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A Prospective Design Identifying Etiological Risk Factors Associated with MTSS and Stress Fractures in Female Intercollegiate Athletes

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by

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ABSTRACT

A Prospective Design Identifying the Etiological Risk Factors Associated with MTSS and Stress Fractures in Female Intercollegiate Athletes

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Michael H. Blackburn, ATC

The identification of risk factors associated with overuse injuries, specifically Medial Tibial Stress Syndrome (MTSS) and Tibial Stress Fractures (TSF), may help professionals with management and prevention of these injuries. The purpose of this study was to identify risk factors associated with MTSS and TSF in female intercollegiate athletes. This study used a mulitifactorial, prospective design for 13-26 weeks. Thirty-nine Division I intercollegiate female student-athletes in volleyball, soccer, and track were examined. Anatomical, physiological (eating disorder and menstrual history), and training (duration and recovery time) characteristics were examined as possible risk factors. Only two injuries were reported during the study; therefore, analysis for risk factors was not possible. Descriptive statistics for the dependent variables were calculated, and comparisons across sport were performed. Differences in leg length values and dorsiflexion ROM were observed across sports. No conclusions could be drawn regarding possible risk factors for MTSS and TSF in this population.

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CONTENTS

Page

Chapter

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Approximately, 10 million Americans run on a daily basis and many sustain an overuse injury in the lower extremity (Gellman & Burns, 1996). The incidence of overuse injuries in the lower extremity ranges from 30% to 76% in athletic and military populations (Bennell & Crossley, 1996; Jones et al., 1993; Wen et al., 1998). These injuries occur when the applied loads are greater than the loads the tissues can handle. The tissues usually weaken due to inadequate recuperation time for the tissues to remodel after activity, resulting in microtears to the tissues. Examples of lower extremity overuse injuries include shin splints, medial tibial stress syndrome (MTSS), stress fractures, and Achilles tendonitis. In a review of the literature, Bates (1985) stated that MTSS might be responsible for 10-15% of all running injuries and 60% of the lower leg pain in athletes.

The incidence rates reported for MTSS and shin splints range from 3.1% to 13% in the military and athletic populations (Bennell & Crossley, 1996; Cowan et al., 1996; James, Bates, & Osternig, 1978; Kaufman, Brodine, Shaffer, Johnson & Cullison, 1999). MTSS may result in a stress fracture if the amount and intensity of training are not diminished once the individual is diagnosed with MTSS. The incidence rates reported for tibial stress fractures (TSF) are much higher than MTSS, ranging from 5% to 50%, with many of these studies using military populations (Bennell & Crossley; Bennell, Malcolm, Thomas, Reid et al., 1996; Bennell, Malcolm, Thomas, Wark, et al., 1996; Cowan et al., 1996; Giladi, Milgrom, Simkin, & Danon, 1991; Kaufman et al.). The wide range of incidence rates reported in the literature for MTSS and TSF may be due to differences in research design, population, definitions of the conditions, or diagnostic procedures. Two theories have been proposed that postulate that MTSS and TSF may lie on continuum.

Soft tissue inflammation (periostitis) and bone remodeling theories could play a role in the development of MTSS and stress fractures. Michael and Holder (1985) proposed that as the medial one half of the soleus eccentrically contracts during pronation of the foot, it might result in a periostitis over time. These contractions could fatigue the soleus and result in decreased dissipation of forces. Beck (1998) proposed the bone remodeling theory, which stated that osteoblasts and osteoclasts are equal during normal remodeling. However, when MTSS and stress fractures are present, the osteoclasts are greater than the osteoblasts due to increased bone stresses, which may lead to MTSS and ultimately a TSF.

The literature has reported the etiology of MTSS and TSF as anatomical, biomechanical, physiological (diet and menstrual cycle), and/or training. The anatomical risk factors identified in the literature contributing to general overuse injuries in the lower extremity are flexibility deficits in the hamstrings and gastroc-soleus complex, pes planus, excessive pronation, and increased subtalar range of motion (ROM) (Donatelli et al., 1999; Hreljac, Marshall, & Hume, 2000; Kaufman et al., 1999; Wen et al., 1999). For MTSS, the anatomical risk factors identified are similar to those for overuse injuries, with the addition of varus alignment of the forefoot and hindfoot (DeLacerda, 1980; Lillevedt & Kreighbaum, 1976; Messier & Pittala, 1988; Sommer & Vallentyne, 1995; Viitasalo & Kvist, 1983). However, most of these studies used retrospective designs, which cannot best determine the risk factors associated with MTSS or shin splints. Many of the anatomical risk factors identified for TSF are the similar to MTSS, with the addition of increased external rotation of the hip and a narrow tibial bone width (Beck et al. 1996; Bennell, Malcolm, Thomas, Reid et al., 1996; Bennell, Wrigley, & Oakes, 1999; Giladi et al., 1991; Montgomery, Nelson, Norton, & Deuster, 1989). Most of these studies have used a prospective design, which is deemed more appropriate for identifying risk factors for lower extremity overuse injuries.

Very little research has focused on the biomechanical factors associated specifically with MTSS or stress fractures. The focus has been primarily on overuse injuries. Some studies report significant increases in the maximum pronation during running and the velocity of pronation in injured athletes with overuse injuries (Gehlsen & Seger, 1980; Hreljac et al., 2000; Messier & Pittala, 1988). Such findings may further substantiate the theory that the medial soleus eccentrically contracts as the foot pronates during gait, which could lead to an increased traction of the soft tissue attached to the tibia (Michael & Holder, 1985). Previous research also identifies the magnitude and of impact loading and the magnitude of the active peak as possible factors, although these were not significantly different between injured and uninjured (Crossley et al., 1999; Hreljac et al.).

The physiological variables identified in the research as possible risk factors for stress fractures in females are decreased total and tibial bone mineral density (BMD), menstrual history disturbance, and dietary issues (Beck et al., 1996; Bennell et al., 1995; Bennell, Malcolm, Thomas, Reid et al., 1996; Giladi et al., 1991; Winfield, Moore, Bracker, & Johnson, 1997). These factors were identified with prospective and retrospective studies. The risk factors associated with stress fractures in males are decreased tibial and femoral BMDs (Beck et al.). No physiological risk factors have been identified for MTSS in males or females.

Training variables may be associated with development of MTSS or stress fractures, but little evidence exists to substantiate this hypothesis. Interval training and changing shoes has also been associated with increased shin injuries (Wen et al., 1998). Two studies also observed a decreased running mileage per week prior to the study in male and female military trainees with stress fractures (Montgomery et al., 1989; Winfield et al., 1997). Conversely, five studies did not note any differences in training variables between injured and uninjured groups (Bennell & Crossley, 1996; Bennell, Malcolm, Thomas, Reid et al., 1996; Bennell, Malcolm, Thomas, Wark et al., 1996; Hreljac et al., 2000; Messier & Pittala, 1988; Wen et al.). The discrepancy for training variables may have occurred because all of these studies used retrospective designs using an interview or survey at the beginning or end of the study. These designs rely on the subject's memory, so inaccurate information may be given compared to prospective designs.

In summary, much of the research to date has focused on overuse injuries in general, but few studies have concentrated on MTSS or stress fractures. The research on MTSS has examined primarily anatomical and biomechanical factors, while stress fracture research has examined primarily anatomical and physiological factors. Since these conditions are multifactorial in nature, all of these factors need to be investigated using prospective designs (Bennell, Matheson, Meeuwisse, & Brukner, 1999).

Statement of the Problem

The purpose of this study was to identify the etiological risk factors that might contribute to MTSS and tibial stress fractures in female intercollegiate athletes using a prospective design. Only one study has used a prospective design to examine the risk factors associated with shin splints, but none has specifically examined MTSS (DeLacerda, 1980). Prospective designs have been more commonly used in stress fracture research, with four of the six studies using this design to identify possible risk factors (Bennell, Malcolm, Thomas, Reid et al., 1996; Giladi et al., 1991; Montgomery et al., 1989; Winfield et al., 1997). The previous research on MTSS and stress fractures examines only one of these conditions, but this study will examine the risk factors associated with MTSS and TSF since these conditions may lie on a continuum. This study was the first to examine more than one athletic population (soccer, volleyball, track/field, and cross-country). In addition, this study also used measurements that are clinically useful while maintaining the multifactorial approach to identify the possible risk factors associated with MTSS or TSF.

The dependent variable in this study was the injury status - development of MTSS or TSF during the duration of the study. The independent variables assessed were the following: the dorsiflexion ROM, leg length discrepancy, amount of pronation, knee alignment, EAT-26 test score, onset of menarche, number of menstrual cycles in the past year, duration of training, and recovery time between sessions.

Significance of the Study

Little is known about the etiologic factors associated with MTSS and stress fractures. The factors that have been suggested by previous research are flexibility deficits of the gastroc-soleus complex, narrow tibiae, decreased bone mineral density, increased subtalar ROM, and increases in pronation values (maximum pronation and velocity of pronation). The identification of risk factors would help physical therapists, doctors, and athletic trainers in the management and prevention of MTSS and stress fractures. Athletic trainers already typically tape arches, recommend orthotics, and encourage stretching among athletes who have MTSS, but these are just anecdotal in nature. There is little evidence that these treatments will work. Therefore, the identification of risk factors associated with MTSS and stress fractures will help improve the management and treatment of this condition by physical therapists, doctors, and athletic trainers.

Research Hypotheses

The research hypothesis of this study is that subjects who develop MTSS or stress fractures throughout the duration of the study will display different values in the independent variables compared to the subjects who do not develop MTSS or stress fractures. The subjects developing MTSS or TSF would have the following:

H_{a1}: These subjects will have different navicular drop scores.

H_{a2}: These subjects will have different dorsiflexion ROM.

H_{a3}: These subjects will have decreased number of cycles per year and a later onset of menarche.

H_{a4}: These subjects will have different average training durations and recovery times.

H_{a5}: These subjects will have different leg length discrepancy values.

H_{a6}: The knee alignment will be different in these subjects.

$H_{a7:}$ The EAT-26 test scores will be different.

Assumptions

The following assumptions were made for this study:

1) The subjects were honest about their training habits and menstrual history on the questionnaire.
2) Static and dynamic measurements of the lower extremity were related to each other.

Limitations

The limitations recognized by the researcher that may have affected the results of the study are listed below:

1) These subjects were volunteers from local colleges and universities. Volunteers presented threats to the internal validity of this study.
2) Competition levels differ among subjects and may have affected the development of MTSS or stress fractures in this study.

Delimitations

Approximately, 100 female volunteer student-athletes from East Tennessee State University, Milligan College, and Tusculum College served as subjects for this study. The subjects ranged from 18-22 years of age. In addition, these subjects participated in intercollegiate athletics without a lower extremity injury in the last three months and without a history of stress fractures or other fractures to the lower extremity. More specifically, the volunteers participated in cross-country, track, soccer, or volleyball at their respective institutions. The following dependent variables were assessed prior to pre-season practices: the amount of dorsiflexion ROM, leg length discrepancy, amount of static pronation, knee alignment, EAT-26 test, and menstrual history. Data regarding duration of training and recovery time between sessions was obtained throughout the competitive season. This study used a prospective design lasting from 13 to 26 weeks. The subjects were advised not to change their extracurricular activities outside of intercollegiate activities during the duration of the study.

Operational Definition of Terms

In this study, the following terms were operationally defined:

1) Medial tibial stress syndrome (MTSS): pain that is localized in the distal 1/3rd of the posteromedial border of the tibia believed to occur from repetitive running or jumping persisting at least two weeks.
2) Tibial stress fractures: pain that is very tender at specific points along the tibia believed to occur from repetitive running or jumping persisting at least two weeks.
3) Injury: requires treatment from an athletic trainer or physician and interruptted the subject's normal daily routine.
4) Excessive pronation: a navicular drop score of greater than 10-mm.
5) Leg length discrepancy: a difference of 1.5 cm between right and left legs.
6) Q-angle: the angle formed by a line from the ASIS to the midpoint of the patella and a line from the tibial tubercle to the midpoint of the patella.
7) A-angle: the angle formed by a line through the center of the patella and a line from the tibial tubercle to the apex of the inferior pole of the patella.
8) Leg length: measurement from ASIS to medial malleolus.
9) Navicular drop: distance navicular falls between non-weight bearing and weight bearing positions.
10) Observational knee alignment: visual observation and classification of varus, valgus, or same depending if the knee or ankles touch.
11) Onset of menarche: when a female starts her menstrual cycle.
12) Duration of training: length of time an individual is actively practicing.
13) Recovery time: length of time between practice sessions.
14) EAT-26 test: test used to determine if eating disorders or a preoccupation with weight are present.

CHAPTER 2

REVIEW OF LITERATURE

There is an abundance of literature reporting the risk factors for general overuse injuries; however, little research has specifically examined these factors in MTSS and stress fractures. The purpose of this study will be to identify the etiological risk factors that may contribute to MTSS and tibial stress fractures in female intercollegiate athletes. This chapter will discuss the following: (a) incidence rates for overuse injuries of the lower extremity, (b) etiology of MTSS and tibial stress fractures, and (c) identification of the risk factors for MTSS and stress fractures.

Incidence Rates for Overuse Injuries of the Lower Extremity

Overuse injuries occur when the applied loads are greater than the loads the tissues can handle. This imbalance may occur due to inadequate recovery time for the tissues to rebuild prior to the next bout of exercise. The normal bone remodeling process cannot transpire due to the lack of recovery between training periods. This may weaken the bones since ideal remodeling does not occur. Patellar tendinitis, iliotibial band stress syndrome, MTSS, stress fractures, and compartment syndrome are examples of overuse injuries in the lower extremity. These chronic injuries affect athletes and non-athletes alike.

Previous research reports incidences of overuse injuries ranging from 11% to 33% in the military populations (Cowan et al., 1996; Montgomery et al., 1989; Jones et al., 1993; Kaufman, et al., 1999) and 35% to 76% in athletic populations (Bennell & Crossley, 1996; Wen et al., 1998). The incidence rate reported in the military and athletic populations for MTSS range from 4% to 14% (See Table 1). The incidence of stress fractures is much higher than MTSS and ranges from 5% to 50% in the military and athletic populations, with the majority occurring in the tibia (See Table 2) The authors who examined the military populations have used prospective designs lasting 12-weeks to 2 years.

Table 1
Incidence Rates of MTSS and Shin Splints in the Military and Athletic Populations

Study (year)	James et al. (1978)	Bennell & Crossley (1996)	Bennell & Crossley (1996)	Cowan et al. (1996)	Kaufman et al. (1999)
Population	Runners (N=180)	Runners (Male/female) (*n*=54)	Sprinters (Male/female) (*n*=27)	Male military trainees (N=294)	Male military trainees (N=449)
Design	Retrospective	Retrospective	Retrospective	Prospective	Prospective
Data collection technique	Clinic	Interview	Interview	Monitor	Monitor
Incidence Rates (%)	13%	13.6%	5%	4%	4%

Table 2
Incidence Rates of Stress Fractures in Female and Male Athletes and Military Trainees

Study (year)	Bennell et al. (1996)	Bennell et al. (1995)	Winfield et al. (1997)	Jones et al. (1993)	Kaufman et al. (1999)	Giladi et al. (1991)
Population	Track and field athletes (N=101)	Track and field athletes (N=53)	Military trainees (N=101)	Military trainees (N=391)	Military trainees (N=449)	Military trainees (N=312)
Design	Pro	Retro	Pro	Pro	Pro	Pro
Observation period	12 months	Previous history	10 weeks	8 weeks	25 weeks	14 weeks
Rates						
Female:	21.7%	41.5%	11.5%	12.3%	--	--
Male:	20.4%	--	--	2.4%	9%	45%

Note. Pro: Prospective design; Retro: Retrospective design

The large variability in the reported incidence rates for MTSS or TSF may be due to differences in the research design, population, definitions of the conditions, or diagnostic procedures. A retrospective design does not obtain the true incidences because these designs use interviews or past medical history for diagnosis. Compared to a prospective design, these procedures probably falsely inflate these rates due to reliance on subject's memory. Prospective designs use physicians and instrumentation for diagnosis and confirmation of the conditions. For example, Bennell et al. (1995) reported a rate of 42% in a retrospective study using interviews; however, Bennell, Malcolm, Thomas, Wark et al. (1996) reported an incidence rate of only 22% in these same athletes using a prospective design in which the athletes were monitored for injury. Therefore, the design chosen may account for the large variability in the incidence rates (See Table 2). Another reason for the variability in these rates is the population that is examined. The rates for athletes may be underreported because athletes typically do not report injuries unless their performance is affected. Conversely, the military populations may report higher rates due to footwear or training habits as compared to the athletic population. The variability in the rates may also be due to different definitions or terminology for these conditions between studies. For example, if a researcher identifies MTSS as shin splints, more subjects may develop the condition because it is a generic term. Higher rates may be reported with stress fractures than MTSS, because these conditions may lie on a bone-stress failure continuum, and are not diagnosed until a stress fracture is present (Batt, 1995; Beck, 1998; Knapp, Mandelbaum, & Garrett, Jr., 1998). MTSS and stress fractures are mild and severe on this continuum, respectively.

Etiology of MTSS and Tibial Stress Fractures

It is generally hypothesized that injuries occur when the applied loads are greater than the loads the tissues can handle. In the case of overuse injuries, the loads are of small magnitude but repetitive and cause microtears in the soft tissues. Individuals will incur an overuse injury when the repetitive loads are larger or more frequent than normal or when the tissues are weakened due to physiologic or structural abnormalities. The direction of the load application is critical for the dissipation of the impact forces applied to the lower extremity. When structural malalignments exist, the direction of the loads may not be applied in their normal directions, resulting in load absorption in directions that are not ideal for the involved tissues. To better understand the etiology of MTSS and stress fractures, appropriate terminology and anatomical structures affected in MTSS and stress fractures will be reviewed. Then, specific theories of the etiology of MTSS and stress fractures will be presented.

Terminology

The terms MTSS and shin splints are used interchangeably in the research for the diagnosis of lower leg pain. However, these injuries are very different from each other in their location and etiology. Shin splints are a “catchall” term for any exercise-induced lower leg pain. Other etiologies that fall into the shin splints classification are compartment syndromes, tendinitis, and periostitis. The location of shin splints is not specific, but usually includes the anterolateral and posteromedial aspects of the tibia (Batt, 1995). Strain in the tibialis posterior, flexor digitorum longus, and flexor hallicus longus located in the deep posterior compartment have been hypothesized as a possible cause of shin splints due to excessive plantarflexion and inversion of the foot during running that may result in inflammation of this musculature (Moore, 1988). Researchers have attempted to use MTSS when reporting pain that occurs in the distal one third of the posteromedial tibia, but shin splints are still used to denote exercise-induced lower leg pain not attributed to stress fractures or compartment syndrome (Kortebein, Kaufman, Basford, & Stuart, 2000).

MTSS is the preferred term by some researchers to describe lower leg pain due to exercise since it denotes a specific location, gives possible etiology, and is less confusing than shin splints (Jones & James, 1987; Kortebein et al., 2000). Mubark, Gould, Lee, Schmidt and Hargen (1982) first described this terminology. The location of MTSS is the distal one third of the posteromedial border of the tibia. Consistent use of MTSS will allow risk factors and pathology to be identified because of its specificity to location. However, Batt (1995) states that MTSS is also a generic term since there are no specific conditions stated with this terminology.

The location and intensity of the pain are used to diagnose MTSS and tibial stress fractures. The pain with MTSS is very diffuse and tender along the distal posteromedial one third of the tibia, but a stress fracture is point tender to specific locations along the tibia, with the pain being intense. Another difference between MTSS and stress fractures is that the activities of daily living (ADLs) are not affected much in MTSS compared to stress fractures. Sleeping patterns can be affected by stress fractures due to the focal pain.

Anatomy

The lower leg is divided into four compartments: the anterior, deep posterior, lateral, and superficial posterior compartments. Moore (1988) stated that the anterior and deep posterior compartments were associated with shin splints. The anterior tibialis, extensor digitorum longus, and extensor hallucis longus are contained in the anterior compartment. These muscles are recruited during dorsiflexion and inversion of the foot. The deep posterior compartment contains the posterior tibialis, flexor digitorum longus, and flexor hallicus longus. These muscles are recruited during plantarflexion and inversion of the foot. The superficial posterior compartment contains the triceps surae muscles (gastrocnemius and soleus). Plantarflexion is the primary role of these muscles. The peroneus longus and brevis are located in the lateral compartment, which are responsible for eversion and assisting with plantarflexion of the foot. The peroneus tertius is also located in the lateral compartment and responsible for eversion; however, it assists with dorsiflexion of the foot.

The posterior tibialis, anterior tibialis, flexor digitorum longus, and soleus are the muscles that may be affected by MTSS. The posterior tibialis and flexor digitorum longus originate on the upper posterior one half of the tibia and insert under the foot on the second to fifth metatarsals. In addition, the posterior tibialis inserts on the navicular and cuneiforms to help support the arch. The anterior tibialis may also help support the arch because this muscle inserts on the medial cuneiform and first metatarsal. The soleus originates on the posterior two thirds of the tibia and fibula and inserts on the calcaneus (Thompson & Floyd, 1994).

The medial longitudinal arch attaches on the calcaneus and medial metatarsals including the navicular and cuneiforms. Kaufman et al. (1999) reported that the plantar fascia, spring ligament, and plantar ligament help maintain the medial longitudinal arch. In addition, the cuneonavicular and cuneometatarsal ligaments might also help support the arch (Hartley, 1995). These ligaments, in addition to the posterior tibialis, anterior tibialis, and flexor digitorum longus provide support to the medial longitudinal arch (See figure 1).

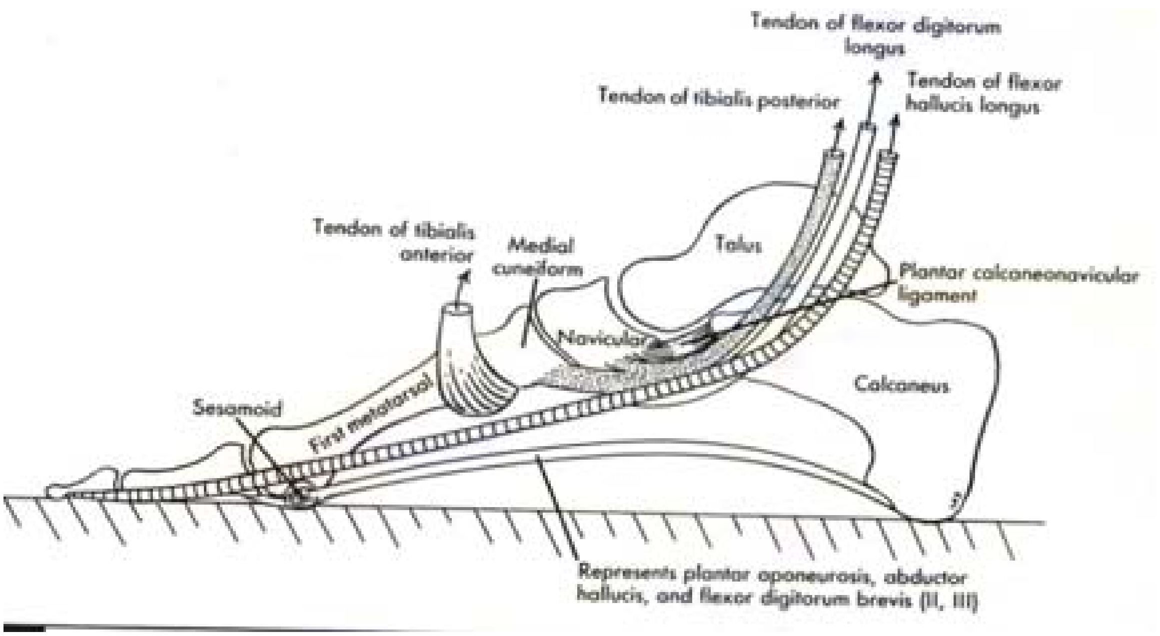

Figure 1
Muscular and ligamentous structures supporting the medial longitudinal arch (Source: Magee, 1992).

Excessive pronation has been identified as a risk factor for MTSS because it may affect how the loads are distributed in the lower extremity (Hintermann & Nigg, 1998). Pronation of the foot is a mechanism that is responsible for dissipating forces in the lower extremity by increasing the impulse. Messier and Pittala (1988) reported that an increased maximum pronation and velocity of pronation were possibly associated with the development of shin splints. The ankle musculature may also play a part in the dissipation of forces since the speed of pronation needs to be moderate to decrease overuse injuries. For example, an individual with excessive pronation in a static position and abnormal strength ratios may not be able to efficiently dissipate the loads dynamically, due to the increased pronation prior to activity. However, an individual with a normal amount of pronation and normal strength ratios may dissipate the loads more efficiently, due to an increased impulse. The excessive pronation may cause the tissues to absorb the extra stresses from impact, which eventually may result in MTSS.

Etiology

The anatomical structures that have been hypothesized in the etiology of MTSS are the soleus, flexor digitorum longus, posterior tibialis, and deep crural fascia. These soft tissue structures are proposed to be associated with MTSS due to their attachment in the distal one-third of the posteromedial tibia. Previous research, using cadaver studies, has reported contradictory results regarding the proximal attachment of the posterior tibialis and soleus. Saxena, O'Brien, and Bunce (1990) reported that the posterior tibialis originated most distally, about 8-cm proximal to the medial malleolus, and no soleus attachment was observed in the distal one third of the lower leg. They also noted that the posterior tibialis and flexor digitorum longus crossed about 8-cm proximal to the medial malleolus. However, they only dissected 10 legs, which may not be a large enough sample to draw this conclusion. Conversely, Beck and Osternig (1994) dissected 50 lower leg cadavers and found that the posterior tibialis did not attach where MTSS occurs but rather more laterally on the tibia. The authors concluded that the soleus, flexor digitorum longus, and the deep crural fascia were the muscles involved with the etiology of MTSS because these muscles attached in the distal one third of the tibia. Michael and Holder (1985) noted that the soleus originated approximately 4-inches proximal to the medial malleolus. They obtained these findings after performing 28 dissections, EMG studies on 10 subjects (two with MTSS), and an open biopsy. The biopsy included removing a portion of the soleus from the medial tibia and a bone biopsy from a subject with a stress fracture. They only examined the medial half of the soleus while passively inverting and everting the hindfoot for EMG analysis. They concluded that the medial aspect of the soleus originates along the distal one third of the posteromedial tibia and inserts on the medial one third of the calcaneus. They also concluded that the medial soleus is a dominant plantarflexor and invertor, which is recruited during pronation of the foot.

Several theories have been proposed regarding the etiology of MTSS and stress fractures. Early researchers proposed that MTSS was a compartment syndrome; however, in 1982, Mubark et al. provided evidence that it was a periostitis and not a compartment syndrome. Compartment syndrome occurs when the pressures in the compartments increase during activity, which causes pain and numbness in the lower leg (James & Jones, 1987). Mubark et al. measured the intramuscular pressures in the posterior and deep posterior compartments while subjects with severe MTSS dorsiflexed and plantarflexed their ankle using an Orthotron. They concluded that MTSS was periostitis because the intramuscular pressures were within normal limits.

In 1985, Michael and Holder proposed that MTSS results from the eccentric contraction of the medial one half of the soleus when the foot moves from supination to pronation. The authors postulated that in individuals with excessive pronation this eccentric contraction might fatigue the soleus and result in fewer forces being dissipated. This fatigue could result in decreased shock absorption in the musculature and may lead to a stress fracture over the long-term because these forces are not dissipated.

A third theory, bone remodeling, was proposed by Beck in 1998. According to this theory, the stresses applied to the bone can result in an increase in bone resorption (osteoclast production). Wolf's Law states that the tissues will adapt to the stresses placed on them, which results in an increase amount of stress tissues can handle before injury occurs. In the normal process of bone remodeling, the production of the osteoblasts and osteoclasts is fairly equal. However, when MTSS or a stress fracture is present, there are more osteoclasts than osteoblasts due to the abnormal bone remodeling and thus, repair of the periosteal damage cannot occur. A stress fracture may occur if an athlete continues to load the tissues at the same rate without any rest.

Identification of Risk Factors for MTSS and Stress Fractures

Though it may be ideal to conduct experimental studies to determine the causative mechanisms that underlie injury, it is seldom practical or feasible to do so. Instead, epidemiological studies are designed to identify risk factors that may predispose individuals to athletic injuries. The identification of risk factors can provide a basis for early screening of athletes and may provide insight about the mechanistic nature of these conditions. If risk factors are established for MTSS and stress fractures, athletic trainers, physical therapists, and doctors may be able to prevent and improve the management of these conditions. An example would be a lower extremity screening that utilizes the main predictors of these conditions, enabling health professionals to possibly determine who may develop these conditions. New instruments or techniques for management of these conditions may also be developed as a result of the identification of these factors. The two designs used to examine injury etiology and identify risk factors are retrospective and prospective designs. The retrospective design performs tests or measurements on the subjects with and without the condition at the present time. However, this design does not obtain incidences and true correlations between individuals, because the measurements obtained may be different between individuals with and without the conditions due to presence of the condition. In prospective designs, the subjects start at the same baseline and are followed into the future to determine the etiologic nature of the condition, depending on the development of the conditions. The prospective design allows for the calculation of incidence rates and correlations of risk factors to the conditions, in this case MTSS and stress fractures (Bennell & Bruckner, 1997; Neutens & Robinson, 1997). Neutens and Robinson also stated that this design allows for better control of quality during the study compared to a retrospective study. Previous literature has used retrospective and prospective designs and has reported the risk factors for overuse injuries as anatomical, biomechanical, physiological, and training variables.

Retrospective Studies

The majority of the research on MTSS or shin splints has used this design because it is less time-consuming and requires fewer subjects. The anatomical factors that have been identified consistently with this design are excessive pronation (static), increased subtalar ROM, and decreased tibial bone width. Lillevedt and Kreighbaum (1976) and Viitasalo and Kvist (1983) reported excessive pronation in athletes using a weight bearing position of the lower leg and in relation to the heel. Both of these studies used athletes with and without shin splints. Sommer and Vallentyne (1995) reported similar findings using the Feis line and subtalar neutral tests on dancers. They reported a Feis line measurement of less than 140° was associated with MTSS. An increased passive subtalar ROM was also noted with goniometry (Lillevedt & Kreighbaum; Viitasalo & Kvist). Lillevedt & Kreighbaum also reported no differences in hamstring flexibility, internal rotation of the hip, and eversion of the ankle between subjects with and without shin splints. Only one study reported narrower tibiae in male athletes with stress fractures that the CT scans confirmed (Crossley et al., 1999).

Some researchers have also found lower leg strength to be associated with shin splints in athletes. Gehlsen and Seger (1980) reported increased plantarflexor strength values in athletes with shin splints ($p<0.05$). They obtained the plantarflexion, dorsiflexion, inversion, and eversion ankle strength measures by using a cable tensiometer with the ankle at 90°. In an abstract by Welker (1997), differences were reported in ankle strength, but the muscles groups were not stated. The Biodex was used to obtain the plantarflexion, dorsiflexion, inversion, and eversion strength values at speeds of 60°/s, 90°/s, and 120°/s. Conversely, no difference was reported in the endurance and peak torque of the plantarflexors in male athletes with and without stress fractures (Ekenman, Tsai-Fellaner, Westbland, Turan, & Wolf, 1996). The subjects performed 100 hundred maximal concentric contractions on a Biodex at a 60°/s to obtain these measurements. A physician's diagnosis and a bone scan were used to confirm the stress fractures in the subjects. The authors also reported no differences in ankle ROM, flexibility of the quadriceps, hamstrings, and hip flexors, or gait analyses between the subjects.

Five studies have investigated the biomechanical factors associated with overuse injuries of the lower extremity (Donatelli et al., 1999; Gehlsen & Seger, 1980; Hreljac et al., 2000; Kaufman et al., 1999; Viitasalo & Kvist, 1983). However, no one has examined MTSS, and only Crossley et al. (1999) have specifically examined stress fractures. The biomechanical factors identified retrospectively are excessive rearfoot movement, increased maximum pronation, and increased maximum pronation velocity. Gehlsen and Seger and Viitasalo and Kvist reported differences in rearfoot movement between athletes with and without shin splints. These groups used the Achilles tendon angle dynamically to obtain the amount of rearfoot movement. Gehlsen and Seger filmed the subjects at 100 Hz while they ran at two speeds with and without shoes. They concluded that as the speeds increased and shoe conditions changed, the amount of angular displacement increased in the shin splint group. Messier and Pittala (1988) also observed an increased maximum pronation and maximum pronation velocity in athletes with shin splints. They filmed the subjects at 100 Hz while running at their training paces, but these speeds were not reported. Conversely, Hreljac et al. reported no differences in maximum pronation and maximum pronation velocity in athletes.

An increased vertical loading rate and impact peak has also been observed in athletes with overuse injuries (Hreljac et al., 2000). These measures were acquired with a camera film speed of 120 Hz and a force platform. The subjects ran over the force platform at 4 $m \cdot s^{-1}$ without altering their technique. The authors concluded that decreasing vertical impact and having a moderate rate of pronation might reduce the athletes' risk of sustaining an overuse injury. Conversely, Crossley et al. (1999) found no differences in ground reaction forces (GRFs) in male athletes with and without stress fractures. They obtained these GRFs (vertical and horizontal) by having the subjects run over the force platform at 4 $m \cdot s^{-1}$.

Several retrospective studies have examined the physiological factors associated with stress fractures, but none of these factors have been examined for MTSS. For stress fractures, these studies have identified a history of menstrual disturbances and dietary concerns as risk factors in females. Bone mineral densities in males and female athletes were also examined, but no differences were reported between groups. Lower bone mineral densities were observed in females and males athletes with stress fractures, but the difference was not significant (Bennell et al., 1995; Crossley et al., 1999). These groups used DEXA to obtain the total and lower limb BMDs. Bennell et al. (1995) concluded that a history of oligomenorrhea and a preoccupation with weight might predict stress fractures in female track athletes. Questionnaires were used to obtain the history of menstrual disturbances and dietary issues between the groups. A later onset of menarche and a decreased number of cycles per year were associated with development of a stress fracture.

Previous research using retrospective designs has not noted any differences in training variables between groups (Bennell & Crossley, 1996; Messier & Pittala, 1988). Bennell and Crossley interviewed the subjects on these same training variables after a 12-month study. Messier and Pittala used a questionnaire to obtain the weekly distances, type of training, and footwear worn by the subjects during training sessions prior to the study. Although no differences have been reported for training variables, the variables that have been proposed in the literature are the duration of training, recovery time between sessions, surface, experience, footwear, and mileage per week.

Prospective Studies

The research on stress fractures has mainly used a prospective design, with very little research on MTSS using this design. The anatomical factors that have been identified with this design are an increased Q-angle, increased external rotation (ER) of the hip, decreased lower leg musculature, and decreased tibial bone width. Cowan et al. (1996) reported an increased Q-angle, but no differences in leg length discrepancy or genu recurvatum in the trainees with shin injuries. Photographs were taken in static positions with markers on the knee, hip, and ankle landmarks. The angles of the joints were obtained through digitization of the markers. These trainees were followed for 12 weeks for the development of overuse injuries. Conversely, another study reported that the Q-angle was not different among females with and without stress reactions (Winfield et al., 1997). This measurement was obtained using a goniometer measuring the angle formed by the intersection of two lines (ASIS-central patella and central patella-tibial tubercle). They also noted no differences in passive subtalar ROM between these subjects. These female trainees were followed for 10 weeks for stress reactions (stress fractures).

The possible association of an increased ER of the hip and stress fractures was investigated by three groups of researchers. Giladi et al. (1991) examined tibial torsion, ankle ROM, and IR/ER of hip, noting only an increased ER of the hip in military trainees with stress fractures after a 14-week study. The ER measurement was obtained using a large protractor while the subject rotated their flexed hip in the supine position. Conversely, a couple of studies did not find differences in the ER measurements in the military and athletic populations (Bennell, Malcolm, Thomas, Reid, et al., 1996; Montgomery et al., 1989). Bennell, Malcolm, Thomas, Reid, et al. (1996) used a gravity goniometer to attain their ER measurement; however, Montgomery et al. used a rigid goniometer while the hip was extended and the subject was prone. Although ER was not different, Bennell, Malcolm, Thomas, Reid, et al. reported a decreased musculature in the lower leg in the females with stress fractures, which was the only study that examined this factor. This measurement was obtained using DEXA to measure the soft tissue in the lower extremity. The authors speculated that by having less musculature in the lower leg, the stresses applied to the bone during exercise might not be dissipated. Some of the anatomical factors found not to be significantly different between the subjects in previous research were the IR of the hip, knee alignment, flexibility of the quadriceps, hamstring, and gastroc-soleus complex, and foot type (cavus/planus) (Bennell, Malcolm, Thomas, Reid, et al.; Montgomery et al.).

A narrow tibial bone width has been associated with stress fractures in this design. These studies have examined this factor in military populations but have used different techniques to acquire the measurements. Giladi et al. (1991) reported significantly narrower tibiae in trainees with stress fractures that were measured with an x-ray. The narrowest point of the tibia was measured in the frontal and lateral planes of the x-rays to obtain this measurement. More recently, Beck et al. (1996) noted a narrower tibia and femur in trainees using DEXA. The distal one third of the lower leg and the middle of the femur were the points scanned with DEXA. Even after the tibial bone width was adjusted to body weight, the width was still significantly different between the groups.

The physiological factors that have been identified prospectively are decreased bone mineral density, history of menstrual disturbances, and diet issues. Beck et al. (1996) and Bennell, Malcolm, Thomas, Reid, et al. (1996) noted a decreased BMD in athletes and military trainees, respectively, using DEXA. Beck et al. reported lower BMDs in the tibiae and femurs in male trainees. Bennell, Malcolm, Thomas, Reid, et al. reported a significantly lower total and tibial BMD in female track and field athletes. In a review by Cameron, Wark, and Telford (1992), the authors stated the BMD should be measured at the location where the stress fractures occur.

Two studies noted a history of menstrual disturbances in athletes and trainees with stress fractures (Bennell, Malcolm, Thomas, Reid et al., 1996; Winfield et al., 1997). These authors also examined whether birth control use was associated with stress fractures and found no differences between groups. A questionnaire was used by these authors, to determine that a later onset of menarche and decreased cycles during the year were associated with development of stress fractures. Other factors such as diet and body composition may also play a role in menstrual history disturbances (Cameron et al., 1992). Bennell, Malcolm, Thomas, Reid et al. reported a significantly lower intake of fat in the female subjects sustaining a stress fracture after a four-day dietary recall. Although a decreased fat intake was observed, no differences were observed in the EAT-40 test scores or calcium intake. The EAT-40 test can identify athletes with preoccupation with food or weight and eating disorders, such as anorexia nervosa.

This design has been used to identify some significant training variables associated with MTSS or stress fractures. Wen et al. (1998) reported that runners performing interval training and changing shoes were associated with shin injuries. Running distances per week and training sessions were also significantly decreased for the trainees with stress fractures compared to those without stress fractures (Montgomery et al., 1989; Winfield et al., 1997). However, two studies did not report significant differences in the mode of training, distance per week, or duration between groups ($p>0.05$) (Bennell, Malcolm, Thomas, Reid et al., 1996; Bennell Malcolm, Thomas, Wark, et al., 1996).

Summary of Risk Factors

The anatomical factors identified retrospectively that are associated with MTSS include excessive pronation, increased subtalar ROM, and flexibility deficits in the gastroc-soleus complex. For stress fractures an increased ER of hip, narrow tibiae, decreased lower leg musculature, decreased tibial bone width, and an increased Q-angle have been identified as anatomical factors. The previous research on the association of lower leg strength with MTSS and stress fractures reports contradictory findings. The biomechanical factors associated with shin splints were excessive rearfoot movement, increased maximal pronation, and increased pronation velocity. Physiological factors identified for stress fractures were decreased BMD, history of menstrual disturbances, and diet issues (fat intake/weight). While history of menstrual disturbance and diet issues were observed only in females, decreased tibial BMD has been associated with stress fractures in males and females. Much of the research did not find associations with training variables between MTSS and stress fractures. However, a decreased weekly mileage and interval training/changing shoes were associated with stress fractures and MTSS, respectively.

Few studies have examined the risk factor of MTSS and stress fractures using a prospective design in the athletic population; the majority of these studies have used retrospective designs. The prospective design will allow for the calculation of correlations and a regression equation that may predict the development of these conditions. Also, by identifying the potential risk factors, the management and treatment of these conditions by doctors and athletic trainers will advance.

Therefore, this study will examine six factors associated with the load and tissue characteristics. The factors related to the load characteristics are the alignment issues consisting of LLD, knee alignment, and arch height. The dorsiflexion ROM of the ankle will attempt to measure the magnitude of the load characteristics. While the frequency of the load characteristics will be assessed using the training variables. The tissue characteristics will be examined indirectly in this study through assessment of menstrual history disturbance and eating disorders because these factors are related to material properties of BMD and soft tissue structures. This study will attempt to investigate risk factors in MTSS and stress fractures implementing a multifactorial approach while selecting measurements that are clinically useful to athletic trainers and physical therapists.

CHAPTER 3

RESEARCH METHODOLOGY

The purpose of this study was to identify the etiological risk factors that might contribute to MTSS and TSF in female intercollegiate athletes using a prospective design. This section will discuss the following topics: a) subjects, b) pilot study, c) instrumentation, d) procedures, and e) data analysis.

Subjects

Sixty-three female student-athletes volunteered to participate in this study. These subjects were obtained from East Tennessee State University, Milligan College, and Tusculum College. In addition, these subjects participated in intercollegiate volleyball, soccer, track, or cross-country at their respective institutions. The criteria for the exclusion of subjects from participation in the study included the following: 1) the subject had sustained an injury to the lower extremity exactly three months prior to the study, 2) the subject was not released by a physician after having major surgery on the lower extremity (ACL reconstruction) exactly six months prior to this study, or 3) the subject had a history of fractures to the lower extremity. 51 subjects participated in the study after the initial screening, but due to attrition only 39 subjects completed the study.

An injury was defined in this study as a condition that required treatment from an athletic trainer or physician, and that interrupted the subject's normal daily routine. Prior to testing, subjects completed and signed the informed consent form explaining the procedures and expectations involved with this investigation.

Pilot Study

A pilot study was performed prior to data collection using 20 female subjects from East Tennessee State University. This pilot study allowed the researcher to practice the anatomical measurement that would be used later and to determine the time frame for the testing of each subject. In addition, reliability values were determined for the anatomical measurements that would be used in the study. Each subject reported for two testing sessions, which were held on consecutive days. During these sessions the following measures were obtained: static pronation, knee alignment, leg length, leg length discrepancy, and dorsiflexion ROM using the procedures detailed below. These anatomical measurements were assessed on consecutive days to allow the primary investigator to determine test-retest reliabilities for the measurements. During each session, the primary investigator obtained three trials of each measure. To determine test-retest reliabilities within a session, the three trials for each measure were examined. To determine test-retest reliability across sessions, the average of the three trials for a given measure during session one were compared against the average of the three trials during session two. Any markings made on the skin during the first session were washed off at the conclusion each session.

The Navicular Drop Test was used to determine the amount of static pronation by obtaining the difference in millimeters between the non-weight bearing and weight bearing measurements. The navicular tubercle was identified with a black marker to measure the amount of (pronation) drop. The examiner measured the amount of pronation while the subject sat in a chair with her feet on the ground (non-weight bearing) with her feet in subtalar neutral position. This test was repeated with the subject standing on both feet shoulder width apart (weight bearing). A mark was placed on the index card where the navicular tubercle is located in both positions, which resulted in a difference score in millimeters (Starkey & Ryan, 1996). The average difference in the navicular drop between the measurements in millimeters was calculated after three trials for the left and right foot, which were used for the data analysis. A navicular drop score of greater than 10-mm has been observed in excessive pronators (Mueller, Host, & Norton, 1993). This test has reported an intratester and intertester reliability ranging from .83 to .92 and .73 to .85, respectively (Saltzman, Nawoczenski, & Talbot, 1995; Sell, Verity, Worrell, Pease, & Wigglesworth, 1994).

Three measures of knee alignment were used in the pilot study: Q-angle, A-angle, and the observational method. The Q-angle was assessed according to the procedures described by Tomsich, Nitz, Threlkeld, and Shapiro (1996). The subject was positioned in supine and a goniometer was used to determine this angle. The ASIS, tibial tubercle, and the midpoint of the patella were identified using a black marker. A line from the ASIS to the midpoint of the patella and a line from the tibial tubercle through the midpoint of the patella created this angle. This test has reported intratester and intertester reliabilities of .63 and .23, respectively (Tomsich et al., 1996). Caylor, Fites, & Worrell (1993) noted intratester and intertester reliabilities of 0.87 and 0.83.

The A-angle was also examined for knee alignment. For this measurement, the subject sat upright on the edge of the table with knees flexed to 90°. The tibial tubercle, midpoint of the inferior pole of the patella, and the superior pole of the patella were identified with a black marker. Two lines formed this angle: a line going through the midpoint of the inferior pole of the patella and a line from the tibial tubercle to the superior pole of the patella (Tomsich et al., 1996, Wen et al., 1996). This angle was also measured using a goniometer. Tomsich et al. (1996) have reported intratester and intertester reliabilities of .61 and .49; while Ehrat, Edwards, Hastings, and Worrell (1994) reported intratester reliabilities ranging from 0.20 to 0.32 and a very poor intertester reliability of –0.01.

Knee alignment was also assessed using the observational technique as stated by Magee (1992). This technique was qualitative in nature because the subject was classified as varus, valgus, or normal. The subject stood with her feet shoulder width apart facing forward and gradually moved her feet closer together until either the medial femoral condyles or the medial malleoli touched. The subject was classified as varus if her medial malleoli touched before the medial femoral condyles. However, if the medial femoral condyles touched before the medial malleoli, the subject was classified as valgus. If the medial malleoli and medial femoral condyles touched simultaneously, the subject was classified as normal.

True leg length was measured from the ASIS and medial malleolus using a tape measure. The subject was positioned in supine with her knees extended and feet approximately 15-cm apart. The ASIS and medial malleolus were marked with a black marker on each subject prior to the measurement. This marking was used to help maintain the same landmarks, which can decrease the amount of error associated with each measurement. The examiner recorded this measurement in centimeters by using the tape measure. This measurement was obtained by alternating the right and left sides for a total of three values for each side. The difference in length between the right and left leg was calculated as a measure of leg length discrepancy. The average of each side were used for data analysis. This measurement has reported reliabilities ranging from .79 to .93 and .67 to .98 for intratester and intertester, respectively (Beattie, Isaacson, Riddle, & Rothstein, 1990; Gorgia & Braatz, 1986; Hoyle, Latour, & Bohannon, 1991; Jonson & Gross, 1997).

The amount of dorisflexion ROM measurement was also obtained for this study that used a goniometer. The subject was positioned in prone with her knees extended and the ankles hanging over the edge of the table. The head of the fibula, fifth metatarsal, and the lateral malleolus were identified with a black marker for reference points. This measurement was obtained with the axis of the goniometer on the lateral malleolus; the stationary arm aligned with the head of the fibula and the movable arm was aligned with the fifth metatarsal. The subject actively dorsiflexed her foot while the examiner passively dorsiflexed her foot at the same time until tension was noticed. This measurement was taken three times on each ankle and an average of each ankle was used for data analysis. This measurement has reported intratester and intertester reliabilities of .74 and .65, respectively (Jonson & Gross, 1997).

Instrumentation

The instruments that were implemented during this investigation included questionnaires, a goniometer, and a tape measure. The researcher obtained menstrual history information about the age onset of menarche and the number of cycles per year using the medical history and sport questionnaire. In addition, the EAT-26 questionnaire was also used to determine if the subjects had an eating disorder or a preoccupation with weight. Garner, Olmsted, Bohr, and Garfinkel (1982) have reported reliabilities for the EAT-26 ranging from 0.83 to 0.90. This test has also reported a validity of 0.90 when the EAT-40 test was the criterion measure.

The tape measure was used for measurement of leg length discrepancy. This tape measure was pliable and had a centimeter scale on one side, with inches on the other side. A standardized 12.5-inch plastic goniometer was use to obtain the measurements of the A-angle, Q-angle, and amount of dorsiflexion ROM for each subject. A goniometer with 1° increments was used for these anatomical measurements.

Procedures

The primary investigator obtained permission from the head athletic trainer, head coaches, and athletic director at the respective institutions. Upon approval, the primary investigator met with each team at their initial team meetings to discuss the requirements of the study and ask for volunteers. During this meeting, potential volunteers were given the medical and sport history questionnaire (Appendix C) to exclude those subjects who could not participate in this study. In addition, the subjects completed the EAT-26 test to determine if there was the presence of an eating disorder or a preoccupation with weight (Appendix D). The subjects also answered questions pertaining to menstrual history disturbances, such as the onset of menarche, number of cycles in past 12 months, and use of birth control medication. During subsequent scheduled preseason screenings, the subjects who agreed to participate and were not excluded from the study completed and signed the informed consent form approved by the East Tennessee State University Institutional Review Board (Appendix A). The subjects were dressed in shorts and a tee shirt at the time of testing, which occurred in the athletic training rooms at the respective universities.

After completing the informed consent form, the subject's weight and height were obtained. Next, the anatomical measurements including the navicular drop, A-angle, Q-angle, observational knee measurement, leg length, leg length discrepancy, and the amount of dorsiflexion ROM were assessed using the procedures that have been previously discussed in the pilot study section. All of these static measurements were recorded on a specific data sheet for each subject (See Appendix E). The mean of the three trials for each variable was calculated to determine a representative value for each leg for each subject. This mean value was used in subsequent statistical analyses.

Subjects were monitored throughout the duration of this study for development of MTSS or stress fractures. A certified athletic trainer at each university evaluated the injuries for inclusion of subjects participating in the study according to the following criteria. First, the pain had to be chronic in nature, lasting for more than two weeks. Second, the pain had to occur from repetitive running or jumping with no other suspected causes of the injury, such as a contact injury or an infection. MTSS was defined as pain localized in the distal 1/3rd of the posteromedial border of the tibia. A tibial stress fracture was defined as specific tenderness in certain spots along the tibia. Third, the subject had to receive treatment from the athletic trainer or physician, and fourth, the condition had to alter their normal daily routine. If a subject met these criteria, the subject was referred to an orthopedic doctor for diagnosis of the condition. The athletic trainer and orthopedic doctor also documented the classification of the injury, either MTSS or TSF (See Appendix F). In addition, a bone scan was used for confirmation of any stress fractures. Medical personnel interpreted the bone scan to determine if a stress fracture was present by using the classification system used to diagnose bone scans (Zwas, Elkanovitch, & Frank, 1987).

Weekly logs reporting the details of any exercise performed during the duration of study were collected from the subjects. This weekly log was used to document the duration of training for each practice throughout the study. In addition, the weekly logs provided the researcher with details about the intensity of each session and any extracurricular training performed by the subjects (See Appendix G). The weekly averages for the duration and recovery times were calculated.

Data Analysis

This study used a prospective design ranging from 13 to 26 weeks. The dependent variable was whether the subject developed MTSS or a TSF during the study. Menstrual history (onset of menarche and number of cycles in past year), the EAT-26 test score, navicular drop score, A-angle, Q-angle, observational knee alignment**,** leg length, leg length discrepancy, dorsiflexion ROM of the ankle, and training variables (duration and recovery times) were the independent variables in this study. The statistics were performed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) with the alpha level established at 0.05 for statistical significance. Following data collection, descriptive statistics were calculated for the independent variables. Because only two subjects developed MTSS, it was not possible to analyze the data for risk factors as originally proposed. Instead, a descriptive approach was taken for the analysis. Descriptive statistics were calculated for all variables. A two-way ANOVA with repeated measures was used to determine if there were significant differences in anatomical measurements between the right and left legs across sports. Finally, the two subjects who developed injuries were presented as case studies. All of the statistical analyses that were done used SPSS. Statistical significance was accepted at $p < 0.05$.

CHAPTER 4

RESULTS

The purpose of this study was to identify the etiological risk factors associated with MTSS and TSF in female intercollegiate athletes. Because only two injuries were reported during the time period examined, analysis for risk factors was not possible. Instead, a descriptive approach was taken for the analysis. The results of these analyses are presented in this chapter, which includes the following sections: a) pilot study, b) subject demographics, c) physiological variables, d) anatomical measurements, e) training log information, and e) injury information (case studies).

Pilot Study

Prior to this present investigation, a pilot study was performed using 20 female volunteers who were attending East Tennessee State University. This enabled the researcher to increase the reliability of the measurements used in the study and determine a time frame for the testing. The researcher obtained navicular drop, A-angle, Q-angle, leg length values, leg length discrepancy, and dorsiflexion ROM measurements using the procedures that have been previously discussed. These measurements were obtained on two consecutive days. The intertrial and day-to-day reliability coefficients were calculated for the anatomical measurements. In order to be recognized as acceptable the intertrial and day-to-day reliability coefficients need to be at least 0.90 and 0.80, respectively. These reliabilities are classified in the literature by the following categories: excellent - 0.90 to 1.0, good – 0.80 to 0.89, moderate – 0.70 to 0.79, and poor – below 0.69 (Blesh, 1974). The intertrial reliability values ranged from 0.83 to 0.99. While, the day-to-day reliability values were lower than the intertrial values, ranging from 0.72 to 0.97. These reliability coefficients and the standard error of measurement (SEMs) associated with each of the anatomical measurements are shown in Tables 3 and 4.

Table 3
Intertrial and Day-to-Day Reliabilities

Anatomical Measurements	Right Side		Left Side	
	Intertrial Reliability	Day-to-Day Reliability	Intertrial Reliability	Day-to-Day Reliability
NDA	0.92	0.77	0.87	0.82
AA	0.95	0.79	0.95	0.80
QAL	0.93	0.89	0.92	0.92
LL	0.97	0.95	0.97	0.96
DFL	0.98	0.97	0.98	0.97
LLD	0.89	0.72	N/A	N/A

Note. N/A: not applicable; Measurements-- NDA: navicular drop test, AA: A-angle, QAL: Q-angle, LL: leg length, DFL; dorsiflexion ROM, and LLD: leg length discrepancy

Table 4
Standard Errors of Measurement (SEMs) for the Intertrial and Day-to-Day Measurements

Anatomical Measurements	Right Side		Left Side	
	Intertrial	Day-to-Day	Intertrial	Day-to-Day
NDA (mm)	0.6	1	0.3	0.1
AA (deg)	0.6	1.2	0.7	1.3
QAL (deg)	0.5	0.7	0.6	0.6
LL (cm)	0.2	0.2	0.1	0.1
DFL (deg)	2.8	3.5	2.7	3.4
LLD (cm)	0.3	0.5	N/A	N/A

Note. N/A: not applicable; Measurements-- NDA: navicular drop test, AA: A-angle, QAL: Q-angle, LL: leg length, DFL; dorsiflexion ROM, and LLD: leg length discrepancy
SEMs: were averaged for the intertrial and day-to-day values

Subject Demographics

Sixty-three female subjects were screened to determine if the inclusion criteria was met with a medical history questionnaire. The subjects were excluded from participation in the study if they had sustained an injury to the lower extremity exactly three months prior to the study, were not released by a physician after having major surgery exactly six months prior to this study, or if they had ever sustained a fracture to their lower extremity. These subjects were volunteer intercollegiate student-athletes from East Tennessee State University, Milligan College, and Tusculum College. In addition, the subjects were participating in volleyball, soccer, track & field/cross-country at their respective institutions. Only 51 subjects were accepted into this study after the initial screening, but due to attrition only 39 subjects completed the study. Twelve subjects dropped out of the study because they lost interest, sustained an injury prior data collection, or stopped participating in intercollegiate athletics. The duration of this prospective-study design ranged from 13 weeks to 26 weeks. The volleyball and soccer participants were involved with this study for 13 weeks, the length of their competitive seasons. The track/cross country participants were involved in this study for 26 weeks, which was until the end of the indoor track season.

These subjects were 17 to 21 years old (X=19 yr.; SD=1 yr.), weight ranged from 102 to 164 lbs. (X=137 lb.; SD=17 lb.), and height ranged from 59 to 72 in. (X=66 in.; SD=3 in.). In addition, 33 of the 39 subjects were of Caucasian ethnicity, and 6 of the 39 subjects were of Hispanic or African American ethnicity. These subjects participated in the following sports: soccer (*n*=15), volleyball (*n*=14), and track/cross country (*n*=10) at their respective institutions. The subjects obtained from East Tennessee State University participated in volleyball (n=8) and track/cross country (n=6). The 15 subjects obtained from Tusculum College participated in soccer (*n*=5), volleyball (*n*=6), and track (*n*=4). Only 10 subjects were obtained from Milligan College, who participated in soccer.

Physiological Variables

The physiological variables that were examined in this present investigation included information about the subject's menstrual history and the presence of an eating disorder or a preoccupation with weight. The menstrual history information obtained from the questionnaire consisted of the onset of menarche, number of menstrual cycles, and the use of birth control. The majority (87%) of the subjects were eumennorheic, meaning they had at least nine menstrual cycles in the past year. The EAT-26 test score determined if the subjects had an eating disorder or a preoccupation with weight. A score of at least 20 has been associated with an eating disorder. Only 4 of the 39 subjects had an eating disorder as determined by the EAT-26 test. Therefore, 90% of the sample did not have an eating disorder present or a preoccupation with weight. The average for onset of menarche was 13 years of age for all subjects. The EAT-26 score for all subjects was 8. Descriptive statistics for the physiological variables across sport is shown in Table 5.

Table 5
Physiological Variables (N=39)

Sport	Soccer (*n*=15)	Volleyball (*n*=14)	Track (*n*=10)
Number of menstrual cycles (%)			
≥9:	80	93	90
≤ 3:	7	7	10
Age of onset of menarche (yrs)	13	13	13
EAT-26 score	8	7	9
No birth control use (%)	80	93	70

Anatomical Measurements

The anatomical measurements used were the navicular drop, A-angle, Q-angle, leg length values, leg length discrepancy, and dorsiflexion ROM. The averages for these anatomical measurements with the right and left sides separated are depicted in Table 6.

A two-way ANOVA was performed to determine if differences occurred between the right and left legs or across sports for all variables except leg length discrepancy. No significant differences were found between legs or across sport for navicular drop or knee alignment (A-angle and Q-angle). However, significant differences were found for leg length and dorsiflexion ROM. For leg length, a significant difference was found between legs, with the right leg being longer for subjects in all sports (LL_{right} = 89.7+4.6 cm; LL_{left}=89.4+4.5 cm; *p*=0.003). For dorsiflexion ROM, a significant legXsport interaction was found (*p*= 0.033). Dorsiflexion ROM was greater in the right ankle for subjects participating in soccer and track, with no difference between legs for the subjects participating in volleyball.

A one-way ANOVA was calculated to determine differences across sport for leg length discrepancy. No significant difference was found in leg length discrepancy across sport.

Table 6
Anatomical Measurements (N=39)

Sport	Soccer (*n*=15)	Volleyball (*n*=14)	Track (*n*=10)
Navicular drop (mm)			
Right:	2 ± 6	2 ± 5	2 ± 6
Left:	2 ± 6	1 ± 5	3 ± 6
A-Angle (deg)			
Right:	30 ± 3	31 ±2	30 ± 3
Left:	30 ± 2	30 ± 2	30 ± 3
Q-angle (deg)			
Right:	9 ± 2	9 ± 1	9 ± 1
Left:	9 ± 2	9 ± 1	9 ± 1
Leg length (cm)			
Right: *	87.2 ± 4	92.3 ± 4	89.8 ± 5
Left:	87 ± 4	91.7 ± 3	89.6 ± 5
Leg length discrepancy (cm)	0.1 ± 0.5	0.5 ± 0.7	0.1 ± 0.3
Dorsiflexion ROM (deg)			
Right:	99 ± 5§	97 ± 7	103 ± 7§
Left:	97 ± 5	97 ± 7	100 ± 7

Note. * Significant difference between right and left legs for all subjects. (*p=0.003*).
§ Significant legXsport interaction, with right DFL > left DFL for Track and Soccer (*p=0.033*).
Values are reported as M ± SD

Training Log Information

The subjects were required to keep a daily training log, which allowed the researcher to determine the duration of practice, the amount of recovery time prior to the next practice, and any extra training performed. After collection of these data, an average duration and recovery time were calculated to provide insight to why injury might have occurred. Only 14 of the 39 (36%) subjects returned their training log information to the researcher, so descriptive statistics were calculated for the entire group and not broken down by sport. The average duration and recovery times for the subjects in this study were 2.9 hours • day^{-1} and 26.1 hours, respectively.

Injury Information (Case Studies)

The subjects were monitored by the ATCs at their respective institutions for the development of MTSS or a TSF. Only 2 of the 39 subjects developed an injury, and the medical director diagnosed both injuries as MTSS. This was a 5% incidence rate. These subjects were competing in volleyball and track/cross country at East Tennessee State University at the time of injury. After an initial evaluation by the ATC, the condition was classified based on the criteria that have been previously discussed. The subjects were referred to the medical director for diagnosis of the condition and any diagnostic testing that was required. The medical director used the same criteria as the ATC to diagnose these conditions. There was no diagnostic testing required during the study, such as an x-ray or a bone scan, because the physician diagnosed them as MTSS and the conditions did not worsen.

CHAPTER 5

DISCUSSION AND CONCLUSION

ATCs, physicians, and physical therapists work with athletes on a daily basis. Overuse injuries are a common occurrence in the competitive and the recreational athlete. Therefore, it is important to try and understand the etiology associated with the development of overuse injuries, specifically MTSS and TSF. The identification of the risk factors would help ATCs, physicians, and physical therapists in the management and prevention of MTSS and TSF. The primary purpose of this study was to identify some etiological risk factors associated with the development of MTSS and TSF in female intercollegiate athletes. Because of the low number of injuries, risk factors could not be identified. However, the data from this study do represent the first comprehensive descriptive data set in this area for volleyball, soccer, and track female athletes. These descriptive data will be discussed as well the differences reported in the previous chapter. This chapter will include the subsequent sections: a) pilot study, b) physiological measurements, c) anatomical measurements, d) training log information, and e) injury and case study information.

Pilot Study

The majority of the reliability coefficients in this current study for the anatomical measurements were higher than those previously reported in the literature. In addition, the coefficients for the intertrial and day-to-day reliabilities were within acceptable values, but several of the anatomical measurements demonstrated only moderate reliability. These measurements include leg length discrepancy, A-angle, and navicular drop for the day-to-day reliabilities. There has not been any research to the author’s knowledge examining the day-to-day reliabilities for these measurements; only the intratester and intertester reliabilities have been examined. For example, the navicular drop test reported an intertrial reliability of 0.83 for the left side on day one, with the other intertrial reliabilities for this measurement ranging from 0.91 to 0.93. The reason for this lower reliability for one day is unknown because the right side had a reliability of 0.91. The improper position of subtalar neutral prior to the measurement may have been attributed to the differences between sides. The navicular drop is used to estimate the amount of static pronation, which can be altered if the foot is not placed in the subtalar neutral position prior to measurement. The values in this study are in agreement with Sell et al. (1994) who reported intertrial reliabilities ranging from 0.83 to 0.95. However, Picciano et al. (1993) reported lower intertrial reliabilities ranging from 0.61 to 0.79. These findings may be lower because two inexperienced physical therapists obtained this measurement after having only two hours of training.

The A-angle reported excellent intertrial reliability coefficients ranging from 0.94 to 0.96, which is very interesting because the previous research has reported much lower reliability values. This study used a procedure that has not been examined in the previous research. Therefore, no comparisons can be made regarding these procedures or possible reasons for the higher reliabilities in this study. This study suggests that knee angle and position are important measurement components. Therefore, there needs to be research done implementing both of these procedures to determine if one procedure produces better reliability values than the other.

The Q-angle reliability coefficients in the current study ranged from 0.90 to 0.95, which were higher than the values that have been previously reported in the literature. Another study examined the intertrial reliabilities of this measurement using the same procedures of the current study and found a value of 0.63 (Tomsich et al., 1996). However, these examiners had only two hours of practice before obtaining the measurements, which may have contributed to the lower reliability value. Caylor et al. (1993) reported an intertrial reliability of 0.83, but the subjects were standing, not lying in a supine position. A few other factors that may affect the Q-angle in the standing position but not in the supine position include pronation of the foot, pes planus, and positioning of the foot. Guerra, Arnold, and Gajdosik (1994) noted that this measurement was more reliable across trials in the standing position (0.84 to 0.87) compared to a supine position (0.73 to 0.75) when the foot and hip positions were standardized. It is very important to standardize the position of the foot and knee to decrease the amount of variability in a standing position. Further research needs to be completed examining both methods with standardization of the foot, hip, and knee to determine if one of these methods reports higher reliabilities.

The intertrial reliability coefficient for the measurement of leg length values in this study was 0.97, slightly above the values reported in the literature. Other research studies have examined the reliability of leg lengths when using a tape measure and have reported lower values. Hoyle et al. (1991) examined 25 subjects and stated that the intertrial reliabilities ranged from 0.89 to 0.95. In another study, Jonson and Gross (1997) performed anatomical measurements to include leg length discrepancy on 63 subjects in the Army and reported an intertrial reliability of 0.86. The current study may have reported higher reliabilities because the majority of the subjects were lean. The ASIS and medial malleoli were easily identified due to the decreased amount of soft tissue around these landmarks. If the subjects are obese, there is difficulty in the identification and palpation of the anatomical landmarks.

The dorsiflexion ROM intertrial reliability coefficient was 0.98 in this study and was comparable to some values reported in the literature. McPoil and Cornwall (1996) stated the intertrial reliability to be 0.98 using the same procedures as this study. Another group of researchers examined this measurement in 38 subjects with orthopedic problems and determined the intertrial reliability to be 0.82 (Youdas, Bogard, & Suman, 1993). McPoil and Cornwall and this study used healthy subjects, which may have contributed to the differences in reliability. The subjects with orthopedic problems may have more variability in their measurements compared to the healthy subjects.

Anatomical Measurements

The researcher had obtained these measurements approximately two weeks after the subjects began their training regimes for each sport. The majority of these measurements are within the normal values that have been reported in the literature. These measurements were reported separately for the right and left sides because there is limited research stating the values in this manner. It is important to report the right and left sides separately to enhance the generalizability of these measurements because they may not be symmetric.

The values for navicular drop found in the present study ranged from 3.4 mm to 8.5 mm, which were slightly lower than the normal values for navicular drop testing in the literature. This measurement has been used to obtain the amount of pronation occurring at the subtalar joint. The previous literature states these values range from 4.2 mm to 13.2 mm (McPoil & Cornwall, 1996; Picciano et al., 1993; Snook, 2001). Snook examined the isokinetic strength of the ankle and the navicular drop in a control and an excessive pronator group. The control group had values ranging from 4.2 mm to 9.4 mm, compared to the excessive pronators of greater than 13 mm.

This measurement can be influenced by a variety of factors such as the leg length discrepancy, Q-angle, and pes planus.

The A-angle in this present study had values ranging from 28° to 33°, which are higher than the values reported in the literature. Previous research has reported values ranging found values ranging from 8.1° to 25.9°(DiVita & Vogelbach, 1992; Ehrat et al., 1994). However, no comparisons can be made regarding the values because the anatomical landmarks in this study were not previously used for this measurement. The author's measurements used the procedures examined by Tomsich et al. (1996) and Wen et al. (1996). The subjects in this study were seated upright with their legs hanging over the edge of the table during the measurement and the landmarks used for this measurement included the following: a) superior pole of the patella, inferior pole of the patella, and the tibial tubercle. The values in this study may have been larger due to the use of a different procedure that has not been previously examined.

In this study the values of the Q-angle ranged from 7° to 11°, which are slightly lower than the values reported in the previous research. These differences in the measurement may be attributed to using a standing procedure. For example, Woodland and Francis (1992) reported the values for standing and supine in female subjects associated with these positions as 15.8° and 17°. Another group of researchers examined the effect of body position and an isometric quadriceps contraction on this measurement (Guerra et al., 1994). These authors reported the measurement without the contraction in the standing and supine positions were 13.5° and 14.2°, respectively, which is contradictory to the results reported by Woodland and Francis. A possible rationale for these differences could be that although the standing position may be more functional, pronation of the foot may be responsible for increased Q-angles in this position. In 1998, Livingston reviewed the research on Q-angles and noted that these values are between 2.5° and 10° in healthy females, but the position of the measurement was not reported.

There was a significant difference in leg lengths between the right and left leg, with the right being 0.5 cm longer for all subjects. The difference in leg length may be attributed to a true leg length discrepancy, which is where the bony structures may be different. This is the first study to the author's knowledge that normal values for leg length have been reported by leg for females and for multiple sports. There is minimal research reporting the normal values of leg length values because much of this research has focused on leg length discrepancy. This study reported a mean leg length discrepancy of 0.29 cm, which is not clinically significant according to the literature. Jonson and Gross (1997) noted a mean discrepancy of 0.32 cm using 63 subjects in the Army. Although there is not a LLD value that has been consistently stated in the literature as being clinically significant, Neely (1998) suggested that a difference of one-centimeter should be defined as a significant discrepancy in future research. The author did not provide any rationale for this suggestion.

Finally, the amount of dorsiflexion ROM ranged from 2° to 16°. These values are much lower than those that have been previously reported in the literature using the same procedures as this study. McPoil and Cornwall (1996) reported values ranging from 7.9° to 12.3° after evaluating this measurement on 27 subjects (18 female/9 male). However, another study using 63 subjects reported dorsiflexion ROM between 8.91° and 18.43° (Jonson & Gross, 1997). The differences in the values may be due to capsular tissue that may have been scarred from previous injury, such as an ankle sprain (Neely 1998). Previous ankle sprains in these subjects are certainly possible, given the sports that they represent. However, no data were collected to provide evidence of this possibility.

This study also showed a significant legXsport interaction for dorsiflexion ROM. The dorsiflexion ROM was larger in the right ankle for track and soccer subjects, with no differences observed in the volleyball subjects. The reason for the differences between sports is unknown.

Physiological Measurements

Little research has examined these physiological measurements in specific sports. In this study, the average onset of menarche was 13 years of age, which would be classified as an early onset according to Bennell, Malcolm, Thomas, Reid et al., (1996). These authors reported a significant difference in the age onset of menarche in relation to the development of a stress fracture and reported the stress fracture and healthy groups to be 16 and 14 years of age, respectively ($p<0.05$). The onset of menarche may have implications to the development of TSF especially if it is delayed because it may result in lower BMDs due the decreased mineral accretion (Bennell et al., 1999). It is not known at this time if a later onset of menarche can predispose an individual to the development of MTSS. The subjects participating in track had the highest EAT-26 score; 2 out of the 10 subjects had a score of greater than 20, which is associated with an eating disorder. However, only one subject in each sport was classified with an eating disorder for soccer and volleyball. Hulley and Hill (2000) reported a similar prevalence of eating disorders (16%) in female elite distance runners after completing the Eating Disorders Questionnaire. The author did not find any research reporting the prevalence of eating disorders in female soccer and volleyball athletes. Bennell et al. (1995) reported no significant differences in the EAT-40 scores between subjects with stress fractures and healthy subjects. The majority of the subjects in this study were eumennorheic, had at least nine menstrual cycles in the past 12 months. To the author's knowledge, this was the first study that reported the number of menstrual cycles for these three sports. Other research has examined this concept in relation to the development of stress fractures. Bennell, Malcolm, Thomas, Reid et al. (1996) and Winfield and Moore (1997) reported that the subjects with stress fractures had fewer menstrual cycles, were amennorheic compared to the healthy subjects.

Training Log Information

The subjects participating in the study were required to record their training regimes so that an average duration and recovery time could be calculated for each subject. However, only 36% of the subjects returned the training logs to the researcher. The training logs were very simplistic and easy to complete following each training session. Some potential reasons for the low return rate for the training logs were that the subjects lost interest in the study due to the long duration and the limited supervision at the other institutions. Many of the subjects probably lost interest because they were involved for up to 26 weeks and may have forgotten to complete the logs after each session. The subjects may have also thought that completion of these logs was redundant. Another possible reason for the low return rate is that there was limited supervision at the other institutions by the respective head coaches and ATCs. Despite numerous contacts with these institutions, the subjects did not return the training logs. The only training logs received were from the subjects participating in intercollegiate athletics at East Tennessee State University, which was possibly because the researcher constantly reminded them to return their logs every week.

The average duration and recovery times for the subjects who returned their logs were 2.9 hours/day and 26.1 hours, respectively. This is the first study that has reported the average duration and recovery times to the author's knowledge. Various groups of researchers have not provided details of these training variables, but have investigated their relationship to stress fracture development. Winfield et al. (1997) reported that the healthy group ran more than 2.8 miles/session compared to the injured group. In contrast, other researchers did not find significant differences between the training variables (Bennell & Crossley, 1996; Bennell, Malcolm, Thomas, Reid et al., 1996; Bennell, Malcolm, Thomas, Wark et al., 1996).

Injury and Case Study Information

Only 2 of the 39 subjects developed MTSS throughout the duration of this study. This sample was not large enough to perform any statistical analyses between the injured and uninjured groups. The incidence rate in this study was 5%, which is similar to the previous studies ranging from 4% to 14% in military and athletic populations for MTSS or shin splints, respectively (Bennell & Crossley, 1996; Cowan et al., 1996) - see Table 7. Every attempt was made to recruit 100 subjects for this study (as originally proposed). However, the original sample was not obtained for the following reasons: 1) the pilot study testing took much longer than anticipated, 2) the head coaches would not allow their athletes to participate in the study, and 3) there was trouble contacting some of the coaches. A few subjects had to be dropped because their data was not collected due to the subjects sustaining an injury prior to the measurement session. However, the data collection process was completed approximately two weeks after the subjects had started practicing.

Table 7
Comparison of Incidence Rates for MTSS and Shin Splints in Athletic and Military Populations

Study (year)	James et al. (1978)	Bennell & Crossley (1996)	Bennell & Crossley (1996)	Kaufman et al. (1999)	Current Study (2002)
Population	Runners (N=180)	Runners (Male/female) (*n*=54)	Sprinters (Male/female) (*n*=27)	Male military trainees (N=449)	Female Intercollegiate athletes (N=39)
Design	Prospective	Retrospective	Retrospective	Prospective	Prospective
Data collection technique	Monitor	Interview	Interview	Monitor	Self-report
Incidence Rates (%)	13	14	5	4	5

The two subjects who developed MTSS during the course of the study will be discussed using a case study approach (Table 8). Both of these subjects were participating in intercollegiate athletics at East Tennessee State University. In addition, these subjects had normal measurements for the anatomical and physiological data except for the A-angle (Table 9). The A-angle values cannot be evaluated with respect to the normal values because a different procedure was used for this measurement. Therefore, none of the proposed risk factors were associated with the development of MTSS; so other possible variables were examined to identify the etiology of the injury.

Table 8
Characteristics of the Injured Subjects

Subject	Sport	Race	Sport Experience (yrs)	Onset of Menarche (age)	Number of Menstrual Cycles	Birth Control Use
A	Volleyball	Caucasian	4-6 yrs	14	≥ 9	No
B	Track	African American	7-10 yrs	13	≥ 9	No

Table 9
Comparison of Case Study Subjects and Normal Values

Measurement	Subject A	Subject B	Normal
Navicular drop (mm)	4	9	4 to 13
A-angle (deg)	27	34	12 to 23
Q-angle (deg)	10	10	11 to 17
Leg length (cm)	96.6	97.4	N/A
Leg length discrepancy (cm)	0.3	0.2	0.2 to 0.7
Dorsiflexion ROM (deg)	18	18	10 to 20
Onset of menarche (years)	13	13	N/A
EAT-26 score	0	1	N/A
Number of menstrual cycles	≥ 9	≥ 9	≥ 9

Note. N/A – no normal values reported

Subject A was a first-year athlete participating in volleyball. The dorsiflexion ROM for this subject was 18° and 19° on the right and left leg, respectively. These values are much higher compared than the average ROM for the volleyball subjects, 7° on both legs. However, only a decreased dorsiflexion ROM has been associated with the development of stress fractures and shin injuries in the previous research. In a review, Krivickas (1997) stated that a decreased range of motion in the gastroc-soleus complex might be associated with MTSS. Messier and Pittala (1988) was in agreement after examining subjects with shin injuries compared to the healthy group. Therefore, it is unlikely that her increased ROM contributed to the development of MTSS. Subject A had shoulder surgery in August and was playing by the end of the season and, therefore, may have returned to practice too early. The subject probably resumed practice without gradually doing drills at practice, which may be the main reason she developed MTSS. The subject did not have adequate recovery time between sessions. Her recovery time was 23.4 hours between practice sessions, which was 23.7 hours. Beck (1998) proposed a bone-remodeling theory to explain inadequate recovery time as a possible mechanism for the development of MTSS. This theory is based upon the bone rebuilding and resorption process. If there is sufficient recovery time the osteoblasts can repair the microdamage that has occurred to the bone. However, if there is not adequate recovery time, the osteoclasts will outnumber the osteoblasts due to the abnormal bone remodeling resulting in the development of MTSS and ultimately a stress fracture.

Subject B was a second-year track and field athlete. The majority of the anatomical measurements were within the values associated with the other track subjects. However, the A-angle and Q-angle were higher and lower compared to the literature, respectively. The navicular drop was about 4 mm higher than the average of 6 mm for the track subjects. This difference may have been attributed to a pes planus foot-type, which this study did not examine. The increased navicular drop may have played a role in the development of MTSS because her values demonstrate that she may have had an increased amount of pronation compared to the other track subjects, but this was considered normal in the literature. In addition, the subject always wore her spikes during her training sessions, which may have increased this amount of pronation. The training spikes have very little to no support to assist with the absorption of forces during ground impact because the shoes are made for speed. As a result, the body is forced to dissipate the forces instead of having some assistance from the shoes, which may lead to damage to the soft tissue structures in the lower leg. Michael and Holder (1985) postulated that with excessive pronation, the eccentric contraction might fatigue the soleus and result in fewer forces being dissipated. This fatigue could result in decreased shock absorption by the musculature, and the bony structures need to dissipate these forces. Her dorsiflexion ROM was approximately 12°, which is similar to the values reported in the literature. Jonson and Gross (1997) and McPoil and Cornwall (1996) reported these values ranging from 8.91° and 18.43° and 7.9° to 12.3° respectively. Her duration and recovery times were 1.81 hours/day and 16.9 hours between practice sessions, respectively. Her recovery time was the lowest among the track subjects, which could have also played a role in her development of MTSS. However, whether this value is truly representative of her recovery time is questionable because she only returned half of her training logs during this study.

Conclusion

The purpose of this study was to identify some of the etiological risk factors associated with MTSS and TSF in female intercollegiate athletes using a prospective-design. This was the first study that attempted to identify these risk factors using a mulitifactorial approach. However, due to the small sample size, none of the original research hypotheses were examined. The subjects in this study appeared to have normal skeletal alignment measurements. These subjects also had a decreased dorsiflexion ROM compared to the normal values reported in the literature. Although, differences in leg lengths were observed for all subjects, and differences in dorsiflexion ROM between the right and left legs were observed between sports; these differences may be attributed to measurement error. Finally, no conclusions could be inferred regarding the potential risk factors associated with MTSS and TSF in female intercollegiate athletes.

Recommendations

ATCs, physicians, and physical therapists work on a daily basis with athletes who have overuse injuries, specifically MTSS and TSF. The identification of possible etiological risk factors will help these health professionals in the management and prevention of these conditions. Future research must continue to incorporate a multifactorial approach for identification of the risk factors associated with MTSS and TSF. More specifically, the risk factors associated with these conditions in relation to sport and competition level requires further investigation. The anatomical measurements need to utilize the right and left sides due to the asymmetry of these measurements. In addition, the anatomical measurements chosen should be dynamic because they may be more functional. Dynamic measurements may also provide more insight into the etiology of MTSS and TSF compared to static measurements. Finally, the procedures for the anatomical measurements need standardization and further investigation to determine if one procedure results in higher reliabilities. If all of these recommendations are incorporated into future research, the results may be more generalizable to other populations and lead to advances in the management of these injuries

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APPENDICES

Appendix A
Informed Consent Form

East Tennessee State University
Veterans Affairs Medical Center
Institutional Review Board

INFORMED CONSENT

PRINCIPAL INVESTIGATORS: Craig E. Broeder, Ph.D., Kathy D. Browder, Ph.D., Michael H. Blackburn, ATC

TITLE OF PROJECT: A Prospective Study to Identify Etiological Risk Factors Associated with MTSS and Stress Fractures in Intercollegiate Athletes

This informed consent will explain about participating as a research subject in an experiment. It is important that you read this information carefully and then decide if you wish to be a volunteer.

PURPOSE

Medial tibial stress syndrome (or MTSS, commonly called shin splints) and tibial stress fractures are overuse conditions that affect athletes and non-athletes during exercise training. MTSS is characterized by pain on the inside of the lower leg just above the ankle and usually does not affect your activities of daily living. Tibial stress fractures are usually characterized by more severe pain in very specific spots in the lower leg. Tibial stress fractures usually affect your normal activities, including sleeping. Many of the factors that make you more likely to develop these two conditions are not known. Therefore, the purpose of this study will be to identify the anatomical and physiological risk factors for these two conditions.

DURATION

This study will last for the duration of your preseason and competitive seasons (approximately 20 weeks), although your actual time commitment is small. During the first week, you will be required to participate an initial testing session at the time of the preseason physicals required by your institution. This initial session will last approximately 45 minutes. For each of the 20 weeks, you will be asked to complete training logs that document your daily exercise. Completion of the logs will require about 15 minutes each week. The only other time commitment will occur if you develop MTSS or a tibial stress fracture. If you develop any persistent pain in one or both of your legs, you will be asked to report to your institution's Athletic Trainer for an evaluation that will take approximately 15 minutes. After his/her evaluation, he/she may then refer you to an orthopedic doctor for diagnosis. This doctor's visit will require approximately 30 minutes of your time.

PRINCIPAL INVESTIGATORS: Craig E. Broeder, Ph.D., Kathy D. Browder, Ph.D., Michael H. Blackburn, ATC

TITLE OF PROJECT: A Prospective Study to Identify Etiological Risk Factors Associated with MTSS and Stress Fractures in Intercollegiate Athletes

PROCEDURES

As stated above, you will be required to participate in an initial testing session. During this session, you will complete two questionnaires. The first questionnaire asks you questions about your previous medical history, sports experience, and menstrual history. We will use this information to determine whether you are eligible to participate in the study. The second questionnaire is called the EAT-26, and is used to collect information about symptoms and characteristics of eating disorders. It is very important that you answer each question as honestly as possible. Your responses to these questions will be kept confidential.

In addition to these questionnaires, measurements of lower extremity alignment will also be taken on each leg during this initial testing session. Each of the lower extremity alignment measurements is described below.

Static Pronation: Static pronation refers to how high your arch is above the ground in a standing position. The Navicular Drop Test will be used to determine the amount of static pronation. In this test, a black mark will be placed on your foot near your arch (on the navicular tubercle), and the height of the black mark above the ground is measured with an index card. This measurement is taken in a non-weight bearing and weight bearing position. For the non-weight bearing position, the examiner will measure navicular height while are sitting in a chair with your feet on the ground. For the weight bearing position, you will stand with feet shoulder width apart, weight equally distributed on each foot. Three measures will be taken in each position for each foot.

Dorsiflexion Range of Motion (ROM): Dorsiflexion ROM refers to how far you can pull your foot toward the front of your shin. This will be measured using a goniometer, which is a small plastic circle with two plastic ‘arms’ that can measure angles. You will lie on your belly on a table with your knees straight and your ankles hanging over the edge of the table. Black marks will be placed on the outside of your knee, the base of your little toe, and the outside of your ankle. The goniometer will be lined up with these marks, and you will be asked to pull your foot towards your shin. At the same time, the examiner will push your foot in the same direction that you are pulling to help you go as far as possible. This will be done very slowly. When you tell the examiner that your foot cannot go any further, the reading will be taken from the goniometer. Three trials will be taken on each foot.

PRINCIPAL INVESTIGATORS: Craig E. Broeder, Ph.D., Kathy D. Browder, Ph.D., Michael H. Blackburn, ATC

TITLE OF PROJECT: A Prospective Study to Identify Etiological Risk Factors Associated with MTSS and Stress Fractures in Intercollegiate Athletes

Leg Length Discrepancy (LLD): Leg length discrepancy refers to the difference between the leg lengths of your right and left leg. To measure your leg length, you will be asked to lie on a table on your back with your knees straight and feet approximately 6 inches apart. A black mark will be placed on your hip and on the inside of your ankle. The distance between these black marks will be measured using a tape measure. Three trials will be taken on each leg.

Knee Alignment: Knee alignment refers to how well your lower leg lines up with your thigh. Three measures of knee alignment will be taken: Q-angle, A-angle, and observational method. The procedures for each is described below:

Q-angle: You will lie in on your back on a table, and a black mark will be made on your hip, just below your knee, and on the center of your kneecap. A goniometer will be used to measure the angle formed by the line from the hip to the middle of the kneecap and the line from just below the knee through the middle of the kneecap. Three measures will be taken on each leg.

A-angle: You will sit on a table with knees bent to 90°. A black mark will be made just below your knee and on the top and middle of your kneecap. A goniometer will be used to measure the angle formed by the vertical line passing through the middle of your kneecap and the line from the mark just below the knee to the mark on the top of the kneecap. Three measures will be taken on each leg.

Observational method: You will stand with your feet shoulder width apart, facing forward. You will gradually move your feet closer together until either your knees or your ankles touch each other. Three measures will be taken.

After the initial testing session, there are only two other requirements for the study. First, we ask that you complete training logs for each day of your preseason and competitive season. These logs will be used to determine the duration of practice, amount of recovery between sessions, and any extra training that you may do on your own. It is important that you are honest and consistent when completing these logs since the information will be used for further analyses. You will be given a packet of blank training logs before you leave today. Please return your logs to your Athletic Trainer on Monday of each week.

Second, we ask that you report to your Athletic Trainer if you have any persistent pain (more than 2 or 3 days) or injury in the lower extremity. It is very important that you do this if you agree to be a part of this study. If you do not report injuries or pain to your Athletic Trainer, it will make our information inaccurate. The Athletic Trainer will determine what should be done next with regard to your pain/injury. It is possible that you will be referred to an orthopedic doctor for evaluation.

PRINCIPAL INVESTIGATORS: Craig E. Broeder, Ph.D., Kathy D. Browder, Ph.D., Michael H. Blackburn, ATC

TITLE OF PROJECT: A Prospective Study to Identify Etiological Risk Factors Associated with MTSS and Stress Fractures in Intercollegiate Athletes

POSSIBLE RISKS/DISCOMFORTS:

There will be little to no risk or discomfort to you since you will not be required to physically exert yourself during the measurement session.

POSSIBLE BENEFITS

There will be no financial incentives gained by you for participating in this study. You will receive a free doctor's evaluation if you develop MTSS or a stress fracture during the study. **However, your respective university or health insurance will pay for any diagnostic testing or treatment that is required.** This study may determine relationships between these risk factors and these conditions and possibly provide insight to the reasons why these injuries occur. This study will be one of the first to examine risk factors for MTSS and tibial stress fractures. The results from this study may lead to prevention and improved management of these conditions by health professionals.

CONTACT FOR QUESTIONS

If you have any questions, problems, or research-related medical problems at any time, you may call Michael Blackburn at (423) 439-4208 or Dr. Craig Broeder at (423) 439-5380. In addition, you may also call the Chairman of the Institutional Review Board at (423) 439-6134 for any questions you may have about your rights as a research subject.

CONFIDENTIALITY

Every attempt will be made to see that your study results are kept confidential. A copy of the records from this study will be stored in the Department of Physical Education, Exercise and Sport Sciences for at least 10 years after the end of this research. The results of this study may be published and/or presented at meetings without naming you as a subject. Although your rights and privacy will be maintained, the investigators listed above for this study, the Secretary of the Department of Health and Human Services, the East Tennessee State University/V.A. Medical Center Institutional Review Board, and the Food and Drug Administration have access to the study records. Your medical records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above. Your coaches, athletic trainers, and/or teammates will not have access to any of the individual information collected from you during the initial testing session. Your coaches and teammates will not have access to the training logs that you complete for the study. However, your athletic

PRINCIPAL INVESTIGATORS: Craig E. Broeder, Ph.D., Kathy D. Browder, Ph.D., Michael H. Blackburn, ATC

TITLE OF PROJECT: A Prospective Study to Identify Etiological Risk Factors Associated with MTSS and Stress Fractures in Intercollegiate Athletes

trainer will have access to these logs since you will be turning them in to the trainers. We will ask the athletic trainers not to review the logs, but cannot guarantee this confidentiality.

COMPENSATION FOR MEDICAL TREATMENT

East Tennessee State University (ETSU) will pay the cost of emergency first aid for any injury, which may happen as a result of your being in this study. They will not pay for any other medical treatment. Claims against ETSU or any of its agents or employees may be submitted to the Tennessee Claims Commission. These claims will be settled to the extent allowable as provided under TCA Section 9-8-307. For more information about claims call the Chairperson of the Institutional Review Board of ETSU at 423-439-6134.

VOLUNTARY PARTICIPATION

The nature, demands, risks, and benefits of the project have been explained to me as well as are known and available. I understand what my participation involves. Furthermore, I understand that I am free to ask questions and withdraw from the project at any time, without penalty. I have read, or have had read to me, and fully understand the consent form. I sign it freely and voluntarily. A signed copy has been given to me.

Your study record will be maintained in strictest confidence according to current legal requirements and will not be revealed unless required by law or as noted above.

____

Signature of the Volunteer Date

____

Signature of the Investigator Date

____

Signature of the Witness Date

Appendix B

Narrative Description

NARRATIVE DESCRIPTION GUIDELINES

1. PROJECT TITLE: A Prospective Study to Identify Etiological Risk Factors Associated with MTSS and Stress Fractures in Female Intercollegiate Athletes

PRINCIPAL INVESTIGATORS: Craig E. Broeder, Ph.D., Kathy D. Browder, Ph.D., Michael H. Blackburn, ATC

2. PLACE TO BE CONDUCTED: This study will be conducted at the athletic training rooms of East Tennessee State University, Milligan College, and Tusculum College.

3. OBJECTIVES: The major objectives of the study are the following:

   a) To identify anatomical and physiological risks factors that may be associated with MTSS and stress fractures in female intercollegiate athletes.

   b) To obtain the incidence rates for MTSS and stress fractures in female intercollegiate athletes.

4. SUMMARY:

Medial tibial stress syndrome (MTSS) and tibial stress fractures affect athletes and non-athletes during their training regimes. These can be debilitating injuries to the individuals since their athletic performance and activities of daily living may be affected. Little research has examined the risk factors associated with these conditions in the athletic population. This study will attempt to identify the anatomical and physiological risk factors associated with MTSS and stress fractures. One hundred female intercollegiate student-athletes will be recruited to participate in the study. During preseason physicals, each subject will complete a questionnaire about eating disorders and previous medical history. Lower extremity alignment measurements will also be obtained. During the preseason and the competitive season, subjects will keep a weekly training log and will be monitored for the development of MTSS or a tibial stress fracture. If one of these conditions develops, a Certified Athletic Trainer (ATC) will classify the condition using the criteria established by the primary investigator. A medical doctor (M.D.) will diagnose the condition and recommend the appropriate treatment. At the completion of the study, anatomical and physiological factors will be compared between subjects who developed MTSS or a stress fracture and subjects who did not.

5. SPECIFIC ROLE OF HUMAN SUBJECTS: One hundred female subjects will be recruited for this investigation. The subjects must not have a history of stress fractures or other fractures to the lower extremity and must not have sustained a lower extremity injury in the past three months. The subjects will also be excluded if they have had a major surgery (e.g., ACL Reconstruction) in the past six months. The subjects must be participating in intercollegiate soccer, volleyball, cross country, or track and field at their respective institutions.

Each subject will complete an initial testing session that will take 30 to 40 minutes. During this session, the subjects will complete two questionnaires, and lower extremity alignment will be measured for each leg. The first questionnaire was designed by the investigators and will be used to obtain previous medical, sports, and menstrual history. Subjects may be excluded from the study at this time if (1) they a history of stress fractures or other fractures to the lower extremity, (2) in the past 3 months, they have sustained a lower extremity injury that interrupted their normal daily routine and required treatment from an athletic trainer or physician, or (3) in the past 6 months, they have had major surgery (e.g., ACL reconstruction) on either lower extremity. The second questionnaire is the EAT-26 and will be used to obtain information on symptoms and characteristics of eating disorders. Each of the lower extremity alignment measurements is described below.

a. Static Pronation: The Navicular Drop Test will be used to determine the amount of static pronation. In this test, the navicular tubercle is marked with a black marker and the vertical height of the navicular tubercle above the ground is measured in millimeters by placing a mark on an index card where the navicular tubercle is located. This measurement is taken in a non-weight bearing and weight bearing position, and static pronation is determined by the difference score between the two positions. For the non-weight bearing position, the examiner will place the subject's foot in a subtalar neutral position and measure navicular height while she is sitting in a chair with her feet on the ground. For the weight bearing position, the subject will stand with feet shoulder width apart, weight equally distributed on each foot. Three trials will be taken in each position and the average of the difference scores will be calculated and utilized for data analysis.

b. Dorsiflexion Range of Motion (ROM): Dorsiflexion ROM will be determined using a goniometer. The subject will lie prone with her knees extended and the ankles over the edge of the table. The head of the fibula, fifth metatarsal, and the lateral malleolus will be marked with a black marker as reference points. The axis of the goniometer will be placed on the lateral malleolus. The proximal arm will be aligned with the head of the fibula and the distal arm will be aligned with the fifth metatarsal. The subject will actively dorsiflex her foot while the examiner passively dorsiflexes her foot at the same time. This will be done very slowly. When the subject indicates that she can go no further, the reading will be obtained from the goniometer. Three trials will be taken on each foot, and the average for each foot will be calculated and utilized for data analysis.

c. Leg Length Discrepancy (LLD): Leg length for each leg will be measured from the ipsilateral anterior superior iliac spine (ASIS) and ipsilateral medial malleolus using a tape measure. The subject will lie supine with their knees extended and feet approximately 15 cm apart. The ASIS and medial malleolus will be marked with a black marker on each subject prior to the measurement. The right and left sides will be alternated. The difference in length between the right and left leg will be calculated as a measure of LLD. Three trials will be taken on each leg, and the average LLD will be calculated and utilized for data analysis.

d. Knee Alignment: Three measures of knee alignment will be taken during this session: Q-angle, A-angle, and observational method. The procedures for each is described below:

Q-angle: The subject will lie in a supine position, and the ASIS, tibial tubercle, and the midpoint of the patella will be marked with a black marker. A goniometer will be used to measure the angle formed by the line from the ASIS to the midpoint of the patella and the line from the tibial tubercle through the midpoint of the patella. Three trials will be taken on each leg, and the average angle for each leg will be calculated and utilized for data analysis.

A-angle: The subject will sit on the table with knees flexed to 90°. The tibial tubercle, midpoint of the patella, and the superior aspect of the patella will be marked with a black marker. A goniometer will be used to measure the angle formed by the vertical line passing through the midpoint of the patella and the line from the tibial tubercle to the superior aspect of the patella. Three trials will be taken on each leg, and the average angle for each leg will be calculated and utilized for data analysis.

Observational method: This technique will be qualitative in that the subjects will be classified as varus, valgus, or normal. The subject will stand with her feet shoulder width apart, facing forward. She will gradually move her feet closer together until the medial femoral condyles or the medial malleoli touch. She will be classified as varus if the medial malleoli touch before the medial femoral condyles. If the medial femoral condyles touch before the medial malleoli, she will be classified as valgus. If the medial malleoli and medial femoral condyles touch simultaneously, she will be classified as normal. Three trials will be taken, and the most frequently occurring classification will be used for data analysis.

After the initial testing session, subjects will be monitored throughout their preseason and season (approximately 20 weeks) for development of MTSS or a stress fracture. Subjects will be asked to report to their institution's athletic trainer if they develop any lower extremity pain or injury during the course of the study. The Certified Athletic Trainer (ATC) will classify the condition using the following criteria:

- Pain must be chronic in nature lasting for more than two weeks.
- Pain must occur from repetitive running or jumping with no other suspected causes of the injury, such as a contact injury or infection.
- Subject must receive treatment from the athletic trainer or physician, and the condition must alter their normal daily routine.

If a subject meets these criteria, she will be referred to an orthopedic doctor for diagnosis of the condition and recommendation for appropriate treatment. MTSS will be defined as pain that is localized in the distal 1/3rd of the posteromedial border of the tibia. A tibial stress fracture will be defined as specific tenderness in certain spots along the tibia.

Subjects will also be responsible for keeping a weekly training log throughout the study, which will be turned into the athletic trainer at their institution by Monday of each week. This log will be used to determine the duration of practice, amount of recovery between sessions, and any extra training that the subjects may do on their own.

6. SPECIFIC RISKS TO SUBJECTS: There may be some risk and discomforts during the testing, but these will be little to none since the subject will not be required to physically exert herself during the measurement session.

7. BENEFITS TO SUBJECTS: There will be no financial incentives gained by participating in this study. The subject will receive a free doctor's evaluation if they develop MTSS or a stress fracture. **However, their respective university or health insurance will pay for any diagnostic testing that is required.** In addition, this study may determine relationships between these risk factors and these conditions and possibly provide insight to the reasons why these injuries occur. This study will be one of the first to examine risk factors for MTSS and tibial stress fractures. The results from this study may lead to prevention and improved management of these conditions by health professionals.

8. INDUCEMENTS: No payment will be given to subjects.

9. SUBJECT CONFIDENTIALITY: Each subject's right to privacy will be maintained. The medical information will be available for inspection by the Food & Drug Administration, the Department of Health and Human Services, and the ETSU IRB. All information about the subject will be treated confidentially and will not be revealed, except as noted above, unless required by law.

10. INFORMED CONSENT: The Informed Consent is attached. All subjects will have the Informed Consent explained to them and all their questions will be answered. The subject will be required to sign the Consent in order to participate in the project.

11. ADVERSE REACTION REPORTING: All adverse reactions will be reported verbally to the ETSU/VA IRB Chairman within 24 hours, and in writing to the ETSU/VA Institutional Review Board Coordinator within 5 days from the date it becomes known to the Investigator.

12. PERTINENT LITERATURE:

1) Beck, B.R. (1998). Tibial stress injuries – An aetiological review for the purpose of guiding management. Sports Medicine, 26, 265-279.

2) Knapp, T.P., Mandelbaum, B.R., & Garret, W.E., Jr. (1998). Why are stress fractures so common in the soccer player? Clinics in Sports Medicine, 17, 835-853.

3) Michael, R.H., & Holder, L.E. (1985). The soleus syndrome: A cause of medial tibial stress (shin splints). American Journal of Sports Medicine, 13, 87-94.

4) Starkey, C., & Ryan, J.L., (1996). The foot and toes. Evaluation of orthopedic and athletic injuries. Philadelphia: F.A. Davis.

13. LOCATION OF RECORDS: The data from each subject will be coded numerically. Only the primary and co-investigators will have access to a master list of the subjects. A copy of the records from this study will be stored in the Department of Physical Education, Exercise and Sport Sciences for at least 10 years after the end of this research.

Attachments: Informed Consent
Medical & Sports History Questionnaire
EAT-26 Questionnaire
Training Logs and Instructions
Memorandum from Dr. Todd Fowler agreeing to participate as the orthopedic doctor in the study

Appendix C

Medical & Sport History Questionnaire

MEDICAL & SPORT HISTORY QUESTIONNAIRE

Name: ________________________________ **Subject #**:__________

Date: __________________________________

University or School: ___________________

Collegiate Sport: ________________________

Race or Ethnic Group (please circle one):

Caucasian African American Hispanic Asian Native American

Age: _____ **Year in School** (please circle one): FR SO JR SR

Previous Medical History (Please circle one):

1) Have you had a lower extremity injury in the past six months that required treatment by an athletic trainer or doctor? YES NO

If YES, please give date of injury and explain: ____________________________

____

2) Have you ever had surgery?

YES NO

If YES, please give dates and explain: _________________________________

____

3) Have you ever had a stress fracture or fracture to the lower extremity?

YES NO

If YES, please give dates and explain: _________________________________

____

4) Do you wear orthotics or assistive devices (arch supports)? YES NO

- If YES, how many years have you worn them? _____________
- If YES, when do you wear them? _______________________
- If YES, what type (rigid, soft, or semi-rigid): ________________

5) Are you currently taking any medication? YES NO

If YES, please list all medications:____

____

Sport Specific Questions:

1) What leg would you prefer to use to kick a ball? RIGHT LEFT

2) How many years have you been participating in your sport?
1 to 3 years 4 to 6 years 7 to 10 years > 10 years

3) Please describe your conditioning program for the past 3 months. ________________

____

Menstrual History:

1) What was your age of menarche onset? ________________________________

2) How many menstrual cycles have you had in the last 12 months (Please circle one)?
≤ 3 cycles 4 to 8 cycles ≥ 9 cycles

3) Are you currently taking birth control pills (Please circle one)?
YES NO

- If YES, please list which type: ________________________________
- If NO, have you ever taken birth control pills? YES NO
- If YES, please state when you last took birth control pills (months or years): ____________________

For Office Use Only

Exclusion Criteria

___ History of stress fracture or fracture of the lower extremity.

___ History of lower extremity injury in the last three months.

___ Not released by physician in the past six months after having a major surgery (ACL Reconstruction) on the lower extremity.

___ **ACCEPTED** ___ **NOT ACCEPTED**

Appendix D

EAT-26 Test

Subject #: ___________ Date: _________________

Eating Attitudes Test- Eating Disorder

EAT © David M. Garner & Paul E Garfinkel (1979), David M. Garner, et al., (1982)

The Eating Attitudes Test (EAT-26) was the screening instrument used in the 1998 National Eating Disorders Screening program. The EAT-26 is probably the most widely used standardized measure of symptoms and concerns characteristics of eating disorders. The EAT-26 alone does not yield a specific diagnosis of an eating disorder. Neither the EAT-26, nor any other screening instrument, has been established as highly efficient as the sole means for identifying eating disorders.

Age ☐ Sex: F ☐ M ☐ Height: ☐ Current Weight: ☐

Highest Weight: ☐ Lowest Adult Weight: ☐

Education: if currently enrolled in college/ university, are you a:

Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Grad Student ☐

If not enrolled in school, level of education completed:

Jr. High/ Middle School ☐ High School ☐ College ☐ Post College ☐

Ethnic / Racial Group:

African American ☐ Asian American ☐ European American ☐ Hispanic ☐ American Indian ☐ Other ☐

Do you participate in athletics at any of the following levels:

Intramural ☐ Inter-collegiate ☐ Recreational ☐ High School Teams ☐

Please Circle a Response for Each of the Following Statements:

Question	Always	Usually	Often	Sometimes	Rarely	Never
1. Am terrified about being overweight	3	2	1	0	0	0
2. Avoid eating when I am hungry.	3	2	1	0	0	0
3. Find myself preoccupied with food.	3	2	1	0	0	0
4. Have gone on eating binges where I feel I may not be able to stop.	3	2	1	0	0	0
5. Cut my food into small pieces.	3	2	1	0	0	0
6. Aware of the calorie content of foods I eat.	3	2	1	0	0	0
7. Particularly avoid food with a high carbohydrate content (bread, rice, potatoes, etc.)	3	2	1	0	0	0
8. Feel that others would prefer if I ate more.	3	2	1	0	0	0
9. Vomit after I have eaten.	3	2	1	0	0	0
10. Feel extremely guilty after eating	3	2	1	0	0	0
11. Am preoccupied with a desire to be thinner.	3	2	1	0	0	0

12. Think about burning up calories when I exercise.	3	2	1	0	0	0
13. Other people think I'm too thin.	3	2	1	0	0	0
14. Am preoccupied with the thought of having fat on my body.	3	2	1	0	0	0
15. Take longer than others to eat my meals.	3	2	1	0	0	0
16. Avoid foods with sugar in them.	3	2	1	0	0	0
17. Eat diet foods.	3	2	1	0	0	0
18. Feel that food controls my life.	3	2	1	0	0	0
19. Display self-control around food.	3	2	1	0	0	0
20. Feel that other pressure me to eat.	3	2	1	0	0	0
21. Give too much time and thought to food.	3	2	1	0	0	0
22. Feel uncomfortable after eating sweets.	3	2	1	0	0	0
23. Engage in dieting behavior.	3	2	1	0	0	0
24. Like my stomach to be empty.	3	2	1	0	0	0
25. Have the impulse to vomit after meals.	3	2	1	0	0	0
26. Enjoy trying new rich foods.	0	0	0	1	2	3

Please respond to each of the following questions:

1. Have you gone on eating binges where you feel that you may not be able to stop? (Eating much more than most people would eat under the circumstances). No ☐ YES ☐

   If YES, on average, how many times per month in the last 6 months? ☐

2. Have you ever made yourself sick (vomited) to control your weight or shape?

   No ☐ YES ☐

   If YES, on average, how many times per month in the last 6 months? ☐

3. Have you ever used laxatives, diet pills or diuretics (water pills) to control your weight or shape? No ☐ YES ☐

   If YES, on average, how many times per month in the last 6 months? ☐

4. Have you ever been treated for an eating disorder? No ☐ YES ☐

   If YES, when? ☐

5. Have you recently thought of or attempted suicide? No ☐ YES ☐

   If YES, when? ☐

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Appendix E

Data Sheet for Anatomical Measurements

DATA SHEET FOR ANATOMICAL MEASUREMENTS

Name:____________________ **Subject #**: ______

University or School: ___________________

Collegiate Sport: _______________

Height (in): ________ **Weight** (lbs):______

Measurement	**Trial 1**	**Trial 2**	**Trial 3**	**Average**
1) Navicular Drop (mm)				
Right:	_____	_____	_____	_____
Left:	_____	_____	_____	_____
Difference	_____	_____	_____	_____
2) Observational Knee	_____	_____	_____	_____
3) A-angle (deg)				
Right:	_____	_____	_____	_____
Left:	_____	_____	_____	_____
4) Q-angle (deg)				
Right:	_____	_____	_____	_____
Left:	_____	_____	_____	_____
5) LLD (cm)				
Right:	_____	_____	_____	_____
Left:	_____	_____	_____	_____
Difference:	_____	_____	_____	_____
6) DF ROM (deg)				
Right:	_____	_____	_____	_____
Left:	_____	_____	_____	_____

Appendix F

Documentation Record for MTSS and TSF

INJURY DOCUMENTATION RECORD FOR THE ATHLETIC TRAINERS AND PHYSICIAN

Name: _________________________ **Subject #**: ________________
Date: ___________

University or School: ___________________

Collegiate Sport: _______________

PLEASE CHECK ONLY THE MTSS OR TIBIAL STRESS FRACTURE CRITERIA

Criteria for MTSS: (All of following criteria need to be present for this injury)

____ Pain has persisted at least two weeks believed to occur from repetitive running or jumping **(no other suspected causes such as contact injury or infection).**

____ Pain is localized along the distal posteromedial 1/3rd of the tibia **(no specific tenderness).**

____ Subject received treatment for an athletic trainer or physician and injury interrupted their normal routine.

Criteria for tibial stress fracture: (All of the following criteria need to be present for this injury)

____ Pain has persisted at least two weeks believed to occur from repetitive running or jumping **(no other suspected causes such as contact injury or infection).**

____ Pain is very intense at specific points along the tibia.

____ Subject received treatment for an athletic trainer or physician and injury interrupted their normal routine.

Athletic Trainer Notes:

____

____

____

____

____

Signature: _________________________ **Date:** ______________

Physician's Diagnosis **Date: ____________**

PLEASE CHECK ONLY THE MTSS OR TIBIAL STRESS FRACTURE CRITERIA.

Criteria for MTSS: (All of following criteria need to be present for this injury)

____ Pain has persisted at least two weeks believed to occur from repetitive running or jumping **(no other suspected causes such as contact injury or infection).**

____ Pain is localized along the distal posteromedial 1/3rd of the tibia **(no specific tenderness).**

____ Subject received treatment for an athletic trainer or physician and injury interrupted their normal routine.

Criteria for tibial stress fracture: (All of the following criteria need to be present for this injury)

____ Pain has persisted at least two weeks believed to occur from repetitive running or jumping **(no other suspected causes such as contact injury or infection).**

____ Pain is very intense at specific points along the tibia.

____ Subject received treatment for an athletic trainer or physician and injury interrupted their normal routine.

Recommendations:
____
____
____
____

Signature: __________________________ **Date**: _____________

Appendix G

Daily Training Questionnaire

DAILY TRAINING QUESTIONNAIRE

Name: _________________ **Subject #**: _______

INSTRUCTIONS: Please report the start and end times for each practice session everyday throughout the study. Also please report the intensity of the practice and finally any extra training that was performed. Answer YES to the extra training only if you do impact exercises (running, jumping, or stairs) on your own. Please return this sheet to the athletic trainer at your respective institutions by Monday of each week.

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

Season (please circle one): **Date**: ____________
PRESEASON REGULAR
Start time: ________ **End time**: ________

Intensity: (please circle one): **Extra training** (please circle one)**:** YES NO
LOW MEDIUM HIGH If YES, please report the duration/distance: ______________

VITA

MICHAEL H. BLACKBURN

Personal Data:	Date of Birth: August 18, 1977 Place of Birth: Dixon, Illinois Marital Status: Single
Education:	Medford Area Senior High, Medford, Wisconsin Winona State University, Winona, Minnesota; Athletic Training, B.S., 2000 East Tennessee State University, Johnson City, Tennessee Physical Education, M.A., 2002
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