ABSTRACT

BOERGERS, R. J. Effects of arch taping on peak force, contact surface area and neuromuscular activity at midstance. MS in Exercise and Sports Science-Human Performance, August 2000, 47pp. (R. Mikat)

This study investigated two different arch taping techniques in the treatment of athletes with medial tibial stress syndrome (MTSS). Peak force (PF), surface contact area (SCA), surface electromyography (EMG) at peak and average were analyzed in 8 college aged Ss (5 F, 3 M) during untaped (NT), traditional arch taped (TAT), and experimental arch taped (XAT) walking and running. A foot switch was used to mark time to analyze peak EMG and average EMG during midstance for the tibialis anterior (TA). The EMED SF system was used to collect force and surface area data at 70 Hz. Novel software was used to analyze the data. Statistical analysis using repeated measures ANOVA and a Bonferroni's post hoc indicated there were no significant differences between conditions for walking. Mean PF on the medial aspect of the middle 1/3 of the foot in the TAT condition was significantly ($p \leq 0.05$) greater than the NT condition during running. The mean SCA of the lateral aspect of the middle 1/3 of the foot was significantly less in the TAT than the other conditions. Trends in the data, indicated that in running there was a similar shift of PF and SCA to the lateral aspect of the foot in the XAT condition. In walking, muscle activity of the tibialis anterior (TA) was greatest in the XAT condition, which may be interpreted as a shift of muscle activity from the TA to the tibialis posterior. The data may support the use of the XAT over the TAT to relieve MTSS, due to the unfavorable results for the TAT condition.

EFFECTS OF ARCH TAPING ON PEAK FORCE.

SURFACE CONTACT AREA AND

NEUROMUSCULAR ACTIVITY AT MIDSTANCE

A THESIS PRESENTED

TO

THE GRADUATE FACULTY

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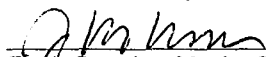Master of Science in Exercise and Sport Science – Human Performance

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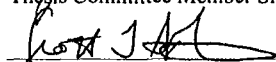
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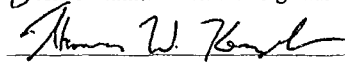
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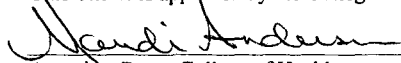Thesis Committee Member Signature   Date

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CHAPTER 1

INTRODUCTION

Background

Present research has not clearly shown whether arch taping a flat footed athlete

with anterior shin pain will alter muscle activation or force patterns in the lower leg with

walking or running. Shin splints are a common injury among athletes. This common

athletic injury along with periostitis and posterior tibial tendonitis are more correctly

referred to as medial tibial stress syndrome (MTSS) (Arnheim and Prentice, 1999). Many

different taping techniques and orthotic devices have been used in prevention and

treatment of MTSS. The effects of arch taping on MTSS is still unknown. Medial Tibial

Stress Syndrome accounts for approximately 10-15% of all running injuries and up to

60% of all conditions that cause lower leg pain in athletes (Levandowski & DiFrori,

1994). Moss, Gorton, and Deters (1993) predict that 75% of all running injuries could be

linked to excessive pronation. A high percentage of the athletes who have shin splints

have a functional pes planus or flat foot (Scranton, Pedegana, & Whitesel, 1982). Pes

planus is characterized by a flattening of the medial longitudinal arch (Starkey & Ryan,

1996). Ryan (1977) is quick to point out that the pronated foot is not the same as a fallen

longitudinal arch. It is important to know the pronated foot is a possible causative factor

for MTSS, and not the fallen longitudinal arch. In order to treat MTSS pain, Arnheim

and Prentice (1999) suggest that correction of abnormal pronation during walking and

running must be addressed with an adjustment of footwear, orthotics or other means.

There seems to be more than one risk factor for MTSS, thus it is prevalent among athletes. Therefore it is important to gain a further understanding of possible mechanisms associated with it in order to develop appropriate treatment strategies.

Medial Tibial Stress Syndrome refers to pain in the medial area of the tibia (DeLacerda, 1980). Specifically, MTSS refers to pain at the medial aspect of the tibia along the proximal two-thirds of the bone, or along the lateral aspect of the tibia (O'Donoghue, 1970). There are many pathological hypotheses as to the etiology of MTSS. According to Clancy (1974), O'Donoghue (1970), and Ryan (1977), small tears of the muscle tendon at the insertion could cause inflammation that produces pain. These authors also suggested that small tears in the muscle itself and possible tears to the interosseous membrane of the tibiofibular joint may have resulted in a painful contraction. Due to these mechanisms it is possible that arch taping strategies may have a differential effect on plantar force distribution and muscle activity of the lower leg.

The muscles of the lower leg control the positioning and movement of the foot. It is apparent from the anatomy that the tibialis anterior (TA) and tibialis posterior (TP) are important in the support of the medial aspect of the foot. In 1980, DeLacerda stated that the TA originates from the upper two-thirds of the lateral aspect of the tibia and inserts on the first cuneiform and first metatarsal head. The first cuneiform and navicular are positioned one anterior to the other respectively and create a joint. DeLacerda (1980) also stated that the TP originates from the posterolateral aspect of the tibia and inserts on the navicular tuberosity.

The forces produced during walking and running place much stress on the muscles of the lower leg. In a pronated foot, the medial border of the foot has to absorb abnormal stress from the rearfoot (Lutter, 1978). Since the TA and TP muscles support the medial longitudinal arch, and become overstressed due to excessive foot pronation, which results in increased tensile forces on the muscles themselves (Arnheim & Prentice, 1999). Because of the anatomical structure of the foot, DeLacerda (1980) realized that there should be some relationship between the displacement of the navicular tuberosity and shin splints. He found a significant positive correlation between displacement of the navicular tuberosity and incidence of MTSS. The study found manual muscle testing of isolated muscle actions in 81 subjects also revealed pain of MTSS in the TA and the TP in 41 and 48 cases respectively (DeLacerda, 1980). Research by Messier and Pittala (1988) also supports DeLacerda (1980) findings. In their study of recreational runners, those with shin splints exhibited more pronation and a greater velocity of pronation. Messier and Pittala (1988) further hypothesized that excessive stress is placed on the TP during toe-off in order to compensate for weak gastroc/soleus complex, resulting in the inflammation of the TP and causing MTSS. In 1999, Kaufman, Brodine, Shaffer, Johnson, and Cullison examined the effects of foot structures on overuse injuries in the military. They reported that subjects with a pes planus were more at risk of developing an overuse injury. These authors further stated that the malalignment of the tarsal bones causes the muscles to support the load rather than the bony structure, leading to the collapse of the medial longitudinal arch. Certified Athletic Trainers will often try to correct the excessive pronation with arch taping.

Since MTSS is often linked with excessive pronation of the foot, it would seem reasonable to try to treat these pronated feet to alleviate the pain from MTSS. Many types of taping and shoe inserts have been used in order to treat MTSS over the years, but their effects have not been well documented (Scranton, et al., 1982). Schulthies and Draper (1995), suggested that arch taping may provide support to the medial longitudinal arch when excessive pronation of the subtalar joint was corrected. Arnheim and Prentice (1999), and Perrin (1995) also support arch taping as a viable treatment for pronated feet that are related to MTSS. Measuring the alterations of forces under the foot during the support phase of gait may provide valuable information in determining what treatments would be successful (Scranton, et al., 1982). Therefore, in order to assess the different effects of various taping conditions, the muscle activity of the lower leg and the distribution of plantar forces need to be examined.

Purpose of the Study

The purpose of this study was to determine the effects of various methods of arch taping on the peak force and surface contact area on the middle 1/3 of the foot in midstance during walking and running. A secondary purpose was to examine the effects of arch taping on normalized peak TA EMG and the average TA EMG amplitudes relative to midstance.

Statement of the Problem

There does not seem to be a clear cut approach to treating athletes with MTSS. Taping an athlete with MTSS can sometimes be "hit or miss" (Perrin, 1995). Often, clinicians perform some type of arch taping if the athlete has a functional pes planus and

is complaining of anterior shin pain. There is lack of research concerning the effects of arch taping on the surface contact area of the middle 1/3 of the foot. Also, it is unclear as to what effect the arch taping has on the neuromuscular control of the TA.

Need for the Study

In a conversation with Robert Pettitt, ATC, Mount Union College, (personal communication, October 24, 1999) it was suggested to this researcher that a modified longitudinal arch taping technique over the dorsal aspect of the foot would be more effective than the traditional longitudinal arch taping over the plantar surface of the foot in the treatment of MTSS. Previous research suggests that the longitudinal arch taping was a viable treatment for MTSS (Scranton, et. al., 1982). The possibility exists that the Pettitt technique could provide more support to the musculature of the foot, thus pulling up on the medial longitudinal arch, forcing the foot out of pronation to some extent. This would be represented by a decrease in the TA activity, shift in peak force from the medial to the lateral side of the foot, and a decrease in surface contact area on the medial aspect of the plantar surface of the foot.

Null Hypotheses

1. There are no differences in peak TA EMG amplitude between the traditional arch taping (TAT), the experimental arch taping (XAT) and the untaped (NT) foot during walking.

2. There are no differences in peak TA EMG amplitude between the TAT, the XAT, and the NT foot during running.

3. There are no differences in average TA EMG amplitude between the TAT, the XAT, and the NT foot during walking.

4. There are no differences in average TA EMG amplitude between the TAT, the XAT and the NT foot during running.

5. There are no differences in surface contact area of the middle 1/3 of the foot between the TAT, the XAT and the NT foot during walking.

6. There are no differences in surface contact area of the middle 1/3 of the foot between the TAT, the XAT and the NT foot during running.

7. There are no differences in peak force of the middle 1/3 of the foot between the TAT, the XAT and the NT foot during walking.

8. There are no differences in peak force of the middle 1/3 of the foot between the TAT, the XAT and the NT foot during running.

Assumptions

1. Peak EMG amplitude is a valid means of evaluation of the neuromuscular response of the TA.

2. The navicular drop test is a valid means of testing for pes planus.

Limitations and Delimitations

1. Only eight volunteer subjects with a current history of anterior shin pain were used.

2. The TA was the only surface EMG measure obtained.

3. The study did not examine the effects of other taping techniques.

4. Running speeds for all subjects were standardized to a range of 1.6 to 2.0 m/s.

5. Walking speeds for all subjects were standardized to a range of 0.9 to 1.25 m/s.

6. Five trials for each experimental condition were performed.

7. All subjects had a navicular drop test of 5mm or greater.

Definition of Terms

Peak Force - the maximum force occurring beneath a plantar region; it reflects the amount of strain placed on that anatomical region (Sneyers, et al., 1995).

Pes Planus - the structural abnormality and alteration of the positioning of the bones which causes a lowering of the medial longitudinal arch (Booher & Thibodeau, 1994).

Pronation - more than 4 degrees of calcaneal valgus with eversion of the forefoot (Moss, et al., 1993).

Medial Tibial Stress Syndrome (MTSS) - a condition causing pain in the anteromedial or anterolateral aspect of the lower leg.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The effects of arch taping on peak force, surface contact area and muscle activity of the lower leg are unclear. This chapter reviews pertinent literature on force distribution analysis using the EMED (Novel, Germany) system and other systems for pressure analysis. Also, articles dealing with EMG of the lower leg are reviewed. The relationship between MTSS and foot pronation is examined. Experiments dealing with the treatment of MTSS, using taping and various other methods, were reviewed as well.

Foot Pronation and MTSS

According to O'Donoghue (1970), longitudinal arch weakness and pronation of the foot are common risk factors associated with MTSS. In 1980, DeLacerda stated that the foot was made of the rearfoot and the forefoot. Between the two joints is the talonavicular and calcaneocuboid joints. Motion at these joints permits the forefoot to adduct and abduct on the rearfoot. In foot abduction, the rearfoot assumes a valgus position and the medial aspect of the foot bears the majority of the weight. Pronated foot is the term given to a foot in this position (DeLacerda, 1980).

In 1987, Donatelli suggested that maximum pronation was achieved at flatfoot and that supination begins at midstance during the gait cycle. Pronating beyond 25% of the stance phase meant excessive pronation. As a consequence, the foot would supinate too late which may cause excessive force on the foot, thus leading to inefficient

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absorpotion of forces by the muscles of the lower leg. Donatelli, (1987) cites both congenital abnormalities of the foot and developmental deformities as causes for pes planus. Root, Orien, and Weed (1977) reported that a forefoot varus is the most common reason for abnormal pronation. Forefoot varus is defined as forefoot inversion on the rearfoot with the subtalar joint in neutral (Root et al., 1977). The talar joint undergoes excessive adduction, plantarflexion and calcaneal eversion as stated by Donatelli (1987). Regardless of whether an athlete is born with pes planus or develops it over time, it could be the reason for MTSS and it needs to be addressed.

Geideman and Johnson (2000) noted that dysfunction of the TP tendon is the most common cause of acquired pes planus. As the TP loses the dynamic stability, radiographic images show that there is a lateral subluxation of the talonavicular joint as the navicular rotates laterally on the talus, which is consistent with research by DeLacerda (1980). Lateral radiographic images indicate a collapse of the medial longitudinal arch and a sagging at the talonavicular, naviculocuneiform and metatarsal-cuneiform joints.

Common developmental deformities that lead to pronation include hip dysplasia, femoral anteversion, tibial torsion, and genu varum or valgus (Donatelli, 1987). Any of the above abnormalities could change the alignment of the calcaneus, talus, cuboid and navicular. This in turn could cause the changes in the arthrokinematics of the subtalar joint (Donatelli, 1987). Subluxing of the calcaneus under the talus causes excessive pronation, which in turn causes the navicular and cuboid to separate. These changes

cause a valgus position of the calcaneus, medial bulging of the navicular tuberosity, abduction of the forefoot and a reduced height of the medial longitudinal arch (Donatelli, 1987).

In 1997, Kitaoka, Luo, and An investigated the importance of the TP tendon in the stabilization of the arch. They believed that a loss of dynamic support provided by the muscles of the foot was related to flat feet. In their cadaver study, they reported that the TP tendon provided significant stability to the arch. All of this research suggests that a change in the bony structure of the foot may lead to a flattening of the foot, place added stress on the muscles of the lower leg, and possibly lead to MTSS.

Effects of Arch Taping Support

There is limited research concerning the effects of arch taping on pronation. According to Schulthies and Draper (1995), arch taping may help in controlling excessive pronation at the subtalar joint. Overall, management of MTSS using orthotics or some form of taping has produced mixed results. In 1993, a study by Moss, Gorton, and Deters compared the effects of the reverse 8-stirrup taping technique, the low-dye taping technique, and orthotics while running on a treadmill. The results indicated that there were significant changes in maximum pronation and total rearfoot movement. Results showed that the no support and the low-dye taping conditions were significantly greater than the reverse 8-stirrup taping in degrees of maximum pronation (Moss, et al., 1993). The authors stated in the article that excessive pronation at the subtalar joint was probably directly linked to MTSS which prompted their study.

Scranton, et al. (1982) examined the distribution of forces under the foot with low-dye arch taping, heel cups, medial arch supports and barefoot. Low-dye arch taping was explained to be similar to the TAT as described by Perrin (1995). This investigation used subjects with a functional pes planus. The results for Scranton, et al. 1982, showed that the TAT unloaded the medial arch during walking gait. In the taped foot, forces moved through the midfoot at a faster rate than the untaped. Traditional arch taping tends to medialize the heel strike, allowing for a normal force pattern that diminished the duration of the forces under the midfoot (Scranton, et al., 1982).

In 1991, Ator, Gunn, McPoil and Knecht examined the effectiveness of the low-dye arch taping and the double X arch taping. This study compared the ability of the arch taping techniques to support the medial longitudinal arch before and after exercise. Both tapings significantly increased the height of the navicular tuberosity before exercise, but there was no significance post exercise. However, the results did show that the navicular tuberosity height was higher for the taping conditions than the barefoot control after exercise. The researchers concluded that the tapings offered some degree of support to the medial longitudinal arch.

Draper (1991), examined the differences in support of the medial longitudinal arch between orthotics and traditional arch taping. He used electrodynography (EDG) to determine force at the navicular. High force readings in this area would indicate support of muscle and soft tissue structures. The results indicated that the orthotics may have provided significantly more support than the arch taping. However, Draper (1991) also

established that 94% of the subjects felt that the tape provided more support than the orthotics.

Pressure Distribution During Walking

In 1995, Nyska, McCabe, Linge, Laing, and Klenerman used the EMED-SF platform to examine contact area and peak pressure in subjects under barefoot conditions and wearing various types of shoes. A metronome was used to set the cadence for walking. The study showed that during the midstance, the foot supinated and the heavier the subject, the greater the peak pressure was on the mid-foot and lateral forefoot. The shoes did not alter this pattern. The only differences found by Nyska, et al. (1995) were that the peak pressures in the heel occurred later in time with the shod foot, which may have been from the heel of the shoe acting as a shock absorber.

A study by Soames (1985) revealed that in barefoot walking, heel strike occurred initially on the posterolateral aspect of the heel and that the peak pressures of the heal were not reached until approximately 25% of the stance phase was completed. During the stance phase, the heel, lateral aspect of the midfoot and the metatarsals were all in contact with the ground. Peak pressure was initially high at heelstrike, which indicated that force was being transferred forward in the foot at a rapid speed. The peak pressure decelerated after heelstrike, but then accelerated again when pressure was across the midfoot (Cavanagh & Ae, 1980). Midfoot pressures during walking were relatively low. The midstance was more a representation of average forces of the forefoot and hindfoot, rather than a true peak pressure of the midfoot (Cavanagh & Ae, 1980). In 1976, Scranton and McMaster showed greater weight bearing in the midfoot region in subjects

with pes planus. As the foot progressed out of the stance phase, the center of pressure moved medially across the metatarsal break and terminates during push off of the first and second toes (Soames, 1985). Soames, (1985) also determined that increasing the speed during walking caused a shift of weight more towards the hindfoot and peak pressure was increased.

Scranton and McMaster (1976) examined force distribution under the foot in walking and running. During normal walking gait, the stance phase is initiated by heel strike and then forces shift smoothly to the lateral midfoot and metatarsals. When push off was initiated, the forces were entirely over the metatarsals and toes. Subjects with pes planus were reported to have an unusual distribution of forces during walking. First contact was made by the midfoot and the midfoot bore a large amount of weight throughout the stance phase (Scranton & McMaster, 1976).

Foot Pressure in Running

In 1980, Cavanagh and Lafortune used a force plate to examine pressure patterns during running. They observed two patterns of initial ground contact. Initial contact was found to be either in the hindfoot (normal) or midfoot area. The midfoot strikers landed with a somewhat flat foot. Some subjects were able to run at the same speed as others but had lower peak forces. These differences in peak pressure did not correlate to the point of first impact (Cavanagh & Lafortune, 1980). Different types of shoes were not examined, and this may have been responsible for the results.

Forces under the foot during running are significantly different than walking (Scranton & McMaster, 1976). Instead of the typical heel to toe progression of forces

that is seen in walking. a different pattern of forefoot contact is seen in running. The duration of hindfoot and midfoot contact is much shorter. the metatarsals bear more weight and there is increased support by the toes. Overall. there is an anterior shift of the forces (Scranton & McMaster. 1976). In pes planus subjects. contact is first made at the midfoot and there is an abnormal distribution of forces between the first and second metatarsal heads (Scranton & McMaster. 1976).

A study by Sneyers. Lysens. Feys and Andries (1995) examined the pressure patterns of various subjects while running using the pododynograph system connected to pressure measuring insoles. The examination of the relationship of injury rate to foot structure was first performed. The results found that the pes planus group had significantly more overuse injuries than subjects with normal foot alignment. The results for pressure analysis showed that in barefoot running. the anteroposterior impulse distribution of the heel was significantly higher ($p = 0.001$) in the pes planus group as compared to the normal group (Sneyers. et al.. 1995).

Muscle activity of TA

According to Basmajian and DeLuca (1985). the TA is responsible for deceleration of the foot at heel strike. There is no muscle activity recorded during midstance and heel off in normal subjects. however those with pes planus have extended muscle activity into the midstance during gait. The patterns of muscle activity in TA suggest that it may not be responsible for medial arch support during walking. During maximum weight bearing at midstance, the TA was relatively inactive in normal subjects (Basmajian & Deluca. 1985).

Rodgers (1988) stated that TA has the majoritiy of a .i··ity at the end of the swing phase in gait. She further stated that in some individuals, TA also pulls the leg forward over the foot after flat foot is reached. This information coincides with what Basmajian & Deluca (1985) previously stated. However it is important to note that some individuals may have activity of TA in midstance.

In 1980, DeLacerda performed an extensive study on the relationship between foot pronation and TA electromyography with subjects with different histories of MTSS. Subjects that had shin splints during the time of the study tested positive for pain during a manual muscle test for the TA or TP. Painful dorsiflexion and inversion of the foot without great toe extension implicated the TA (Kendall, McCreary, & Provance, 1993). He used the navicular drop test to determine pes planus in his subjects and then examined the right leg of all subjects. DeLacerda did not examine the muscle activity of TA during walking or running, but rather he examined it in non-weight-bearing (NWB), unipedal and bipedal stances. The bipedal stance was represented by the subject bearing weight equally on both legs while standing. The unipedal stance represented the subject bearing all weight on one leg. Electrical activity of TA was computed by taking the amplified signal and summing up the means (DeLacerda, 1980). The EMG differential was also calculated. The EMG differential was the largest in the unipedal stance for all the subjects. The unipedal stance would simulate running since only one leg was in contact to the ground. There was a consistent difference when comparing the EMG differential for the bipedal stance and the unipedal stance. The magnitude of the EMG differential

decreased as the valgus angle of the foot increased, which suggested that as the degree of pronation increased, contractile force of TA increased (DeLacerda, 1980).

In 1999, Nawoczenski and Ludewig examined the electromyographic effects of foot orthotics on TA and other muscles of the lower extremity. Foot orthotics are often used to correct structural malalignment of the foot, such as excessive pronation, much like the TAT and the XAT. Runners with lower extremity pain and a structural malalignment were chosen as subjects for the study (Nawoczenski & Ludewig, 1999). Foot orthotics were custom made for each subject and the orthotics were placed into the same type of running sandal for each subject. Electrodes were placed on the TA and other lower leg muscles. Subjects ran on a treadmill and the EMG amplitude was determined for each muscle during the swing and stance phases of the running cycle (Nawoczenski & Ludewig, 1999). The results showed a significant increase (37.5%) in the muscle activity of TA during the sandal/orthotic condition as compared to the sandal/nonorthotic condition during the first 50% of running stance. It was originally hypothesized that the orthotic would reduce the muscle activity of TA. Because of these results, it was unknown whether orthotics gave the TA a mechanical advantage to supinate the foot (Nawoczenski & Ludewig, 1999). The authors of the study speculated that the orthotic interfered with normal muscle function of TA.

Reber, Perry and Pink (1993) studied muscle firing patterns in the ankle during running. They found TA activity at the midswing and late swing, and it was also noted that TA sustained a higher level of activity than any of the other muscles tested. The TP had significantly higher muscle activity during the early stance phase than the peroneus

brevis. This would support the idea that TP is responsible for controlling normal pronation forces. Since hyperpronation injuries are a nusance to runners, strengthening of the TP could help in the avoidance of of excessive pronation in the stance phase (Reber, et. al., 1993).

Challenges in establishing speed of ambulation in gait research

During gait research it is necessary to standardize the speeds for walking and running, so that the speed itself does not become a confounding variable. Speed of ambulation will affect ground reaction forces. Newton's law states that force is the product of mass and acceleration. Mass of the subject will not change, however acceleration needs to be standardized to limit the variability of the forces produced. Regulation of speed is also necessary for collecting EMG data. A subject moving at a rate of 10 m/s would have greater muscle activity than a subject moving at a rate of 2 m/s. Stride length and rate of contact (foot strike/min) is highly individualized. Using a treadmill to account for the speed variable could alter a subject's natural stride length and rate and may also alter motor unit recruitment (Winter, 1987).

Winter (1987), stated that the typical cadence for walking is between 80 and 120 foot strikes per min. Craik and Oatis (1995) calculated means for walking velocities in males and females. Their research reported that males averaged 1.18 m/s and females averaged 1.12 m/s. Setting a fixed cadence with a metronome or on a treadmill could accommodate one gender but not the other, thus causing a potential disruption in the natural gait pattern (Pettitt, 1998).

Summary

In summary, there is some indication that arch taping and other devices may be successful in correcting pronation of the foot and relieving signs and symptoms of MTSS. There is also some evidence that showed that the TA should be relatively inactive at midstance. Peak pressure and surface contact area could be decreased with some of the devices used to treat pronation of the foot.

CHAPTER III

METHODS AND PROCEDURES

Introduction

This study investigated the contact area of the middle 1/3 of the plantar surface of the foot during walking and running using the EMED SF pressure distribution measurement system of pressure analysis. EMG of the TA occurring at the midstance of gait was also assessed during walking and running. Each subject was assessed with a TAT, with the XAT, and without tape. Prior to the investigation, one subject with a functional pes planus performed one trial in each condition to ensure that all equipment was functioning properly. The study was approved by the university's Institutional Review Board before data sampling took place.

Subject Selection

The subjects (N = 8; 5 female, 3 male) with a mean age of 20 ± 1.1 were recruited from the University of Wisconsin-La Crosse men's and women's outdoor track teams. Permission was received from the head coach of each team for the recruitment process. Each subject signed a document of informed consent to participate in the study (see Appendix A). All of the subjects were experiencing self reported anterior shin pain at the time of the study. All subjects had to have a functional pes planus as well.

The navicular drop test was used to determine foot pronation during weight bearing. Each subject sat in a chair with both feet on the floor with the subtalar joint in a neutral position, and a marking was placed over the navicular tuberosity. A 3 X 5 index

card was placed next to the medial longitudinal arch and a mark was made that corresponded to the marking on the navicular tuberosity. The subject then stood up in a full weight bearing position with both feet on the ground. The new level of the navicular tuberosity was then recorded on the 3 X 5 index card. If the distance between the two marks was 10 mm or more, the subject was considered to have hyperpronation of the foot (Starkey & Ryan, 1996). Mean for the navicular drop test was 7.75 mm ± 1.8. Subjects had no previous history of knee or hip injury over the past year. The subject's dominant lower limb was determined by having him/her indicate which leg they could kick a soccer ball the furthest distance (Tanaka, et al., 1996). The subjects had a 6:2 ratio of right to left leg dominance.

Methods and Procedures

Taping Procedure

Each subject was taped by the same NATABOC certified athletic trainer. This study utilized the TAT technique described in Perrin (1995). The taping procedures utilized 1.5 in. and 1 in. Johnson and Johnson non-elastic adhesive tape. An anchor strip was first placed around the metatarsal heads using 1.5 in. tape. A 1 in. strip was then applied from the base of the great toe, wrapping around the heel, and back to the starting position. The foot was passively everted and the first metatarsal was plantarflexed during this application (Schulthies & Draper, 1995). The second 1 in. strip was applied from the base of the fifth toe, wrapping around the heel and back to the starting position. Two more strips were applied in the same fashion starting at the base of the second and fourth

toes respectively (Perrin, 1995). A closing strip of 1.5 in. tape was placed where the
initial anchor strip was to complete the taping procedure. Figure 1 illustrates this taping.

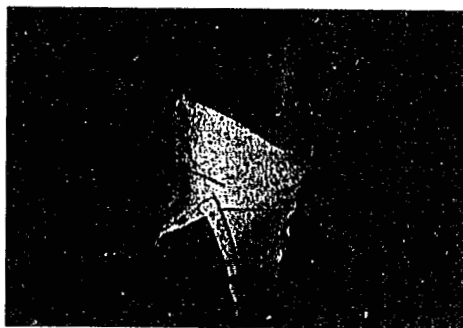Figure 1. Traditional Arch Taping

Figure 2. Experimental Arch Taping

The XAT described by Pettitt (personal communication October 24, 1999) utilized the same principles of the TAT by Perrin (1995). This taping however, was performed over the dorsal aspect of the foot, in contrast to the plantar surface of the foot used in the TAT technique. Figure 2 illustrates the experimental arch taping.

EMG procedure

The TA was the only muscle investigated in this study. Standard EMG data collection and analysis procedures were followed (Newton, Kraemer, Hakkinen, Humphries, & Murphy 1996). In order to locate the motor points of TA, a portable TENS unit (Iomed, Inc) was used. The procedures for locating the desired motor points first involved circulating two, 3.5 by 4.5 cm leads and gradually increasing the current's amplitude in order to illicit an electrical paresthetic response. The amplitude was increased while circulating the leads until the motor point of TA was found. When the placement of the leads caused dorsiflexion of the ankle and inversion of the foot, these points were marked on the leg with a black marker to indicate the motor point. Excess body hair around the marked area was removed with a single blade razor. To minimize electrode impedence (< 5KΩ), a 400-10 grit sandpaper was used to remove dead skin and an alcohol swab was then applied to cleanse the surface (Avela, Kyrolainen, & Komi 1999).

EMG data sampling

Preamplified rectangular bar leads (5 cm) were placed over the marked motor points in parallel fashion. All wires were attached proximally on the body of the subject and were fixed with Dermaclear tape. A loop was placed in the wire to eliminate any

cable movement that may interfere with the EMG signal. The Ariel Performance Analysis System (APAS) was utilized to collect and analyze all EMG measurements. Bipolar surface electrodes with an inter-electrode distance of 1.5 cm were used to collect the analog signal which was amplified (Gain – 100, Input Range –+/-1 V, Resolution – 0.5 mV, bandwidth – 10-500 Hz, Notch Filter – 60 Hz, Sampling Frequency – 1000 Hz) and transferred through an A/D converter to a computer for visualization and analysis. The raw EMG signal was full-wave rectified then peak (mV) and average peak (mV) values were determined for a specified time period. EMG data collection was initiated during each trial by a foot switch, which marked the location of heelstrike. From the foot force measurements (EMED) the time from heelstrke to midstance was determined and this interval was used as the time period in which the EMG was analyzed.

Synchronization of midstance with the EMG activity during the six test conditions

A foot switch (Motion Analysis Systems) was used to serve as a time marker for the EMG activity from heel strike to midstance. The foot switch was placed over the plantar surface of the heel covering an area of 3.0 cm in diameter. The wires were situated proximally and the wiring was connected to an open channel on the A/D board of the APAS.

EMED Measurements

The EMED-SF platform system (Novel, Germany) was used to determine peak pressure (in N/cm^2) and contact area. The platform was 445 mm x 225 mm, and contained a sensing area of 2016 mm. Data collecting speed was 70 Hz. The platform was set flush in the runway which measured 180 cm by 580 cm. Peak pressure was

displayed on the color monitor with the pressure levels represented by color codes. The platform was calibrated with the patented calibration system in which all sensors were simultaneously loaded and the calibration curve for each sensor was calculated.

EMED Analysis

The data collected with the EMED-SF system was analyzed using software from Novel. Each foot image was masked into separate areas so that only the middle of the foot would be examined using the Multimask software. The mask settings were at 30% and 60% of the length of the foot longitudinally. Hesinger (1986), defined the midfoot as the region from the point between the calcaneus and the cuboid to the point between the cuboid and base of the metatarsals. The width of the middle 1/3 of the foot was masked at 50% to separate the medial and lateral aspects of the foot. (See Appendix B for masking percentages). All data were normalized to the body weight of the subject. Force values were recorded in Newtons and surface area was measured in cm^2.

Testing Conditions

The six testing conditions of NT walking, NT running, TAT walking, TAT running, XAT walking and XAT running were performed on the platform. Jogging speed was between 1.6 and 2.0 m/s. Walking speed was between 0.9 and 1.25 m/s. In order to minimize any within subject variability, the running and walking for each condition were grouped together. This eliminated any subtle changes that a slight change in pressure or pattern during re-application of the tape may cause. Each taping condition endured a total of 10 trials (5 walking, 5 running). All testing orders were randomized. Testing order along with other data were recorded on the subject data sheet (see Appendix C).

Regulation of running and walking speeds

A photoelectric timing system was used to control for speed in running and walking. Two photocells (Cutler Hammer, Inc.), were clipped to poles and aimed at reflectors across the width of the runway. The two were set a distance of 2 m from each other with the pressure plate being in between the two photocells. The photocells were interfaced with a digital clock (KEPtrol). One photocell started the digital clock while the other stopped it. All values were expressed to the nearest .01 sec. To prevent triggering from the subjects' arms, the photocells were set at the height of the subject's greater trochanter. All wires from the EMG and footswitch were fastened to the subject to prevent premature triggering from the wires. The subjects were instructed to start walking or running before the first photocell and continue past the second photocell.

Statistical Treatment

All values were examined as a percentage of the untaped (NT) mean. A general linear model analysis of variance (ANOVA) with repeated measures was used to compare the untaped (NT), traditional arch taped (TAT), and experimental arch taped (XAT) conditions during walking and running. Within subject differences were examined. Significant results were explored using Bonferroni's post hoc test. All probability levels were set at $p = .05$.

CHAPTER IV

RESULTS

The results indicated no significant differences between peak force (PF), surface contact area (SCA), peak EMG, and average peak EMG among the three taping conditions in walking. During running, PF on the medial aspect of the arch in the TAT condition was significantly ($p < .05$) higher than the NT condition. Surface contact area during running in the TAT condition was significantly ($p < .05$) lower on the lateral aspect of the foot than both the NT and XAT conditions.

Peak EMG

Peak EMG of the tibialis anterior (TA) at midstance during walking in the experimental arch taped (XAT) condition was greater than the untaped (NT), and traditional arch taped (TAT) conditions, however at alpha levels of 0.05, was not significant. Running showed the highest peak EMG in the NT condition. Raw scores in running ranged from an average of 0.126-0.570 mv in the NT condition, 0.131-0.358 mv in the TAT condition, and 0.143-0.724 mv in the XAT condition. Table 1 illustrates the trends in the data expressed as averages of the NT control.

Average EMG

There was a decrease in average EMG of TA to midstance in running with both the TAT and XAT. Walking showed exact opposite effects. Experimental arch taping had the highest EMG mv readings, while NT was the lowest. Table 2 illustrates the statistics.

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Table 1. Peak EMG of the Tibialis Anterior (TA) Expressed as a Percentage

Condition	N	Peak EMG Walking Mean ± SD	Peak EMG Running Mean ± SD
NT	8	100 ± 0	100 ± 0
TAT	8	107.87 ± 20.53	86.16 ± 27.37
XAT	8	123.33 ± 66.65	86.26 ± 36.10
Total	24	110.40 ± 39.73	90.81 ± 25.86

Table 2. Percentage of Average EMG of TA During Midstance

Condition	N	Average EMG Walking Mean± SD	Average EMG Running Mean ± SD
NT	8	100 ± 0	100 ± 0
TAT	8	103.47 ± 12.82	85.91 ± 19.02
XAT	8	127.06 ± 61.19	88.33 ± 23.46
Total	24	110.18 ± 36.61	91.41 ± 17.81

Peak Force

Peak force of the middle 1/3 of the foot was divided and was analyzed as the medial aspect (where the medial longitudinal arch is located) and the lateral aspect. The

purpose of arch taping was to create support for the medial longitudinal arch thus shifting forces laterally. In both walking and running, PF on the medial side was greatest in the TAT condition, second greatest in the XAT condition, and least in the NT condition. Traditional arch taping was significantly higher ($p < .05$) than NT during running. Figure 3 illustrates the differences between the two taping conditions. Trends in the lateral aspect of the middle 1/3 of the foot indicated the greatest amount of force produced was by the XAT condition in running. Walking showed the greatest force in the lateral side in the TAT condition, followed by the XAT.
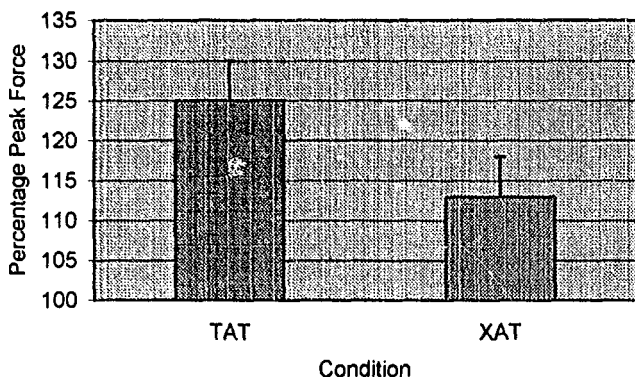

Figure 3. Percent Differences in Peak Force in the Medial Aspect of the Middle 1/3 of the Foot During Running in the Conditions Traditional Arch Tape (TAT), and Experimental Arch Tape (XAT) (Mean ± SD).

Surface Contact Area

     Surface contact area was also analyzed in the medial and lateral aspects of the middle 1/3 of the foot. In running, SCA ranged on the lateral aspect of the foot ranged from a mean of 90.12 to 100%. The TAT condition was significantly lower ($p < .05$) than both the XAT and NT conditions. In walking, the TAT had the highest mean SCA on the lateral side. In both the walking and running, contact surface area was greatest on the medial aspect of the foot in the TAT condition. Figure 4 illustrates the differences in the mean medial surface area. Table 4 illustrates the differences in the mean lateral surface area expressed as a percentage of the control condition.
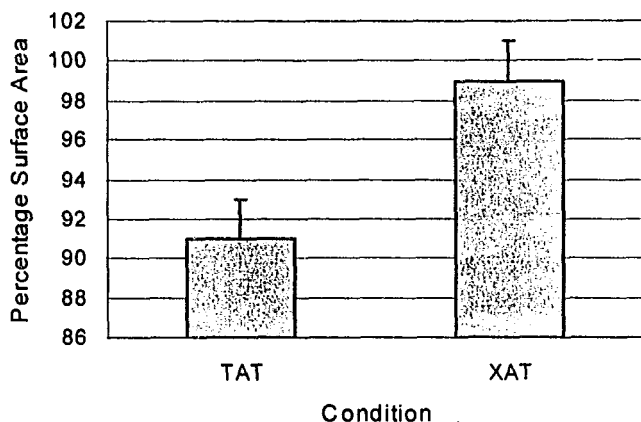

Figure 4. Percentage of Mean Contact Surface Area for the Medial Aspect of the Middle 1/3 of the Foot During Running in the Conditions of Traditional Arch Tape (TAT), and Experimental Arch Tape (XAT) (Mean ± SD).

Table 3. Mean Surface Area for Lateral Aspect of the Middle 1/3 of the Foot

Condition	N	Average CSA Walking Mean ± SD	Average CSA Running Mean = SD
NT	8	100 ± 0	100 ± 0
TAT	8	124.51 ± 41.11	107.03 = 14.58
XAT	8	101.74 ± 17.14	104.13 ± 15.28
Total	24	108.75 ± 27.08	103.72 ± 12.02

Summary

The results of this study suggest that TAT significantly decreased the lateral CSA and increased the peak force of the medial 1/3 of the foot. These findings are contradictory to what research suggests (Arnheim & Prentice, 1999; Schulthies & Draper, 1995). These results suggest that the TAT increased pronation at the subtalar joint, thus causing more force in the arch and less contact on the lateral side of the middle 1/3 of the foot. While there were no significant findings between the XAT and NT conditions in walking, the trends in the data seemed to indicate that the XAT was somewhat successful in alleviating the pronation at the subtalar joint, shifting forces to the lateral surface and also increasing muscle activity of the TA.

CHAPTER V

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Discussion

The purpose of this study was to determine if either of the arch tapings changed force patterns or patterns in muscle activity. The results of this study give support to the usefulness of the XAT technique to relieve MTSS in athletes with excessive pronation. However, results for the TAT may not be beneficial in the treatment of MTSS. In running trials for the TAT condition, there was significantly ($p < .05$) more force on the medial longitudinal arch than the NT control. Also, there was significantly ($p < .05$) less surface contact area on the lateral aspect of the middle 1/3 of the foot. These data suggest that the TAT was not successful at shifting forces to the lateral aspect of the foot and unloading the medial longitudinal arch. Although there was no significant difference in the results for the XAT, trends in the data indicate that this taping was unloading the medial longitudinal arch.

While the results indicate that the TAT is ineffective in unloading the medial longitudinal arch, this contradicts the conclusions by Scranton, et al. (1982). Their research indicated that the TAT was useful in unloading forces from the medial longitudinal arch, shifting forces toward the lateral border of the foot. Research by Moss, et al. (1993) supports the findings of the current study. They found that the TAT may actually cause a greater degree of maximum pronation in the foot. While it is not

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known why the TAT would increase pronation in the foot, research indicates that it may not be useful in providing support to the medial longitudinal arch to alleviate MTSS.

Although there was no significance for the shift in forces and surface contact area to the lateral aspect of the foot in the XAT condition, trends in the data indicated that these values were higher than the NT control. Ator, et al. (1991), similarly did not have significant findings to indicate the arch taping as providing support after exercise. However, it was noted that the height of the arch was greater in the taping conditions over the untaped control. The authors concluded that the taping methods still provided some degree of support to the medial longitudinal arch, and prevented joint motion to the end of the range. The results from this research are similar, and it should be noted that the XAT does provide some support to the medial longitudinal arch.

Research by Draper (1991) did not support the use of TAT. His results indicated that an orthotic may provide more support to the medial longitudinal arch than TAT. He further explained that the subjects reported that they believed the TAT provided more support than the orthotic. A subjective measure of rating of perceived support was not attained in this study, however data suggested that the TAT did not relieve foot pronation and did not cause a shift of forces to the lateral aspect of the foot.

Also of interest were the subject variables. The mean and SD for the navicular drop test used in this study was 7.75 mm ± 1.83. All of these subjects had self reported MTSS. In a study by DeLacerda (1980), subjects with MTSS had a navicular drop of 8.90 ± 2.89, and those without MTSS had 5.56 ± 2.32. These data for navicular drop

compared to subjects with MTSS is similar. While the number of subjects for this study was only 8, they are still a valuable representative population.

The increase in the peak and average EMG of the TA during walking in the XAT condition suggest that the TA activity is increasing which allows the activity of the TP to decrease, taking the strain off of the TP. Reber et al. (1993), suggest that the TA can sustain higher levels of activity than any others of the low leg. It is possible that since the TA is responsible for dorsiflexion and inversion, and the TP is responsible for plantarflexion and inversion, the TA is compensating for the TP, which is the muscle most associated with MTSS (Arnheim & Prentice, 1999). Results from a study by Nawoczenski and Ludewig (1999), were different in that the neuromuscular activity of the TA increased during the first 50% of stance when running on a treadmill with orthotics. The orthotics should provide the same function (support for the medial longitudinal arch) as the arch taping. Data generated from running suggest that the TAT and XAT decreased the muscle activity of the TA. Data from this study is supported by Kameyama, Ogawa, Okamoto, and Kumamoto (1990). Their data suggests that electrical activity of the TA peaks just after heelstrike as did the subjects in the present study. It is not clear why the XAT increased muscle activity of the TA in walking but decreased activity during running when compared to the NT condition. Further research is needed to determine which muscles compensated for the TA in running.

This researcher hypothesized that the TAT condition to have a greater SCA on the medial side of the arch due to the tape being applied on the plantar aspect of the foot, thus creating more of a surface. According to the results, the TAT seemed to cause the subject

to pronate, thus having more force on the medial arch and more SCA. These results are contradictory to the basic function that arch taping plays (Schulthies & Draper, 1995). The TAT needs to be examined further to determine if it helps or hinders an athlete with pes planus who is experiencing MTSS.

Conclusions

The results of this study suggest that the experimental arch taping (XAT) may be a more effective treatment for MTSS than the traditional arch taping (TAT). The trends in the data indicated that it somewhat effective in reducing pronation at the subtalar joint and shifting forces to the lateral aspect of the middle 1/3 of the foot, even though these findings were not significant. With the data generated by this research, the value of the traditional arch taping should not be compromised. The traditional arch taping is most often accompanied by the taping of the transverse arch, which would also aid in correcting pronation biomechanics (Arnheim & Prentice, 1999; Perrin, 1995). Despite, having significant negative effects in this study, other research shows the TAT to be valuable in correcting for flat foot (Scranton, et al., 1982). Further research is needed to examine the value of the experimental arch taping.

Recommendations

While ankle taping has received much attention, research on the effects of arch taping is an area that has been void and is not well documented (Scranton, et. al., 1982). Too often, clinicians use tape with only anecdotal evidence. This study attempted to investigate the usefulness of arch taping for individuals with pes planus and shin splints. Future research should determine whether arch taping is a viable means for controlling

MTSS in individuals with pes planus. Specifically, the use of the XAT needs to be further examined. While there is anecdotal evidence suggesting its usefulness, along with trends in this data providing support for it, it needs to be further examined to determine if it is a viable alternative to the TAT.

The variability of the subjects was a major concern to this study. It would be ideal to test at least 10 subjects of the same gender. Fortunately in this study, all the subjects were heel strikers and did not strike at midfoot as discussed by Cavanaugh and Lafortune, 1980. Variability within this study may have been due to the lack of repeated trials at the same speeds for each condition. It would be optimal to test at 10 trials per condition. A treadmill study using pressure insoles at controlled speeds for 10 trials in each condition could help in the removal of the variability of speed, and reduce the standard deviations in the data.

A possible factor that could have influenced the results was the adherence of the tape to the subjects' skin. The procedure in this study involved removing any sweat or dirt particles from the feet with a dry towel, and then tape was applied directly to the foot. Liquid spray skin adhesive was not used prior to the application of the tape. Perspiration from the activity may have affected the integrity of the tape.

Future research should include the wearing of athletic shoes, since athletes typically participate in sport with shoes. Differences in arch support and the cut of the athlete's footwear could certainly change any pronation biomechanics. Risser (1968) suggests examining an individual's shoe to determine whether it is related to foot or leg pain. The use of insoles would also eliminate the problem with "targeting" when using

the EMED SF pressure plate. McPoil, Cornwall and Yamada (1995) stated that subjects may change their gait in order to step on the platform. An unnatural cadence can affect force distribution and muscle activity which could change the results of the data.

Another important area that coincides with taping is the duration of time that it is supportive. There have been numerous studies regarding ankle taping and the length of time before support is diminished (Alt, Lohrer & Gollhofer, 1999; Greene & Hillman, 1990; and Gross, Bradshaw, Ventry & Weller, 1987). Green & Hillman (1990) found a maximal loss in taping restriction of motion 20 min post exercise. Findings in a study by Alt, et al. (1999) indicated a loss of tape stability of 14% after 30 minutes of exercise. There is little research concerning the duration of time that arch taping provides support. Ator, et al. (1991) concluded that after 10 minutes of exercise, both a low-dye taping and a double X taping did not significantly affect the height of the navicular tuberosity. Further research via video analysis is necessary to determine the length of time the tape is effective in supporting the medial longitudinal arch.

Another area that could have been researched was subjective measures of perceived support and comfort. In 1991, Draper included a subjective evaluation to his subjects on their perceived support of orthotics and TAT. His research indicated that the orthotics provided more support to the medial longitudinal arch, however his subjects believed that the TAT was superior in providing support. He believed the subjects confused the tightness of the tape for support. When trying to determine which arch taping is superior, the TAT or XAT, it would be useful to collect some subjective

information via a questionnaire. If the results in the data support the subjective information, it could provide more support for using one taping over another.

Future studies should focus on the EMG activity in the TP, since it is the actual muscle that provides support to the medial longitudinal arch (Kitaoka, et. al., 1997). This study could not use invasive procedures that would be necessary to evaluate the TP. Since the TP inserts on the navicular tuberosity, and the navicular tuberosity is displaced due to excessive pronation, this creates much stress for the TP (Arnheim & Prentice, 1999). In severe overpronation, the navicular rotates laterally on the talus creating a sag at the talonavicular and naviculocuneiform joints (Geideman & Johnson, 2000). It would be useful to determine whether arch taping reduces the activity of the TP by reducing stress placed on the muscle. Positive results would lend support to the use of arch taping for treatment of some forms of MTSS.

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APPENDIX A

CONSENT FORM

INFORMED CONSENT FOR PARTICIPATION
IN A RESEARCH PROJECT ENTITLED "EFFECTS OF ARCH
TAPING ON PEAK FORCE, CONTACT SURFACE AREA AND
NEUROMUSCULAR ACTIVITY AT MIDSTANCE"

I _____, give my informed consent to participate in a study examining the effects of arch taping on plantar loading and neuromuscular activity during walking and running. I have been informed that my identity will be referred to by number throughout the study and that any measure collected on me will be pooled into a group of measures taken from other subjects for analysis. I consent to presentation and publication or other dissemination of study results so long as the information is confidential and disguised so that no personal identification can be made.

I have been informed that the use of motor point electrical stimulation may produce temporary discomfort, but in no means poses any real danger to my health. I have been informed that I will receive electrical stimulation of an intensity to elicit a muscle contraction and that the electrodes will be moved until the best motor point is determined. It has been explained to me that electromyography (EMG) surface electrodes will be attached to my leg and that I will be required to walk and run over a pressure plate. I have also been informed that I will have to shave body hair from my lower leg in accordance with proper EMG procedure. I have been informed that there is a risk of skin irritation or rash from the EMG also. I have been informed that I am free to withdraw from the project at any time without penalty.

If I have any questions regarding any aspect of this study, I am free to contact the principal investigator or the faculty thesis chair. I am free to contact Richard J. Boergers Jr. at 785-4682 or the thesis chair, Dr. Rick Mikat, at 785-8182 or in person at 0129 Mitchell Hall. Questions regarding the protection of human subjects may be addressed to Dr. Garth Tymeson Chair, University of Wisconsin-LaCrosse Institutional Review Board (IRB) for the Protection of Human Subjects at (608) 785-8155.

At this time, I do not know of any physical or orthopedic problems that would preclude my participation in the study, and I give my full informed consent to be a participant.
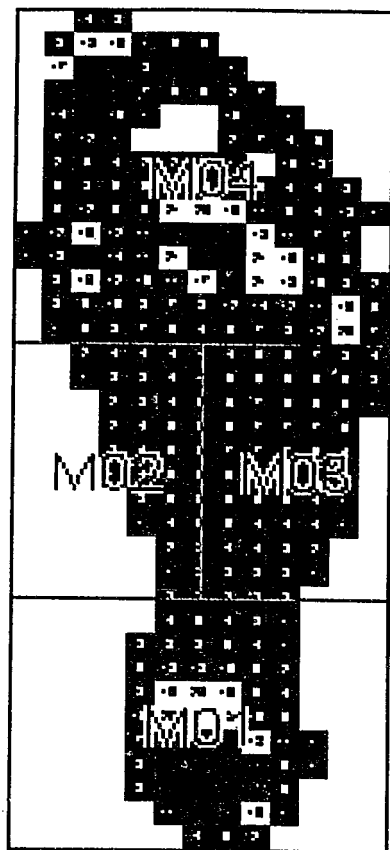

_____   _____

(Participant Signature)   (Date)

_____   _____

(Investigator)   (Date)

APPENDIX B

PERCENTAGE MASKS

MO2 = Medial ½ of the Middle 1/3 of the Foot

MO3 = Lateral ½ of the Middle 1/3 of the Foot

APPENDIX C

SUBJECT DATA SHEET

Subject Data Sheet

Name _____

Subject # _____

Weight (kg) _____

Gender _____

Leg dominance _____

Shin Splints _____

Navicular drop test (mm) _____

Trochanteric Ht: _____

Other injuries _____

Age _____

List of Test Condition Order:

_____   _____

Condition	PF Lateral	PF Medial	CSA Lateral	CSA Medial	Average EMG	Peak EMG
NTW	_____	_____	_____	_____	_____	_____
TATW	_____	_____	_____	_____	_____	_____
XATW	_____	_____	_____	_____	_____	_____
NTR	_____	_____	_____	_____	_____	_____
TATR	_____	_____	_____	_____	_____	_____
XATR	_____	_____	_____	_____	_____	_____