Medial Collateral Ligament – Grade I – There will be few ligamentous fibers torn, the joint is stable during valgus stress tests with little no joint effusion. There might be joint stiffness and point tenderness just below the medial joint line, but still full passive and active range of motion.

Medial Collateral Ligament – Grade II – There will be a complete tear of the deep capsular ligament and partial test of the superficial layer of the medial collateral ligament or a partial tear of both. No gross instability but minimal joint laxity during full extension. Valgus stress test will be slightly positive with end point. Swelling and pain will be slight to absent depending on the integrity of adjacent structures. The joint will be stiff and tight, with
loss of passive range of motion, athlete will not be able to place heel on the ground.

**Medial Collateral Ligament – Grade III** – There will be a complete loss of medially stability, valgus stress test will be fully positive with gapping. Moderate swelling and severe immediate pain with a dull ache will be present at the medial joint line. There will be full loss of range of motion due to pain and swelling.

**Lateral Collateral Ligament – Grade I** – There will be few ligamentous fibers torn, the joint is stable during varus stress tests with little no joint effusion. There might be joint stiffness and point tenderness just below the lateral joint line, but still full passive and active range of motion.

**Lateral Collateral Ligament – Grade II** – There will be a complete tear of the deep capsular ligament and partial test of the superficial layer of the lateral collateral ligament or a partial tear of both. No gross instability but minimal joint laxity during full extension. Varus stress test will be slightly positive with end point. Swelling and pain will be slight to absent depending on the integrity of adjacent structures. The joint will be stiff and tight, with loss of passive range of motion, athlete will not be able to place heel on the ground.

**Lateral Collateral Ligament – Grade III** – There will be a complete loss of lateral stability, varus stress test will be fully positive with gapping.
Moderate swelling and severe immediate pain with a dull ache will be present at the lateral joint line. There will be full loss of range of motion due to pain and swelling.

**Posterior Cruciate Ligament – Grade I** – The athlete will feel a pull at the back of the knee, with little to no popliteal swelling or tenderness. Special tests will all be negative.

**Posterior Cruciate Ligament – Grade II** – The athlete might report feeling or hearing a pop in the back of the knee with moderate popliteal swelling and tenderness. Special tests will elicit pain but not necessarily positive.

**Posterior Cruciate Ligament – Grade III** – The athlete will report feeling or hearing a pop in the back of the knee with moderate popliteal swelling and tenderness. Special tests such as sag and posterior drawer will elicit not only pain but provide a joint laxity with no end point.

**Anterior Cruciate Ligament – Grade I** – The athlete will feel a pull in the knee, with little to no immediate swelling or tenderness. Special tests will all be negative.

**Anterior Cruciate Ligament – Grade II** – The athlete might report feeling or hearing a pop in the knee with moderate swelling and tenderness. He/She will complain that their knee is “coming apart” or sliding” Special tests will elicit pain but not necessarily positive.
Anterior Cruciate Ligament – Grade III – The athlete will report feeling or hearing a pop in the knee with immediate intense swelling and pain. Special tests such as Lachman’s and anterior drawer will elicit not only pain but provide a joint laxity with no end point.

Medial Meniscus – There will be an obvious amount of swelling and joint stiffness at the medial joint line. The joint line itself will be point tender, and quite painful. Athlete will complain of catching, and popping. An obvious mechanism of sudden stop and twisting will be revealed in the history.

Lateral Meniscus – There will be an obvious amount of swelling and joint stiffness at the lateral joint line. The joint line itself will be point tender, and quite painful. Athlete will complain of catching, and popping. An obvious mechanism of sudden stop and twisting will be revealed in the history.

Patella Dislocation – The athlete will experience pain, swelling and a complete loss of knee function; the patella will rest in an abnormal position. Most commonly the patella will dislocate medially towards the VMO.

Quadriceps Strain – Grade I – The muscle itself has retained all integrity and very few fibers will be stretched and torn. There will be little to no swelling, point tenderness, and/or ecchymosis. The athlete will complain of pain during activity, but no loss of range of motion, passive or active.

Quadriceps Strain – Grade II – The muscle itself will exhibit small microtears. There will be mild swelling, point tenderness, and ecchymosis. The
athlete will have pain during activity, with a loss of passive and active range of motion. A deformity might be felt.

**Quadriiceps Strain – Grade III** – The muscle itself will be torn with deformity visible to the eye; divot or dimple in the skin. There will be moderate swelling with extreme point tenderness and eccymosis. The athlete will often collapse in extreme pain. They athlete will have loss of function, and complete loss of active range of motion.

**Hamstrings Strain – Grade I** – The muscle itself has retained all integrity and very few fibers will be stretched and torn. There will be little to no swelling, point tenderness, and/or eccymosis. The athlete will complain of pain during activity, but no loss of range of motion, passive or active.

**Hamstrings Strain – Grade II** – The muscle itself will exhibit small microtears. There will be mild swelling, point tenderness, and eccymosis. The athlete will have pain during activity, with a loss of passive and active range of motion. A deformity might be felt.

**Hamstrings Strain – Grade III** – The muscle itself will be torn with deformity visible to the eye; divot or dimple in the skin. There will be moderate swelling with extreme point tenderness and eccymosis. The athlete will often collapse in extreme pain. They athlete will have loss of function, and complete loss of active range of motion.
Knee Fractures – The athlete will commonly hear a snap and the knee will give way. Swelling is immediate and extensive because of hemarthrosis. There will be considerable pain.

Lateral Ankle Sprain- Grade I – There will be mild pain and possible disability at the anterior talofibular ligament. Weight bearing is minimally impaired. Point tenderness and swelling over the ligament with no joint laxity.

Lateral Ankle Sprain- Grade II – There might be a disruption of the anterior talofibular ligament and a stretch and tear of the calcaneofibular ligament. The athlete will feel or hear a pop on the lateral ankle. Moderate pain, swelling, point tenderness, and ecchymosis will all be present. Positive special tests will include talar tilt and positive anterior drawer.

Lateral Ankle Sprain- Grade III – There will be injury to all three lateral ankle ligaments, anterior talofibular ligament, calcaneofibular ligament, posterior talofibular ligament, to some varying degree. There will be severe pain, swelling, point tenderness and ecchymosis around the lateral malleolus. Weight bearing will not be possible. All special tests will be positive for pain and laxity.

Medial Ankle Sprain – Grade I – There will be mild pain and possible disability at the deltoid ligament. Weight bearing is minimally impaired. Point tenderness and swelling over the ligament with no joint laxity.
Medial Ankle Sprain– Grade II – There might be a disruption of the deltoid ligament. The athlete will feel or hear a pop on the lateral ankle. Moderate pain, swelling, point tenderness, and eccymosis will all be present. Special tests will be positive for pain, with no joint laxity.

Medial Ankle Sprain – Grade III – There will be severe pain, swelling, point tenderness and eccymosis around the medial malleolus and deltoid ligament. Weight bearing will not be possible. All special tests will be positive for pain and laxity.

Achilles Tendon – Grade I – The athlete will feel a slight pull of the tendon with microtears. Pain, point tenderness, and swelling might be present. There will be no loss of strength or range of motion.

Achilles Tendon – Grade II – The tendon will exhibit tearing of the fibers either within the tendon or at the tendon/bone junction. There is an increase of length in the tendon itself with a decrease in strength and range of motion. Pain, tenderness, and swelling might be present.

Achilles Tendon – Grade III – The athlete will likely rupture the tendon and pain is immediate but rapidly subsides. There will be point tenderness, swelling and discoloration superior to the heel. The tendon itself will have deformity either an indentation or a knot where the tendon rolled up into the gastrocnemius. Athlete will be unable to do toe raises and have positive Thompson’s test.
**Peroneal Tendon – Grade I** – There will be flattening of the retinaculum with no tear. Pain and swelling will be evident behind the lateral malleolus.

**Peroneal Tendon – Grade II** – There will be partial thickness split of the retinaculum, with weakness or instability of the joint; possible subluxation of the peroneal tendon. Recurrent pain, and snapping and crepitus behind the lateral malleolus are likely.

**Peroneal Tendon – Grade III** – A full-thickness split of the retinaculum with eccymosis and pain. Snapping of the peroneal tendon ill occur with active and passive range of motion.

**Ankle fracture/dislocation** – The athlete will exhibit extreme swelling and pain. There will be a possible deformity and eccymosis.

**Importance of Age and its Risks**

According to Emory\(^9,10\) age is an important factor due to the maturity of the athletes body; how well muscles are trained, and bones are ossified. Emory focuses on skeletal growth being a physiological factor in the athlete’s body. An injury is not pure trauma, but bone growth almost being a predisposal to injury. Emory also touches on the fact that growth of muscle size does not always correlate hand in hand with growth of muscle strength. Therefore, muscle imbalances commonly occur in athletes who are
undergoing physical development which can potentially lead to soft tissue injury.

It’s important to note that middle school age and high school age athletes are often grouped together. However, according to McGuine that not only with age does the body undergo develop, but the athletes gains sport related experience and knowledge. With age comes a more pronounced knowledge of the game, athletic ability, and overall better performance. Furthermore, Schultz points out that not only with experience comes more power, and performance, but the rate of secondary injuries increases also. The older the athlete gets the risk factors don’t necessarily increase but the injuries from previous years can be a factor.

A study by Leninger inquires into the question of what type of injury is more widespread in certain age groups. The authors specifically looked at soccer, but definitively conclude that as athletes get older more injuries occur of the soft tissue type. This is proposed because of the ossifying of bones making them less susceptible to trauma as the athlete grows older.

In contrast, Emery holds an opposite view that examines how an athlete’s knowledge of the game and injury grow as he/ she plays the game every day. This knowledge translates into more participation in the given sport, but a decrease in injury. This renders the athlete more aware of his/ her body and the possible pit falls and risks of injury. This concept is
noteworthy because as athletes get older they not only become larger, and more powerful, but able to protect themselves better from trauma, and hopefully learn how to avoid high risk situations for injury [20].

**Significance of Timing of Injury and its Risks**

Fatigue is an interesting factor when associating it with injury, because it is different for each athlete. Fatigue also occurs at different points in competition for each athlete. Fatigue of the body, the muscles, and the mind can all be a contributing factor to musculoskeletal injury. Beynnon suggests that reaction times play a huge role in injury prevention. Beynnon observes that injury prevention can often be aided by strength. An increase in strength can often yield a decrease in injury. Beynnon discusses the ankle more than the knee, but suggests that overall core strength may help all aspects of the body.

Timing during competition in which fatigue takes place, ie the last quarter of the game, can be a contributing factor to lower extremity injury. The muscles surrounding the ankle and knee can become tired and not provide enough support to translate the forces through the joint. When forces cannot be translated or balanced throughout the limbs and body injury is inevitable. Fatigue has been studied in a laboratory setting to a great deal,
but there is little to no research regarding fatigue and injury rate during competition.

**Competition versus Practice**

The level of competition is naturally increased in competition compared to practice in all athletes. A number of studies observe injury rates increasing in number and severity as athletes compete in games versus practice. Junge examined injuries in practice and games and found that nearly two thirds of injuries occurred during games as opposed to practices. Emery found that the intensity in competition raised injury rates six times as compared to the rate of practice injuries. Agel and Dick monitored the NCAA for 16 years looking into the surveillance of injury rates among collegiate athletics. They found that all around competition injury rates were greater, but based on sport, age, and sex they differed slightly. Their study was normalized per thousand exposures. The NBA almost doubled and tripled the NCAA when it came to competition injury rates; this influences not only competition versus practice, but age factors also. Their study detected that soccer saw a three to four times increase, basketball two times increase, and football a nine times increase in injury rate when it comes to comparing competition to practice.
Limitations

Research studies involving epidemiology always provoke some sort of limitation or drawback. Research at high schools has the obvious problem of tracking injuries due to the fact the student athletes aren’t under the Athletic Trainers supervision one hundred percent of the time. The athletes might even bypass the athletic trainer to an emergency room or primary care physician. Injuries can often go unreported or misrepresented. Socioeconomic, different athletic training educational backgrounds and environmental factors also play a role in injury rates.\(^{17}\) This specific study also only represented a small geographical area making any weather or environmental risks difficult to correlate to other parts of the country.\(^{20}\)

Summary

As stated before the research regarding high school injury rates is focused mainly on sex, sport, and taping versus bracing, very few, if any studies, have been watchful of age and fatigue. Age and fatigue are factors that have been studied extensively, but never in correlation with injury rate at the middle school and high school age levels. The data collected and inferred can foreshadow potential at risk individuals, at risks groups, and provide some substance to injury prevention. All the information gathered
can hopefully provide some insight into injury prevention at the ankle and knee to decrease the injury rate at the middle school and high school age level.
Chapter 3

Methods

Data Source

Data on high school age athletes were collected from eleven Toledo Ohio and Southern Michigan area high schools in the sports of football, volleyball, boy’s and girl’s soccer, and boy’s and girl’s basketball. Middle school age data were collected from Toledo area youth leagues in the sports of girls and boys basketball, football, and girls and boys soccer. Athletes’ ages ranged from 10-19 years of age. All data were collected by certified Athletic Trainers and provided to the primary investigator.

Procedure
Data was obtained by each athletic trainer at each high school and youth league site using a notebook of data collection forms provided by the primary investigator. The athletic trainer each week was asked to report his or her findings from the week prior regarding the injuries to the lower extremity; specifically looking at the traumatic or acute injuries to the knee and ankle. Along with the number of injuries reported from each site, the numbers of activity exposures were also reported. An exposure was defined by any player that participated on each day. Accounting for activity exposures allows the calculation of the number of injuries per exposure to be made. The following injuries were tracked: lateral and medial ankle sprains, peroneal tendon sprains, achilles tendon strains, fracture or dislocation of the ankle and knee joint, hamstring and quadriceps strains, anterior and posterior cruciate ligament injuries, medial and lateral collateral ligament injuries, patellar dislocation, and medial and lateral meniscus injuries.

**Statistical Analysis**

The data collected was input directly into SPSS 17.0 (SPSS, Inc., Chicago, IL). The number of each type of injury served as the dependent variables. The independent variables were age (middle school age, high school age), timing of injury, (1st quarter, 2nd quarter, 3rd quarter, 4th quarter) sex, and competition/practice. For sports that did not have quarters
inherent to their timing, the event was split into 4 equal parts based on the total competition time. For each dependant variable, frequency descriptives are represented according to each independent variable.
Chapter 4

Results

There were 83210 exposures overall in all ages all sexes 6170 middle school age males, 270 middle school age females, 59096 high school age males, and 17668 high school age females.

Age

Middle school age athletes had a higher injury rate (4.03 injuries per 1000 exposures) compared to high school age athletes (3.13 injuries per every 1000 exposures). When splitting the ages up according to sport, middle school age football players had 1.55 injuries per 1000, while high school age had 1.46 injuries per 1000 exposures. In soccer, middle school age girls had 0.16, middle school boys 0.62, high school age girls 0.05, and high school boys 0.30 per 1000 exposures. In basketball middle school age girls had 0.62, middle
school boys 1.09, high school age girls 0.35, and high school boys 0.87 per 1000 exposures. From these data, we can observe that middle school boy’s football and basketball had the highest injury rates. (Figure 1,5,6,7)

Timing of Injury

Overall, in the breakdown of a competition, athletes were most likely to get injured during the 3rd quarter. Together, middle school age and high school age athletes recorded 0.51 injuries per 1000 in the 1st quarter, 1.22 injuries per 1000 in the 2nd quarter, 2.08 injuries per 1000 in the 3rd quarter, and 1.28 injuries per 1000 in the 4th quarter. However, the timing of injury differed by age group. Middle school age athletes recorded 0.31 injuries per 1000 in the 1st quarter, 0.93 injuries per 1000 in the 2nd quarter, 1.86 injuries per 1000 in the 3rd quarter, and 0.93 injuries per 1000 in the 4th quarter. High school age athletes were different than middle school age athletes getting injured most likely in the 4th quarter. High school age athletes recorded 0.20 injuries per 1000 in the 1st quarter, 0.30 injuries per 1000 in the 2nd quarter, 0.22 injuries per 1000 in the 3rd quarter, and .35 injuries per 1000 in the 4th quarter. (Figure 2)
Competition/ Practice

When comparing practice injuries versus competition injuries, there were more injuries in practice. There were 1.70 injuries recorded for every 1000 practice exposures; while there were 1.50 injuries for every 1000 games exposures. (Figure 3)

Male/ Female

When comparing males versus female injury rates, males overall had a larger injury rate (5.82 injuries/1000 exposures) compared with females (1.34 injuries/1000). Comparing middle school age athletes, and high school age athletes, male middle school age athletes had the largest injury rate per 1000 exposures at 3.26 injuries for every 1000 exposures. High school age males were second at 2.60 per 1000 exposures; middle school age females were next at 0.78 per 1000, and female high school athletes were the lowest at 0.56/1000 exposures. (Figure 4)

Injuries
The most common injuries were lateral ankle sprains grades I, and II, medial ankle sprain grade I, medial collateral ligament knee sprain grade I, lateral collateral ligament knee sprain grade I, quadriceps strain grade I, and hamstrings strain grade I.

Grade I lateral ankle sprains accounted for 1.33 injuries for every 1000 in high school age athletes, and 1.71 injuries per 1000 for middle school age athletes. Grade II lateral ankle sprains represented 0.38 injuries for every 1000 in high school age athletes, and 0.62 injuries per 1000 for middle school age athletes. Grade I medial ankle sprains tallied 0.17 injuries per 1000 exposures in the high school athletes.

Grade I medial collateral ligament knee sprain were more prevalent in the middle school age athletes (0.31 injuries/1000), than the high school age athletes (0.22/1000). Grade I lateral collateral ligament knee sprain accounted for 0.12 injuries per 1000 in high school age athletes. Grade I quadriceps strains occurred in the middle school age athletes at a rate of 0.62 injuries per every 1000 exposures; while grade I hamstring strains were experienced in the high school athlete at 0.12 injuries for every 1000 exposures.

Among the 240 high school injuries, there were 160 ankle injuries, which accounted for 66.7% of all injuries. Lateral ankle sprains were most common at 57%, with 42.5% being Grade I lateral ankle sprain, 12% were
Grade II lateral ankle sprains, and 5.4% of injuries recorded were Grade I medial ankle sprains. All other ankle injuries accounted for 11% of injuries. Of these 240 injuries to high school athletes, 32% were knee injuries (n=77). Medial collateral knee ligament injuries were the most common at 9%, with 7% of those being grade I. All other knee injuries accounted for 23% of all injuries. (Figure 8,9,10,11,12,13,14,15)
Figure 1:

![Bar chart showing total number of injuries per 1000 between middle and high school.]
Figure 2:

Timing of Injury per 1000

- MIDDLE SCHOOL
- HIGH SCHOOL

Timing of Injury

# of Injuries in each Quarter (per/1000)
Figure 3:

Injuries in Practice vs. Games per 1000
Figure 4:
Figure 5:
Figure 6:

![Bar chart showing total number of injuries per 1000 exposures for different groups: Middle School Girls, Middle School Boys, High School Girls, High School Boys. The chart indicates a significantly higher rate for Middle School Boys compared to other groups.](chart.png)
Figure 7:

Injury per 1000 in Each Sport By Age

# of injuries per 1000

- MIDDLE SCHOOL GIRLS
- MIDDLE SCHOOL BOYS
- HIGH SCHOOL GIRLS
- HIGH SCHOOL BOYS

Sports:
- FOOTBALL
- SOCCER
- BASKETBALL
Figure 8:

Popular Injury Rates per 1000

# of Injuries per 1000

- ANKLE LATERAL I
- ANKLE LATERAL II
- ANKLE MEDIAL I
- KNEE MEDIAL COLLATERAL I
- KNEE LATERAL COLLATERAL I
- KNEE QUADRICEPS I
- KNEE HAMSTRINGS I

HIGH SCHOOL
MIDDLE SCHOOL
Figure 9:

![Bar chart showing popular injury rates. The x-axis represents different types of injuries such as Ankle Lateral I, Ankle Medial I, Ankle Lateral II, Knee Medial Collateral I, Knee Lateral Collateral I, and Knee Hamstrings I. The y-axis represents the percentage of each injury out of 240 total injuries. The chart indicates that Ankle Lateral I injuries are the most common, followed by Ankle Lateral II and Knee Medial Collateral I.]
Figure 10:

![Bar chart showing total number of injuries, with 'All Ankle Injuries' having a bar height reaching 160 and 'All Knee Injuries' having a bar height reaching 80.]
Figure 11:
Figure 12:
Figure 13:

![Bar chart showing the total number of injuries for different locations: Lateral Ankle, All Other Ankle, Knee ACL, Knee MCL, and All Other Knee. The chart indicates that the Lateral Ankle has the highest number of injuries, followed by All Other Knee.]
Figure 14:

Injuries per 1000 exposures

- Lateral Ankle
- All Other Ankle
- Knee ACL
- Knee MCL
- All Other Knee
Figure 15:

% Injuries of 240 total Injuries

- Lateral Ankle
- All Other Ankle
- Knee ACL
- Knee MCL
- All Other Knee
Chapter 5

Discussion

The purpose of this study was to examine how age, timing of injury, sex, and competition affected the injury rates of the lower extremity in middle school and high school age athletes. Injury and exposure rates were recorded by area athletic trainers at their places of employment during the football, volleyball, soccer, and basketball seasons. It was hypothesized that 1: Younger middle school age athletes will have a lower rate of frequency of overall injury compared with the high school age athletes, 2: Athletes will have a higher occurrence of injury during the end of competition as compared to the beginning because of fatigue factors, 3: There will be a higher rate of injury in competition versus practice, 4: High school age male athletes will have a higher incidence of injury as compared to younger male and all female athletes. While all hypothesizes were proven incorrect, important conclusions
can still be drawn that speaks to the intended purpose and significance of the study to further injury rate epidemiology.

**Age**

For a number of reasons high school age athletes were hypothesized to have a higher injury rate. While the high school athletes had a higher number of injuries, the injury rate per one thousand exposures for the younger middle school age athletes was higher than the high school age athletes. High school age athletes were thought to possess more power, and more exposures placing them at a greater risk for injury, when in fact middle school age athletes were more at risk, perhaps due to their body types, and lack of experience.\(^9,10\) The literature agrees with the fact that muscle and bone imbalances can play a large factor in age versus injury arguments.\(^9,14,15\) This discrepancy could be due to the larger number of exposures that high school age athletes get during a regular week’s practice and game schedule. Additionally, it is possible that the younger middle school age athlete’s body is more at risk for bony and soft tissue injury then one would have predicted.

Other literature suggests body imbalances, power and strength differences, but other literature fails to break down male and female, and more importantly fails to separate middle school age, and high school age athletes.\(^4,9,15,17\) The difference in experience, level of competition, sport,
intensity, body, and mind are so drastically different between the ages, that it is not to be looked over. Most studies group middle school age and high school age together as adolescents or young adults and compare them to collegiate or professional athletes. This is a problem with other studies because it does not differentiate between the younger athlete and his or her specific differences. The young athlete is a growing population, increasing by millions over the past decade, and its specific interests need to be addressed.

A solution or intervention to address the risk of injury associated with age is to first recognize which ages are most at risk. According to the results of this study it is obvious that middle school age athletes are more at risk for injury. Furthermore, it is important to develop a plan of action to educate the middle school age athletes on injury risks. Long term injury prevention programs at the middle school age level may benefit athletes and communities by reducing injury rates. Our data suggests these prevention programs may need to be implemented in the middle school population, and perhaps even in youth sports leagues or even the elementary level. Recognition leading to prevention can results in athletes developing good habits early in life, and potentially better athletes as they grow into their high school athletics where often a more intense athletic environment may exist.
Timing of Injury

Timing of injury was recorded for competition injuries only, and it was predicted that as an athlete fatigues in a game he or she will be more at risk to injury. Considering there are a number of limitations to this statement including subbing, and proper warm up rituals, the injury data recorded disproved this hypothesis for middle school age athletes, and to an extent supported it for high school age athletes. Middle school age athletes were more likely to get injured in the 3rd quarter as compared to any other quarter. This could be credited to poor warming up after half time. During half time the athletes cool down after talk with coaches, and then run back on the field to play without having an appropriate warm up or stretching session. Without the appropriate warm up the athlete’s muscles and ligaments are not prepared for the level of forces that the athlete demands. Therefore the middle school age athlete, who is already more at risk, may be increasing the risk when returning to competition in the 3rd quarter without the suitable preparation. High school age athletes supported the hypothesis that they were more likely to get injured in the 2nd and 4th quarters nearing halftime, or end of competition. High school age athletes do not fall into the 3rd quarter warm up situation because they might have more experience, and know when and how to warm up properly before participating in the intense athletic competition. The high school age athlete’s timing of injury being higher in the 2nd and 4th quarter can be supported by a fatigue factor. When the athlete
gets tired, and the body’s muscles are weakening from prolonged competition he or she becomes more at risk to injury.

The key to fixing a timing of injury problem would be education and implementation of a universal warm up and stretch for pre game and halftime. Of course pre-game and halftime warm ups will differ each along with differing for each sport, but universally each athlete will have and be required to perform the warm ups. Full community, clinician and parental involvement will be needed to implement the warm ups in the youth and elementary leagues so good habits, and awareness develop at a young age. The fact that most injuries at the middle school age are happening in the 3rd quarter suggest that coaches and athletes may not be aware that a halftime warm up program is necessary. The development of a universal warm up will help ensure athletes are well prepared before they begin activity, and may lead to a decrease in injury rates in this age group.

**Competition / Practice**

Not surprisingly the number of exposures for practices drastically outweighs those of the games. This is likely to explain the larger number of injuries seen in practices, but once normalized by one thousand exposures, practices still have a higher rate of injury than games. The hypothesis of games being more at risk then practice was based on an expected higher
intensity level and severity of the injury. We hypothesized that injuries during games would be worse than those suffered in practice, but this was not the case. In contrast to this study most other studies showed a higher rate of injury in competition than practice.\textsuperscript{12,17} Practice injuries are likely no less severe than game injuries, and the high injury rate in practice may be attributed to the fact that there are many more practices in a given season than there are games. So the intensity level has no bearing on injury rate, but who is to say that practices aren’t as intense as a game?

**Male / Female**

There was a considerable difference in the injury rates between males and females. As expected, males had a higher injury rate than females in both the middle school and high school age group. The difference in injury rates can be attributed to the differences in the sports that were incorporated into the study. For the males, football was included, which is a high contact, high impact sport; while for females, volleyball, a non-contact sport, was included. Also, it is often suggested that male sports are much more intense than that of female sports, therefore, intensity along with the level of competition; body mass, strength, power, and experience may have a bearing on the discrepancies in raw number of injuries between the sexes. The most surprising comparison of sex and injury rate was that younger males had the
highest injury rate. This could be due to the maturation of their body during the middle school age.

The literature suggests that females are the more at risk gender because of their inexperience, and body type. Emery proposes that the physiological changes in females drastically outweigh those of males, and have a higher impact on sports at the middle school and high school age level. Leninger supports the findings in this study by reporting that males have more injuries and surgeries than their counterparts, but they failed to break down middle school age and high school age, and grouped children, and adolescents together. A number of past studies did not find a difference in male and female injury rates, which may be attributed to the studies not being longitudinal enough or simply focused on one sport.

Injuries

The most popular injury in this epidemiological study was the Grade I lateral ankle sprain. This is not shocking as ankle sprains are the often reported as the most common injury in athletics. In reference to the knee, grade I medial collateral ligament sprains were the most common. Both middle school age and high school age sustained lateral grade I ankle sprain and grade I medial collateral ligament sprains, but the injuries differed across the age groups.
In addition, quadriceps injuries were more common in the younger middle school age children while hamstring injuries were more common in the high school age children. This can likely be explained as the high school athletes’ gains experience, power and strength, he or she typically develops a quadriceps to hamstring imbalance leaving the hamstrings as the weaker of the two. Ankle injuries almost doubled the knee injuries in both raw number and normalized per one thousand exposures. This is consistent with previous reports that confirm ankle sprains as the most common sport injury.

Fractures and dislocations accounted for very few of all injuries recorded in all male, female, and middle school, high school aged athletes. Fractures and dislocation can be considered a detrimental injury in most cases, which our results suggest may not be as common.\textsuperscript{14, 17}

**Clinical Relevance**

The longitudinal purpose of this study is to help medical professionals discover the implications behind injury rates and in the long run how to manage them more effectively. This study demonstrated small steps towards this goal by recording and observing the specific injury rate differences in reference to age, timing of injury, practice/competition, and sex. These four variables delve into the risk factor identifiers for injuries. Knowing that middle school age athletes are having a higher injury rate in the 3\textsuperscript{rd} quarter
and that this result may be attributed to the lack of proper re-warming up and stretching, is solid data that can be taken by a clinician and used to educate the middle school age coach in the importance of a halftime warm up.

Also, noting that middle school age athletes are overall more at risk to injury, proper protocols can be written for the younger athlete specifically. Recognizing that grade I lateral ankle sprains are the most common injuries, researchers and clinicians can now use that knowledge to develop procedures to prevent ankle injuries. Having an epidemiological study may help communities manage injuries more effectively by seeing the peaks, valleys and influxes of certain injuries, with certain sports, during certain times of year. This also helps administrators determine how much attention or need for medical personnel is required at each sport or event.

**Conclusion**

On the whole middle school aged males in the 3rd quarter are the most at risk group, with high school males closely behind. Ankle injuries far overshadow knee injuries in all variables. Future epidemiological studies need to keep examining exposure rates, along with all the factors that this study probed into. In addition to those variables, catastrophic injuries, upper extremity injuries, chronic injuries, and head injuries should begin to be incorporated in the epidemiological study. Additionally, these studies should
consider their pre participation physical and what family history risk factors that adds.

As high school and middle school participation continues to increase, injury rates will also continue to increase. Athletic trainers are going to be more in demand due to the increasing injury and liability. This study strongly implies that not only are high school athletic trainer important, but athletic trainers at the middle school age are equally as important. Epidemiological studies will also continue to track injury rates over sports, sex, age, and all variables that can be thought of. In the future protocols and high risk identifiers will be put into place that can predict high risk situations, and athletes. In turn, one would hope that injury rates could plateau for everyday common injuries.
References


Appendix A: Ankle Injury Data Sheet
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Appendix B: Knee Injury Data Sheet
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## Appendix C: Exposure Data Sheet

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