ANALYSIS OF PLANTAR FASCIITIS RISK FACTORS AMONG INTERCOLLEGIATE AND RECREATIONAL RUNNERS: A MATCHED CASE-CONTROL STUDY

by

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ACKNOWLEDGEMENTS

I would like to take this opportunity to thank my committee members Dr. Jeff Housman, Dr. Marie Pickerill and my thesis chair Dr. Rod Harter. Your cooperation, advice, guidance, and patience were greatly appreciated. Dr. Harter, I cannot thank you enough for the time you dedicated to me and my growth as a master's student. I wouldn't be the student and athletic trainer I am today without your guidance. Words cannot explain how grateful I am to have you as my thesis chair. This was an experience like no other and I'm glad we got to complete this journey together. This was an amazing learning opportunity and looking back, words can't explain the feelings I have finally completing this task. This master's program has been through a lot of change in the last year and a half but through it all you stood by my side and pushed me to my limits as a student and I can't thank you enough for that. You will forever be a mentor to me and we are grateful for everything you do here at Texas State University. I also want to especially thank Luke Montgomery, Darcy Downey, Jason Karlik and my fellow athletic trainers at Texas State for your continued support during this process.

Mom and dad, I did it! Thank you for your constant words of encouragement through this process. To all of my family and friends near and far, your love and support will never be forgotten. In conclusion, "Now if you know what you're worth then go out and get what you're worth. But ya gotta be willing to take the hits, and not pointing fingers saying you ain't where you wanna be because of him, or her, or anybody! Cowards do that and that ain't you!" – Rocky Balboa

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LIST OF ABBREVIATIONS

Term	Abbreviation
Body Mass Index	BMI
Navicular Drop Test	NDT
Active Range of Motion	AROM
Passive Range of Motion	PROM
Longitudinal Arch Angle	LAA
Foot Function Index-Revised	FFI-R

ABSTRACT

Context: Plantar fasciitis, the most common cause of inferior heel pain, afflicts as many as 10% of the U.S. population during their lifetimes, and is currently responsible for approximately 1,000,000 physician visits per year. Despite this prevalence, the etiology of plantar fasciitis is not well understood, particularly among physically active populations. **Objective:** To evaluate known and hypothesized risk factors for plantar fasciitis among running athletes to determine which outcome measures are most predictive. **Design:** Case-control. **Setting:** Laboratory setting. **Patients or Other Participants:** 71 intercollegiate and recreational runners completed all aspects of this study (age, 21.8 ± 3.7 yrs; height, 168.0 ± 11.9 cm; mass, 70.29 ± 18.14 kg). We employed a 2:1 ratio of healthy runners to injured runners with plantar fasciitis for the logistic regression analysis using a subset of 63 participants, creating 21 triads that were matched on sex, age and BMI. **Interventions:** None. **Main Outcome Measurements:** Body Mass Index (BMI), dorsiflexion active range of motion (AROM), dorsiflexion passive range of motion (PROM), longitudinal arch angle, navicular drop test, lower leg and foot length, and Foot Function Index-Revised. **Statistical Analysis:** A Group (2) x Limb (2) MANOVA was used to identify differences between the case and control groups and the involved/uninvolved limbs ($\alpha = 0.05$). Odds ratios were calculated using conditional logistic regression in an effort to identify independent risk factors for

plantar fasciitis. A secondary hypothesis investigated the extent to which reduced ankle dorsiflexion AROM, reduced longitudinal arch angle, and increased BMI were risk factors associated with the incidence of plantar fasciitis ($\alpha = 0.05$). **Results:** MANOVA indicated that dorsiflexion AROM and PROM were significantly less in the plantar fasciitis group compared to the healthy control runners ($P < 0.05$). Injury status accounted for 10.6 % and 16.7% of variance in active and passive dorsiflexion range of motion, respectively. Results of the Cox regression analysis indicated that for the hypothesized model, decreased ankle dorsiflexion AROM, decreased longitudinal arch angle, and increased BMI significantly influenced the risk of incurring plantar fasciitis ($\chi^2 = 11.046$; $P < 0.05$). More specifically, each degree of decreased dorsiflexion AROM increased the risk of plantar fasciitis by 14.6% (OR = 1.146, $P < 0.05$). **Conclusions:** Our findings present strong evidence of a link between limited ankle dorsiflexion and plantar fasciitis among physically active individuals. Future research should involve longitudinal, prospective experimental designs with physically active individuals, using these same outcome measures in an effort to establish causal relationships with plantar fasciitis.

Key Words: ankle dorsiflexion, longitudinal arch angle, navicular drop, Foot Function Index-Revise

I- INTRODUCTION

Plantar fasciitis is the most common cause of plantar heel pain and affects as many as 10% of the population in the United States.[1] Plantar fasciitis comprises approximately 25% of all foot injuries in runners and up to 8% of all injuries to people participating in sporting activities. [1-3] Plantar fasciitis currently accounts for approximately 1,000,000 physician visits per year in the USA, with the reported annual costs of treatment exceeding $375 million dollars. [4,5]

Running remains one of the most popular physical activities enjoyed around the world and the numbers of runners has grown substantially over the past decades. [2,3] The incidence of lower extremity injuries in runners is estimated to range from 4.5% to 10% and the prevalence from 5.2% to 17.5%. [3] Survey data indicate that there are currently 50 million runners in the United States. [6] Runners who train year-round run an average of 208 days per year, logging an average of 1,165 miles annually. [6]

A recent systematic review of running-related musculoskeletal injuries found plantar fasciitis to be the third most frequently encountered pathology for running athletes. Despite this level of incidence, the etiology of plantar fasciitis is not well understood, particularly among physically-active populations. Both Taunton et al [7] and Lopes et al [3] have noted the absence of prospective studies of running populations.

However, Taunton et al [7] observed that a higher number of male runners (54%) than female runners (46%) injure the plantar fascia. In fact, plantar fascia injury is the third-most frequent complaint of runners visiting sports medicine clinics. Unfortunately, many relevant studies have not uniformly defined running injuries or running populations. [8]

Risk factors for the development of plantar fasciitis have been previously hypothesized in the literature; however, evidence to support most of these theorized factors is limited or absent. [1] Plantar fasciitis risk factors identified in the literature include increasing age, increasing body mass index (BMI), height and weight gain. Anatomical risk factors for plantar fasciitis include limited ankle dorsiflexion, leg length discrepancy, heel pad thickness, increased plantar fascia thickness, pes planus (excessive pronation of the foot), pes cavus, muscle imbalance, limited first metatarsophalangeal joint (MPJ) range of motion (ROM), and calcaneal spurs. [1,8,9] Previous studies have failed to look specifically at these factors in running athletes. Investigators have reported that more than 2 million patients are treated for plantar fasciitis every year, making it the most commonly encountered condition by foot and ankle surgeons. [4,5,10]

In an effort to better understand the etiology of lower extremity injuries, researchers have long studied the form and structure of the human foot. The foot is an anatomically complex structure whose functions include roles as a compliant shock absorber, static and dynamic base of support, and rigid lever arm. [1,8,9,11,12] The repetitive loads that the foot is subjected to in these and other biomechanical roles can lead to a variety of foot injuries and overuse conditions.

Several intrinsic and extrinsic risk factors have been associated with plantar fasciitis. Pes planus foot types and faulty lower limb biomechanics result in a lower medial longitudinal arch, creating excessive tensile loads within the fascia that produce microscopic tears and chronic inflammation. [10,13,14] Patients with chronic heel pain often present with disorganization of collagen fibers and an increase in mucoid ground substance, decreased fibroblastic activity and inflammation within the fascia. [10]

Pronation of the foot has long been associated with a myriad of sport-related injuries and conditions, and these are not limited to plantar fasciitis, but also involve the shank, knee, hip and low back. [7,15] Excessive pronation was defined by Root et al.[16] as a condition of hypermobility that may lead to numerous injuries of the foot, ankle and lower leg. These authors assessed pronation by measuring the calcaneal position, the subtalar neutral position, and the range of motion at the subtalar joint. Their technique of measuring pronation remains in clinical use today despite the existence of several studies that have reported open kinetic chain goniometric subtalar measurements to have very low inter-examiner reliability, with ICC values ranging from 0.00 to 0.27. [17-19] As a result, closed chain techniques such as the navicular drop test (NDT) and longitudinal arch angle (LAA) have gained greater acceptance among clinicians. [19-21]

Limited evidence suggests that there may be an association between reduced ankle dorsiflexion and heel pain that increases due to a reduction of dorsiflexion.[1,8] Of the 16 studies reviewed by Irving et al.,[1] Riddle et al.[8] had the largest sample size (N = 150). Their measurements of dorsiflexion were considered the most reliable and valid

because of the two-way matching (sex and age) that was carried out. Riddle et al.[8] found that the risk of plantar fasciitis increased as the range of ankle dorsiflexion decreased in a type of "dose-response" fashion.[8] These authors reported that patients with less than 0^o dorsiflexion had a 23.3 times greater risk of incurring plantar fasciitis than those with more ankle dorsiflexion ROM. When compared to BMI and prolonged weight bearing, Riddle et al.[8] concluded that limited ankle dorsiflexion was the most important of these risk factors, in that the greater the limitation in ankle dorsiflexion, the more the plantar fascia is loaded because of compensatory pronation, and the higher risk of developing plantar fasciitis.

The recent systematic review by Irving et al.[1] also found conflicting evidence regarding height, weight and BMI and their associations with plantar fasciitis. An earlier study [8] reported that those plantar fasciitis patients whose BMI was >30 kg/m^2 had a 5.6 times greater risk of developing plantar fasciitis than those with a BMI less than 25 kg/m^2. Only two studies have examined BMI and plantar fasciitis in athletic populations. [7,9] However, both studies appear to be from the same data set and no details were provided on the level of physical activity participants performed. The limited evidence gathered from Irving et al [1] suggests that no association can be made between BMI and plantar fasciitis in athletic populations. Further investigation of the relationship between BMI and plantar fasciitis is warranted.

Brody [22] is commonly credited as the original proponent of the navicular drop test (NDT). However, Schuster[23] first proposed the concept of the NDT in 1956 as a measure of foot pronation. The NDT is a measure of the change in the height of the navicular relative to the ground when measured in static, closed kinetic chain non-

weight bearing and full weight bearing positions. Brody et al.[22] considered NDT results greater than 15 mm to be "abnormal", while those $\leq$ 10 mm displacement were defined as "normal".

More recent studies focusing on static foot posture and dynamic foot motion have been inconclusive despite the fact that pronated foot posture and over-pronation during gait are commonly cited as causative factors.[1] McPoil et al[24] concluded that longitudinal arch angles (LAA) were highly predictive of dynamic foot posture. In addition, McPoil et al[24] suggested that their results validated the inclusion of the LAA in the orthopedic examination of the foot and ankle. The dearth of evidence regarding the relationship between LAA and plantar fasciitis merits for further investigation.

The primary purpose of this study was to evaluate the known and hypothesized risk factors for plantar fasciitis among intercollegiate and recreational runners and identify any differences between the two groups. Second, we looked to establish which outcome measures identify group membership, those with and without plantar fasciitis. Specifically, we hypothesized that significance will be established between groups ($p < 0.05$), and reduced ankle dorsiflexion active range of motion, reduced longitudinal arch angle (LAA), and increased BMI will be identified as significant risk factors associated with the incidence of plantar fasciitis ($p < 0.05$).

Following the successful oral defense of this thesis, an abstract of these findings will be submitted in advance of the November 15, 2016 deadline for a peer-reviewed presentation at the 68th Annual Meeting of the National Athletic Trainers' Association, to be held in Houston, Texas on June 26-29, 2017. In the interim, the

primary manuscript from this thesis will be submitted for publication to the *Journal of Athletic Training*.

II- MANUSCRIPT

Analysis of Plantar Fasciitis Risk Factors Among Intercollegiate and Recreational Runners: A Matched Case-Control Study

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Word Count: 411

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Methods

Design

We employed a cross-sectional, case-control experimental design to identify variables associated with the diagnosis of plantar fasciitis in competitive and recreational runners. Intercollegiate and recreational runners who had been previously diagnosed with plantar fasciitis were assigned to the case group. Intercollegiate and recreational runners who qualified for inclusion in the study who did not have symptoms of plantar fasciitis were assigned to the control group.

The two independent variables for this study were Group (participants with plantar fasciitis, participants without a plantar fasciitis diagnosis), and Limb (involved limb and uninvolved limb). For those participants in the control group, the same side limb as their matched injured runner's "involved" limb was coded as the "involved" limb for purposes of analysis. For example, if a female runner had plantar fasciitis in her left foot and her left foot was her dominant foot, the dominant left feet of the 2 healthy (control group) runners who were sex, age and BMI matched to her were designated as the "involved" limbs for statistical comparison.

The primary outcome measures for this study were dorsiflexion active range of motion (AROM), dorsiflexion passive range of motion (PROM), navicular drop test (NDT), longitudinal arch angle (LAA), body mass index (BMI), foot length, lower leg length, and the score on the patient-oriented (self-report) Foot Function Index-Revised questionnaire.

Participants

Seventy-five collegiate and recreational runners between the ages of 18 and 35 were initially screened for eligibility to participate in this study. A total of 71 runners (40 women, 31 men) met all of the inclusion criteria and subsequently completed all aspects of the study (mean age, 21.84 ± 3.7 yrs; height, 168.0 ± 11.9 cm; mass, 70.29 ± 18.14 kg).

We operationally defined a "recreational runner" as an individual as one who ran a minimum of 5 miles per week for the previous 3 months. Participants who volunteered for this study were screened to ensure that they ran a minimum of 5 miles per week, suffered from symptoms of unilateral plantar fasciitis, had no previous

lower extremity surgeries, traumatic fractures, or stress fracture of the ankle and foot within the last year, and did not have type I or type II diabetes. Twenty of the 71 runners who participated in this study were intercollegiate runners (28%) competing at the NCAA Division I level.

Once a volunteer qualified for participation in the study and provided written consent, they completed a self-report questionnaire that included patient demographic information questions, previous medical history, and running history. In addition, participants answered six 100-mm visual analog scale (VAS) questions that quantified their pain levels during specific activities of daily living and physical activity. We also asked participants to categorize their level of pain and disability using a modified Nirschl scale.[25]

Each participant who was currently suffering from unilateral plantar fasciitis was matched with 2 control group runners based on sex, age and BMI. Twenty-one of the 23 runners in the injured group were perfectly matched based on these criteria. We employed a 2:1 ratio of non-injured (n = 42) to injured runners (n = 21) for the conditional logistic regression analysis in this study.

All data collection sessions were conducted in the Biomechanics and Sports Medicine Laboratory at Texas State University. All data collection took place during one session that lasted approximately 45 to 60 minutes. The possible risks and benefits associated with participation in this study were explained to the volunteers. Volunteers who satisfied the inclusion/exclusion criteria were required to provide informed consent prior to participation in any aspect of this study which was approved by the Institutional Review Board at Texas State University (IRB

#2015D3162). All 71 participants who met all the inclusion criteria completed all aspects of the study. The participants who completed all aspects of the study received a $25 gift card to a regional grocery store.

Instrumentation

A digital goniometer with two bubble levels (Baseline™ Absolute Axis, model 32613) was used to assess talocrural joint active and passive dorsiflexion range of motion bilaterally. In order to standardize the load applied to measure dorsiflexion PROM, a 4.5 kg ankle weight was strapped to the plantar surface of the participant's foot 8 cm from the lateral malleolus while their lower leg was propped up against a 30 cm tall wooden box at a 90^{o} angle.

A large and a small anthropometer (Lafayette Instruments, models 1294 and 1293) were used to assess lower leg (shank) and foot length, respectively.

Experimental Procedures

Individuals who satisfied the inclusion/exclusion criteria provided informed consent prior to participation in any aspect of this study (Table.1). Once consent was obtained, each runner completed a participant demographic form. The purpose of this form was to get a better understanding for each participant's weekly running mileage, minutes per week of physical activity, typical running pace per mile, and history of participation in competitive road races. Any participant who suffered from plantar fasciitis was asked to provide the date of their diagnosis and identify the credentials of the medical professional who diagnosed them.

Table 1. Participant Inclusion and Exclusion Criteria			
Plantar Fasciitis Group (Case)		*Non-Injured Group (Control)*	
Inclusion Criteria	*Exclusion Criteria*	*Inclusion Criteria*	*Exclusion Criteria*
18 to 35 years of age	Any previous lower extremity surgery	18 to 35 years of age	Any previous lower extremity surgery
Run a minimum 5 miles per week	Type I or II diabetes	Run a minimum 5 miles per week	Type I or II diabetes
>120 Minutes (2 hours) of physical activity per weeks	<120 Minutes (2 hours) of physical activity per week	>120 Minutes (2 hours) of physical activity per weeks	<120 Minutes (2 hours) of physical activity per week
Current symptoms and pain associated with plantar fasciitis	Any prior traumatic foot fractures	No previous history of plantar fasciitis	Any prior traumatic foot fractures
Unilateral plantar fasciitis	Stress fracture of the bones of the foot within past year		Stress fracture of the bones of the foot within past year
No active (current) injury	Acute injury of lower leg within the past 6 weeks	No active (current) injury	Acute injury of lower leg within the past 6 weeks

Once this information was obtained, a modified Nirschl pain scale was administered to all participants, followed by 6 visual analog pain scale (VAS) questions using a 100 millimeter line. Once this pain and demographic information was obtained, formal data collection began. Participants were assigned to one of two groups, the case group (n = 21) or the control group (n = 42) based on their injury status.

In order to calculate each participant's body mass index (BMI), body height (cm) was measured with a wall-mounted anthropometer, while body mass (kg) was measured with an electronic digital scale. We calculated BMI using the standard formula: BMI = mass (kg)/height $(m)^2$.

Next, ankle dorsiflexion active range of motion (AROM) was assessed by having the participant lay in a prone position with the hip extended, and knee and ankle flexed to 90^o (Figure 1). We instructed each participant to maximally dorsiflex the talocrural joint 3 times and AROM measurements were obtained bilaterally. The

averages of the 3 measurements at each ankle were calculated and these values were used in our statistical analyses.

Figure 1. Assessment of Dorsiflexion Active Range of Motion

To assess ankle dorsiflexion passive range of motion (PROM), each participant was positioned in a prone position on the examination table with their hip extended, and knee and ankle flexed to 90^{o}. The lower leg rested on a 30cm tall wooden box to prevent activation of the hamstrings and gastrocnemius. A 4.5 kg ankle weight was strapped over the plantar surface of the foot at a distance of 8 cm from the lateral malleolus (Figure 2). Participants were instructed to leave the foot in a limp position and refrain from tightening any musculature in the legs. The ankle weight was strapped on the foot for 15 seconds and a measurement was taken. A 30 second rest period then followed. This protocol was repeated 3 times. The mean of all the measurements were calculated and analyzed.

Figure 2. Assessment of Passive Dorsiflexion Range of Motion

The navicular drop test (NDT) was used to assess the amount of pronation of the foot by measuring the height of the navicular tuberosity of the foot while in non-weight bearing and weight bearing positions. Each participant's subtalar joint was placed in a neutral position with the patient's foot flat against the ground, but non-weight bearing. With the patient non-weight bearing (Figure 3), a small dot was drawn on the navicular tuberosity with a felt-tip marker. While the foot was still in contact with the ground but non-weight bearing, a 7.6 cm x 12.7 cm index card was positioned next to the medial longitudinal arch. A mark was made on the card corresponding to the level of the navicular tuberosity. Participants were then instructed to stand in a single leg, weight-bearing stance with at least 15 to 30 degrees of knee flexion and the foot was allowed to relax into pronation (Figure 4). The new level of the navicular tuberosity was identified and marked on the index card. The

relative displacement of the navicular was determined by measuring the vertical distance between the two dots in millimeters. This protocol was repeated 3 times. The 3-trial average of the navicular drop tests was calculated for each foot, and these values were used in subsequent statistical analyses.

Figure 3. Navicular Drop Test (NDT) in Non-Weight Bearing Position

Figure 4. Navicular Drop Test (NDT) in a Weight Bearing Position

In our efforts to assess the longitudinal arch angle (LAA), the first metatarsal head, navicular tuberosity, and center of the medial malleolus were identified and marked. A felt-tip marker and straight edge (goniometer arm) were used to draw two vector lines onto the foot. The first vector passed through the midpoint of the medial malleolus to the navicular tuberosity and the second vector passed through the midpoint of the medial aspect of the first metatarsal head to the navicular tuberosity (Figure 5). The apex of the LAA is the navicular tuberosity. A small goniometer was used to assess the angle between the two vectors. The LAA was measured 3 times on each foot and 3-trial averages were calculated and used in later statistical analyses.

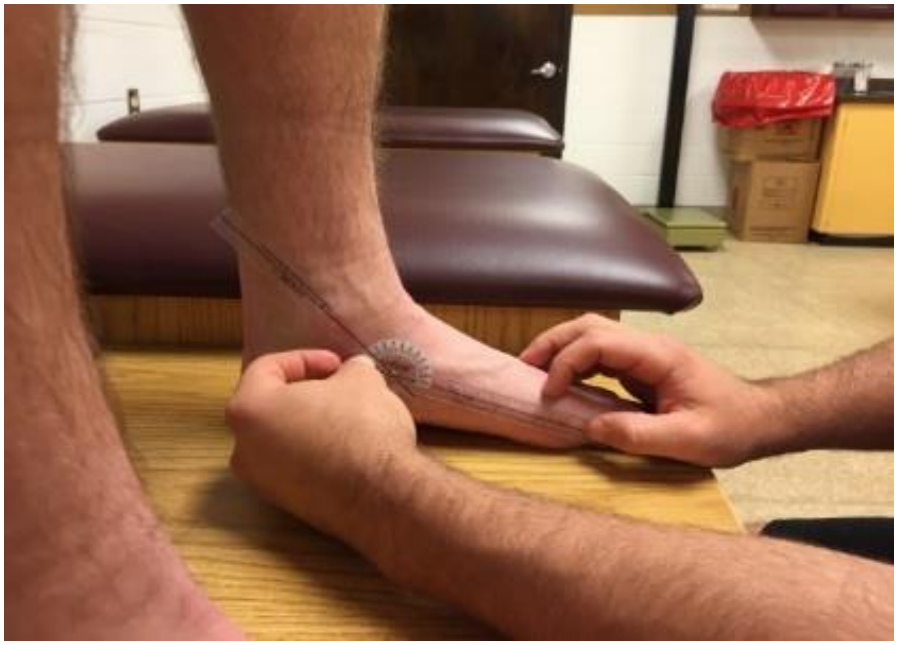

Figure 5. Longitudinal Arch Angle (LAA) Assessment

Foot length inequalities are relatively common musculoskeletal misalignments. We used a standard small anthropometer (Lafayette Instruments,

model 1293) to measure the length of both feet (Figure 6). Three-trial average measurements of foot length were obtained bilaterally for later analysis.

As a second measure of foot length, participants stood on a standard sheet of white computer paper (21.6 cm x 27.9 cm), and the outline of each foot was traced with a pencil. Once the foot was traced, the longest toe was identified. Participants were instructed to stand in a bipedal stance and the distance from the heel to the longest toe was measured 3 times. Similar to other clinical measures, 3-trial average for foot length was calculated for use in our statistical analyses.

In order to measure the length of the lower leg, participants were instructed to lie in a supine position with the hip and knee extended. The foot and ankle were in a relaxed position. The distal tip of the medial malleolus and medial tibial plateau were identified and marked with a felt-tipped pen. The distance between the two dots was measured three times with a large standard anthropometer (Lafayette Instruments, model 1294) and 3-trial averages were calculated for statistical analysis.

Figure 6. Anthropometric Assessment of Foot Length

Figure 7. Anthropometric Assessment of Lower Leg (Shank) Length

Data collection concluded with the administration of the Foot Function Index-Revised (FFI-R), a patient oriented, self-report instrument for measuring pain and disability. [25]

Statistical Analysis

Prior to formal data collection, we conducted a pilot study with 10 physically active volunteers (5 men, 5 women; mean age = 20.9 $\pm$ 2.5 yrs) to establish the intra-rater reliability of the principal investigator (MJM) for all 6 of the clinical outcome measures. According to Shrout and Fleiss [26] intraclass correlation coefficients ($ICC_{3,1}$) values $\geq$ 0.75 are indicative of "excellent" intra-rater reliability. Values between 0.40 and 0.74 are considered "good and fair" reliability, while values $\leq$ 0.39 are viewed as "poor" reliability. As reported in the Table 2, intraclass correlation coefficients ($ICC_{3,1}$) values of greater than 0.75 were obtained for all outcomes measures except leg length inequality and foot length inequalities. Given the poor

test-retest reliability observed for leg length measurements obtained with an anthropometer, we removed this outcome measure from the study.

For our pilot study, individuals were specifically targeted and 3-trial mean averages were calculated. To determine the intrarater reliability with our clinical measures obtained by one examiner (MJM), the intraclass correlation coefficient formula ICC $_{3,1}$ was used since we used 3-trial average measures in our statistical analyses.

Table 2. Pilot Study Results for Intrarater Test-Retest Reliability for All Clinical Measures

Outcome Measure	*Right ($ICC_{3,1}$)*	*Left ($ICC_{3,1}$)*	*Intraclass Correlation Coefficients Category*
Ankle Dorsiflexion AROM	0.99	0.98	Excellent
Ankle Dorsiflexion PROM	0.99	0.84	Excellent
Navicular Drop Test	0.97	0.95	Excellent
Longitudinal Arch Angle	0.99	0.97	Excellent
Leg (Shank) Length Inequality	0.42	0.14	Good and fair/Poor
Foot Length Inequality	0.57	0.58	Good and fair

A Group (2) x Limb (2) multivariate analysis of variance (MANOVA) approach was used to identify differences between runners suffering from plantar fasciitis and healthy control runners, and between the involved and uninvolved limbs ($\alpha = 0.05$). A total of 7 outcome measures—dorsiflexion AROM, dorsiflexion PROM, body mass index (BMI), navicular drop test (NDT), longitudinal arch angle (LAA), foot length, and the patient-centered Foot Function Index-Revised (FFI-R) questionnaire score—were analyzed for significant main effects and interactions. Since we were testing whether there was a difference between the means of identified groups on a combination of dependent variables, we used Wilks' Lambda as the omnibus value for the MANOVA.

The increased risk of plantar fasciitis associated with 7 selected outcome measures was estimated by calculating odds ratios with the use of conditional logistic regression. In this way, we were able to describe the odds that a participant with plantar fasciitis had been exposed to the risk factor, e.g., reduced active dorsiflexion ROM, divided by the odds that a control subject had been exposed to that same risk factor, after adjusting for all other variables in the model.

Lastly, the results of 7 secondary demographic outcome measures, consisting of 6 visual analog scale (VAS) questions quantifying participants' pain levels during specific activities of daily living and physical activity (Appendix), and a modified Nirschl pain rating score (Appendix), were evaluated using paired t-tests to identify the presence of any differences between groups. To control for Type I error, we employed a Rosenthal and Rubin[28] weighted Bonferroni procedure to maintain experimentwise-α at 0.05 for these comparisons.

We used IBM SPSS software (version 23) for all statistical tests.

Results

Seventy-five volunteers between the ages of 18 and 35 were screened for eligibility to participate in this study. The 4 volunteers who failed to meet requirements for inclusion all had previous histories of knee surgery. Seventy-one physically active individuals met all requirements for participation in the study (Table 3). The case group was comprised of 23 runners who met all of the inclusion criteria and were currently suffering from plantar fasciitis. A summary of descriptive statistics for the plantar fasciitis group is provided in Table 4. The control group was comprised of 48 injury-free runners who met all of the inclusion criteria.

Twenty (11 male and 9 female) of the 71 participants (28%) were intercollegiate runners. Of those 20 intercollegiate runners, 7 were currently suffering from plantar fasciitis while the remaining 13 were not. On average, this group ran approximately 16 to 25 miles per week. Fifty-one (31 female and 20 male) of the participants (72%) were recreational runners. Of those 51 recreational runners, 16 were currently suffering from plantar fasciitis, while the remaining 35 were healthy members of the control group. The recreational runners ran an average of approximately 5 to 15 miles per week.

Table 3. Summary of Participant Demographic Data

Group	*N*	*Age*	*Height (cm)*	*Weight (kg)*
Case	23	22.69 ± 4.74	170.28 ± 7.54	72.88 ± 20.21
Control	48	24.43 ± 3.17	166.90 ± 13.41	66.11 ± 11.41
Total	71	21.84 ± 3.76	168.68 ± 11.88	68.30 ± 15.03

Table 4. Descriptive Statistics For Participants with Plantar Fasciitis (N = 23)

	Minimum	*Maximum*	*Mean*	*Std. Deviation*
Age	18.00	35.00	22.69	4.74
BMI	19.06	36.09	24.89	4.89
Height (cm)	158.75	189.23	170.28	7.54
Weight (kg)	49.40	141.60	72.88	20.21

To determine whether the Case and Control groups were statistically different from one another, we performed a 2 x 2 MANOVA and Levene's Test for Equality of Error Variances on all 7 outcomes measures. The omnibus MANOVA results indicated a significant main effect for Group, with differences present between the runners with plantar fasciitis and the healthy control group runners ($F= 9.80$, $P =.001$, $\eta 2 = .487$).

Of the 7 outcome measures included in our MANOVA paradigm, dorsiflexion PROM values and the FFI-R questionnaire score had statistically significant Levene's Tests of Equality of Error Variance ($P < 0.001$). As a result, we suggest that the findings associated with these two measures be interpreted with caution (Table 5). Within the parameters of this study, those suffering from plantar fasciitis had similar Foot Function Index-Revised scores and passive dorsiflexion range of motion values as did the control group.

The MANOVA results indicated that dorsiflexion AROM ($F = 7.9$, $P = .006$, $\eta^2 = 0.106$) and dorsiflexion PROM ($F = 13.46$, $P = .001$, $\eta^2 = 0.167$) were statistically significantly different between the Groups. The average dorsiflexion AROM for runners with plantar fasciitis (13.1 ± 6.7 deg) was significantly less than the healthy control dorsiflexion AROM mean (17.8 ± 6.9 deg) ($P < 0.05$). The plantar fasciitis group's average dorsiflexion PROM (6.7 ± 2.9 deg) was significantly less than the control group's dorsiflexion PROM mean (9.6 ± 3.5 deg) ($P < 0.05$).

In our efforts to determine the relationship between each outcome measure and the risk of plantar fasciitis, the conditional logistic regression analysis with SPSS software was performed using a Cox survival analysis approach. All 7 of the outcome measures were included in the survival analysis model in effort to find relationship(s) to plantar fasciitis. The criterion variable in the survival analysis was the "Status" variable, where the independent variable Group was dummy coded either as "case" (participants with plantar fasciitis) or "control" (participants without plantar fasciitis).

The conditional regression analysis revealed a statistically significant finding ($\chi^2 = 11.046$; $P = .011$) for the hypothesized model indicating that dorsiflexion

AROM, longitudinal arch angle, and BMI had a statistically significant impact of plantar fasciitis risk (Table 6). Active dorsiflexion range of motion had a statistically significant effect of plantar fasciitis risk (OR = 1.146, P =.013), with each 1º loss of dorsiflexion active range of motion increasing the risk of plantar fasciitis by 14.6%. As reported in Table 7, longitudinal arch angle (OR = 0.92, P =.078) and body mass index (OR = 0.77, P =.122) did not significantly affect plantar fasciitis risk.

Table 5. Results of Levene's Tests of Equality of Error Variances

Outcome Measure	*Levene's Test (F)*	*Significance (P)*
Body Mass Index	2.57	0.061
Dorsiflexion AROM	0.06	0.981
Dorsiflexion PROM	4.16	0.010†
Navicular Drop Test	1.38	0.256
Longitudinal Arch Angle	2.24	0.091
Foot Function Index-Revised	6.94	0.001†

† = P < 0.05

Table 6. Omnibus Tests of Model Coefficients

	Overall (score)		
-2 Log Likelihood	*Chi-Square*	*df*	*Sig.*
33.06	11.04	3	.011

Table 7. Results of Conditional Logistic Regression Analysis

					95% CI for Exp (B)	
	B	*df*	*Sig.*	*Exp(B)*	*Lower*	*Upper*
Dorsiflexion AROM	.146	1	.013†	1.14	.770	.970
LAA	-.079	1	.078	0.92	.991	1.181
BMI	-.210	1	.122	0.77	.945	1.611

† = P < 0.05

Independent t-test scores (t = 11.70, P < 0.001) indicated the mean modified Nirschl pain scale scores for those 23 runners with plantar fasciitis (3.69 ± 1.60

points) were significantly higher than those reported by the 48 healthy control runners (1.00 ± 0.00 points).

Independent t-test scores (t=9.38, P < 0.001) indicated the mean visual analog scale scores for case (34.9 ± 16.8 mm) was significantly greater than control mean (5.9 ± 9.3 mm) (Table 9).

Table 8. Independent t-Test Scores for the Modified Nirschl Pain Scale and Visual Analog Scale

Independent Sample Test		*F*	*t*	*Significance*
Modified Nirschl Pain Scale	Equal Variances Assumed	101.014	11.70	.001†
Visual Analog Pain Scale	Equal Variances Assumed	14.22	9.38	.001†

† = P < 0.05

Table 9. Group Statistics for Modified Nirschl Pain Scale and Visual Analog Scale Score for Case and Control Groups

	Group	*N*	*Mean*	*Standard Deviation*	*Std. Error Mean*
Modified Nirschl Pain Scale (7 point maximum)	Case	23	3.69	1.60	.335
	Control	48	1.00	.001	.001
Visual Analog Scale Pain Score (100 point maximum)	Case	23	34.9	16.81	3.50
	Control	48	5.9	9.3	1.33

In our efforts to control for Type I error, a Bonferroni adjustment was used. When an increasing number of contrasts are computed, the weighted Bonferroni procedure is recommended due to its flexibility, simplicity, and generality. [(28)] As seen in Table 10, we prioritized and ranked the 6 visual analog pain scale questions in descending order of importance. All 6 VAS pain question scores were statistically higher in the plantar fasciitis group compared to the control group using the weighted

Bonferroni approach ($P < 0.05$). Group means and standard deviations are summarized in Table 11.

When asked the question "How much pain are you in today?" the mean visual analog scale scores for plantar fasciitis group (13.7 ± 16.2 mm) were greater than control group mean (4.1 ± 9.5 mm). When asked when your symptoms were their worst, how much pain were you in, mean visual analog scale scores for case (64.2 ± 21.5 mm) were greater than control mean (10.0 ± 18.7 mm). When asked how much pain do you experience when taking the first steps of the day, mean visual analog scale scores for case (38.9 ± 30.1 mm) were greater than the control mean (3.6 ± 10.4 mm). When asked how much pain do you currently experience when participating in activities of daily living, e.g. standing, walking, stairs, mean visual analog scale scores for case (26.0 ± 21.2 mm) were greater than control mean (5.8 ± 12.1 mm). When asked how much pain do you currently experience during physical activity, e.g. yoga, Zumba, weight lighting, dancing, mean visual analog scale scores for the plantar fasciitis group were greater (33.1 ± 23.7 mm) than the control group mean (5.8 ± 10.3 mm). When asked how much pain do you currently experience when running, mean visual analog scale scores for case (36.6 ± 26.2 mm) were greater than the control mean (6.1 ± 10.0 mm).

Table 10. Weighted Bonferroni Analysis Using Prioritized Ranking of VAS Questions According to Perceived Level of Importance		
Visual Analog Pain Scale Questions Rank	*α Accepted For Significance*	*Observed Significance (P value)*
6. How much pain do you experience when taking the first steps of the day?	0.05	0.001†
5. How much pain do you currently experience when running?	0.025	0.001†
4. How much pain are you today?	0.016	0.003†
3. How much pain do you currently experience during physical activity, e.g. yoga, Zumba, weight lifting, dancing?	0.0125	0.001†
2. How much pain do you currently experience when participating in activities of daily living, e.g. standing, walking, stairs?	0.01	0.001†
1. When your symptoms were their worst, how much pain were you in?	0.008	0.001†
† = $P < 0.05$		

Table 11. Results of 100-mm Visual Analog Scale Scores for the Case and Control Groups				
Group		*N*	*Mean (mm)*	*Std. Deviation (mm)*
How much pain are you today?	Case Control	23 48	13.65 4.08	16.16 9.49
When your symptoms were their worst, how much pain were you in?	Case Control	23 48	64.17 9.97	21.50 18.66
How much pain do you experience when taking the first steps of the day?	Case Control	23 48	35.86 3.62	30.07 10.35
How much pain do you currently experience when participating in activities of daily living, e.g. standing, walking, stairs?	Case Control	23 48	25.95 5.81	21.15 12.11
How much pain do you currently experience during physical activity, e.g. yoga, Zumba, weight lifting, dancing?	Case Control	23 48	33.08 5.81	23.71 10.32
How much pain do you currently experience when running?	Case Control	23 48	36.56 6.14	26.24 9.98

Discussion

There are very few similar studies of plantar fasciitis risk factors in the medical literature. In the lone, similar case-control study, Riddle and colleagues[8] performed a 2:1 matching ratio on 100 control and 50 patients with plantar fasciitis. These authors recruited 33 women and 17 men into their plantar fasciitis group, with exactly double the number of women (n = 66) and men (n = 34) in their control group. We recruited 71 participants to our study — 13 women and 10 men into the runners with plantar fasciitis group, and 27 women and 21 men into our healthy runners control group.

In the Riddle et al study[8], 22% of the participants (n = 11) were between 30 and 40 years of age. The remaining 39 participants in their case group were older than 40 years old. For their control group, 22% (n = 22) were between the ages of 30 and 40, with the remaining 78 participants being older than 40 years old. We exerted similar experimental controls as did Riddle et al, using a 2:1 ratio of healthy runners to injured runners, and matching on sex, age and BMI. The mean age of the 150 participants in the Riddle et al[8] study was 49.0 $\pm$ 11.0 yrs, with a range of 31 to 85 yrs. In comparison, the mean age of our 71 participants was 23.8 $\pm$ 3.6 yrs, less than half the age of the average participant in the Riddle et al study.

We targeted a rather different demographic population than did Riddle et al, as we recruited only physically active runners between the ages of 18 to 35 years old. Only 5% of the participants (8 of 150) in the Riddle et al[8] study indicated that they were "recreational joggers", and this major demographic difference limits the direct comparisons between our two studies.

However, the findings of the Riddle et al. did indirectly support our hypothesis that limited ankle dorsiflexion, obesity, and prolonged weight bearing at work play a role in the etiology of plantar fasciitis.[8] The odds ratios calculated in both of our studies suggest that dorsiflexion active range of motion may be the most important risk factor of these three.

An exponential relationship was found for ankle dorsiflexion measurements in the Riddle et al study.[8] Limited ankle dorsiflexion on the involved side significantly increased the risk of plantar fasciitis. Compared to those subjects who had greater than 10º of dorsiflexion, those who had 6º to 10º of dorsiflexion had an odds ratio of

2.9. Those who had 1º to 5º of dorsiflexion had an odds ratio of 8.2 and those who had less than 0º had an odds ratio of 23.3 of incurring plantar fasciitis.

We found similar results with our greatest risk factor being diminished active range of motion, which accounted for the statistical significance in the conditional logistic regression. Active range of motion had a statistically significant effect of plantar fasciitis risk (OR = 0.864, $P < 0.05$) with a 1º in range of motion increasing plantar fasciitis risk by 14.6%. One of the most common problems present in both athletes and our general population is a lack of ankle mobility, more specifically, dorsiflexion range-of-motion.

Riddle et al [8] also found that increased body mass index also significantly increased the risk of plantar fasciitis after adjustments for other variables. All participants in their case group (N = 50) demonstrated BMI $\leq$ 25 kg/m^2. Their control group (N = 100) demonstrated BMI averages well over 25 kg/m^2. With our runners, we observed much lower BMI averages in both our case and control groups. In contrast to the Riddle et al study, we found no statistically significant effect of BMI (OR= 1.23, $P > .122$) on plantar fasciitis risk in our study. Our case and control groups had average BMI's of 24.9 kg/m^2 and 23.7 kg/m^2, respectively. The demographic differences in participant age, physical activity levels, and BMI between the Riddle et al study and ours make comparisons between these factors the two studies difficult.

Compared with the general adult population, the influence of a large muscle mass on BMI in athletes and young adults may misclassify these individuals as overweight or obese. Wallner et al [27] suggested that BMI is not an accurate predictor

of “overfatness” in young athletes and non-athletes. Total skin fold thickness and subcutaneous adipose tissue topography patterns assessment are better screening tools to characterize fatness in physically active people.[27]

According to the Centers for Disease Control and Prevention, BMI is a measure of weight adjusted for height, calculated by dividing your weight in kilograms with your height in meters squared. BMI measures excess weight rather than excess fat, and provides an easy, non-invasive and inexpensive means of classifying individuals into weight categories. The CDC concedes that BMI does not calculate your body fat and should not be used as a diagnostic tool to assess health, but rather as an indicator of potential health problems.

A 2007 study of male and female college athletes concluded that BMI incorrectly classifies athletes with normal body fat as overweight and that separate standards should be established for athletic populations. Body composition gives an athletic individual a more accurate profile than BMI of health status in relation to weight because percentage body fat is being measured, and not just body mass. There are several highly-accurate, "gold standard" methods of assessing body composition, e.g., DEXA scan, BodPod™, hydrostatic weighing, all of which are expensive and not readily available.

Riddle et al [8] also found that subjects who reported being on their feet for the majority of the day also had a significantly increased risk of plantar fasciitis. Even though we did not specifically ask this question, similarities were present between those results and the results of our modified Nirschl pain scale and visual analog scale scores. The mean modified Nirschl pain scale for case group was significantly greater

than the control group. The mean visual analog scale scores for the case group was significantly greater than control group.

The three risk factors identified by Riddle et al [8] all appear to have a biologically plausible explanation for causality. The greater the limitation in ankle dorsiflexion, the more the plantar fascia is loaded because of the compensatory pronation and therefore there is a higher the risk for the development of plantar fasciitis. Individuals who spend the majority of the workday weight-bearing and those who are obese also theoretically have increased tensile loads on the plantar fascia compared with those who spend less time weight-bearing and those who have a normal body weight. The Riddle et al study [8] was not designed to examine the risk factors for plantar fasciitis specifically in athletes or competitive runners. The findings of that study should probably not be generalized to athletic populations

We examined risk factors for plantar fasciitis in the context of a case-control study in athletic populations. Case-control designs are commonly used to establish causality. A common issue and limitation with case-control designs is how to determine a relationship between the risk factors and the disorders. The proposed risk factors can only be assessed after the disorder has been diagnosed. To establish causality, case-control studies must avoid bias, demonstrate a strong relationship between risk factors and the condition and provide reasonable explanations for the relationship. We performed a 2:1 matching to minimize confounding and gain efficiency due to our small sample size. We believe that we lessened the risks of confounding factors by matching on sex, age and BMI, three parameters that have been suggested to influence the risk of the disorder.

We also took into consideration to grouping runners accordingly to their average mileage per week and average minutes per week of physical activity. We found what we consider to be a strong association between plantar fasciitis and the risk factors that were studied, especially limited dorsiflexion AROM. The relationship between the reduced ankle dorsiflexion AROM and plantar fasciitis is prevalent but it is hard to determine whether or not the development of plantar fasciitis caused the reduction in ankle dorsiflexion or visa-versa. In theory, reduced ankle dorsiflexion would be a causative risk factor for plantar fasciitis.

When musculoskeletal structures and tissues of the gastrocnemius-soleus complex are restricted, the fascia connecting to the plantar aponeurosis is pulled. The plantar surface of the foot is often complicated by issues further up in the kinetic chain. Shortened and restricted tissues of the superficial back line of the body can contribute to plantar fasciitis pain. This biomechanical disadvantage is typically seen in athletic population and could be the primary cause of the development of this pathology.

Passive range of motion requires that someone or something, (in our case, a fixed load) apply a force to move a joint. Several factors can affect both active and passive range of motion such as lifestyle habits, injury, chronic conditions, excess skin, or adipose tissue. When a clinician assesses for a joint's passive range of motion, typically the joint is pushed to its end range. In most cases and what clinicians typically expect is for the passive range of motion to be greater than the active range of motion. Participants in our study demonstrated greater ankle active dorsiflexion range of motion values when compared to passive ankle dorsiflexion

range of motion values. We used a fixed load (4.5kg) to assess for ankle dorsiflexion passive range of motion. This fixed load may not have been enough force to account for those individuals with stiffer ankle joints. We chose these procedures to measure passive range of motion to establish a fixed load and to make our study replicable. In conclusion, given the wide range of body masses of the participants in our study, a 4.5 kg uniform load we used may not be sufficient to assess for passive stiffness. Future investigations should look to determining a more appropriate loading protocols in order to achieve maximal passive ankle dorsiflexion range of motion.

Another aspect to consider is the tremendous shear force and axial loads the rigid lever arm of the foot and plantar fascia take on during weight bearing activities, let alone running. When a runner sets up in the blocks to prepare for a race, the ankle is in an exaggerated dorsiflexed position with the 1st toe hyperextended. When the gun fires for the start of the race, the athlete forcefully pushes against the starting blocks plantar flexing the ankle while the great toe is still extended. This is a vulnerable position for the plantar fascia that could cause severe pain and micro-tears.

In order to run fast, significant force is applied into the ground in a stiff and slightly plantar flexed position. Runners are typically instructed to foot strike with the ball of their foot so the foot lands in front of the body's center of gravity propelling them forward and increasing their ground contact time. The shorter their ground contact time, the faster they run. Many runners over stride and heel strike upon contact which could lead to overuse injuries. Landing on the heel can act as a braking mechanism which could lead to insufficiencies and slower running times. This could also cause abnormal shock to the knees, hips and low back. Sprinters and distance

runners have very different running techniques that need to be taken into consideration. Sprinters are instructed to propel down the track on the ball of the foot while in some elite distance runners the heel does make slight initial contact with the ground. This is a constant topic of debate among runners, coaches and athletic trainers.

The FFI-R has 4 subscales: pain and stiffness (19 questions), social and emotional outcomes (19 questions), disability (20 questions), and activity limitation (10 questions). The FFI has 3 subscales: pain (9 questions), disability (9 questions), and activity limitation (5 questions). These questions are intended to evaluate overall foot function, foot health and perceived quality of life. With both the FFI and FFI-R, the sum of all 68 questions is calculated; higher scores indicate worsening foot health and poorer foot-related quality of life. The overall scores for both the case and control group were similar in nature ($P > 0.05$). The FFI-R has been extensively studied and used in clinical practice, but the questions might not be applicable to high functioning individuals.

In the past 2 decades, the FFI and FFI-R have been widely used throughout the United States and internationally in clinical practice as well as in research studies. These instruments have been administered to over 4,700 study participants worldwide, across various age groups, with 20 different diagnoses consisting of congenital, inflammatory/degenerative, acute and chronic foot and ankle problems. In an assessment of prevalence and usage of the FFI and FFI-R in various populations and study locations, rheumatoid arthritis and plantar fasciitis were the two most common diagnoses. They were also noted to be the most painful and disabling foot

conditions. A systematic review by Budiman-Mak et al in 2014 evaluated 78 eligible articles for its usage in medical literature. A total of 11 studies have previously included the Foot Function Index for quantification of plantar fasciitis and/or heel pain. As categorized by Budiman-Mak et al, the FFI was used twice to assess "measures of disability", twice for "surgery", four times for "orthosis", and three times for "other".

In 2006, the Foot Function Index was revised to the FFI-R in response to criticism from researchers. Several items were added to address psychosocial activities and quality of life related to overall foot health. The FFI-R was created to be more user friendly and practical for researchers. The chief change from the original Foot Function Index to the Foot Function Index -Revised was the addition of the psychosocial scale.

Conclusions

Our findings present strong evidence of a link between limited ankle dorsiflexion and plantar fasciitis among physically active individuals. Future research should involve longitudinal, prospective experimental designs with physically active individuals, using these same outcome measures in an effort to establish causal relationships with plantar fasciitis.

III- SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

Summary

Plantar fasciitis accounts for 15% of all adult foot complaints requiring professional care and is prevalent in both athletic and non-athletic populations.[1] Plantar fasciitis manifests as chronic pain on the plantar surface of the foot, emanating from the origin of plantar fascia near the medial tubercle of the calcaneus. Typical complaints consist of pain under the medial heel during weight bearing activities especially in the morning and at the beginning of weight-bearing activities. Synonymous with the terms "painful heel syndrome" and "chronic plantar heel pain", plantar fasciitis has been reported to affect between 10% and 20% of athletes.[13]

In an effort to better understand the etiology of lower extremity injuries, researchers have long studied the form and structure of the human foot. Risk factors for the development of plantar fasciitis have been previously hypothesized in the literature; however, evidence to support most of these theorized factors is limited or absent. Despite the high prevalence, the etiology of plantar fasciitis is not well understood, particularly among physically active populations. The purpose of this study was to evaluate known and hypothesized risk factors for plantar fasciitis among running athletes to determine which outcome measures are most predictive.

Ankle dorsiflexion active range of motion had a statistically significant effect of plantar fasciitis risk. Visual analog pain scale scores were also significantly different between those with and without plantar fasciitis. Given the lack of evidence and published literature on athletic populations, we appear to have found strong evidence linking limited active dorsiflexion with plantar fasciitis.

Recommendations for Future Research

To provider stronger evidence in athletic populations, future research should be conducted to examine the relationship between these risk factors and plantar fasciitis in athletic populations using a larger sample with a longitudinal, prospective experimental design to order to establish cause and effect relationships when plantar fasciitis occurs. We need to encourage more research on these variables in physically active populations. Increasing the amount of total study participants will increase statistical power in future studies. Additional investigation is also warranted into roles that leg length, foot length, and limitations in hamstring and gastrocnemius-soleus flexibility play in athletes with plantar fasciitis.

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APPENDIX SECTION

OVERVIEW OF THE STUDY

Purpose of Study: The primary purpose of this study will be to evaluate the known and hypothesized risk factors for plantar fasciitis among intercollegiate and recreational runners and determine group differences. Second, we look to establish which outcome measures identify group membership, those with and without plantar fasciitis.

Experimental Hypotheses:

- Specifically, we hypothesize that significance will be established between group differences ($p < 0.05$).
- We also hypothesize that the following outcome measures will be identified as significant risk factors associated with the incidence of plantar fasciitis ($p \leq 0.05$):
    - Reduced active ankle dorsiflexion ROM
    - Reduced longitudinal arch angle
    - Increased BMI

Assumptions:

- This study assumed that participants were health and were collegiate or recreational runners.
- This study assumed that participants fully complied with all aspects of the research protocol
- This study assumed that participants answered honestly for all questions
- This study assumed that all testing equipment used were reliable and accurate
- This study assumed that those with plantar fasciitis were previously diagnosed with the condition from a medical professional and are currently still suffering from symptoms.

Delimitations:

- This study is delimitated by the recruitment of collegiate and recreational runners ages 18-35.

Limitations:

- Time constraints
- Longitudinal Effects
- Truthful responses to VAS and FFI-R.
- Lacking previous research on physically active runners
- Wearing of arch supports or orthotics prior to data collection was not taken into consideration

Operational Definitions:

Plantar fasciitis- pain and inflammation on the bottom of the foot from the heel to the toes

Recreational runner- runs a minimum of 5 miles per week

Collegiate runner- currently competing in collegiate cross country or track and field

Recommendations for Future Research

- Increase the amount of total study participants to increase statistical power of the study.
- Study these variables in a longitudinal study by adding these outcome measures to a pre-participation physical exam for collegiate running teams and find out how many develop the pathology during their collegiate running career.
- Further investigation into leg length, foot length, and limitations in hamstring and gastrocnemius soleus flexibility in athletes with plantar fasciitis.
- Blinding of the researcher to those who have and do not have plantar fasciitis.

IRB SYNOPSIS

ANALYSIS OF PLANTAR FASCIITIS RISK FACTORS AMONG INTERCOLLEGIATE AND RECREATIONAL RUNNERS: A MATCHED CASE-CONTROL STUDY

1. *Identify the sources of the potential subjects, derived materials or data. Describe the characteristics of the subject population, such as their anticipated number, age, sex, ethnic background, and state of health. Identify the criteria for inclusion or exclusion. Explain the rationale for the use of special classes of subjects, such as fetuses, pregnant women, children, institutionalized mentally disabled, prisoners, or others, especially those whose ability to give voluntary informed consent may be in question.*

A total of 80 elite (NCAA Division I athletes) and community-based recreational runners between the ages of 18 to 35 years from central Texas will be recruited to this study. Participants who are currently suffering from unilateral plantar fasciitis will be matched with 3 control group runners based on sex and age (same decade). A 3:1 ratio of non-injured (n = 60) to injured runners (n = 20) will be employed. Participants in both groups will be matched on duration of activity (minutes per week), sex, and age.

The exclusion criteria for this clinical study include previous lower extremity surgery, Type I or Type II diabetes, prior traumatic foot fractures, and stress fractures within the past year. We will not use any of the special classes of participants.

2. *Describe the procedures for recruitment of subjects and the consent procedures to be followed. Include the circumstances under which consent will be solicited and obtained, who will seek it, the nature of information to be provided to prospective subjects, and the methods of documenting consent. (Include applicable Consent Form (s) for review.) If written consent is not to be obtained, this should be clearly stated and justified.*

Participant recruitment will begin following receipt of IRB approval of this proposal and will continue through December 2015, or until all 80 participants have been recruited. Recruitment efforts will utilize emails and flyers. We will collaborate with the Texas State University Department of Intercollegiate Athletics' team physicians as well as local physical therapy clinics in order to recruit active persons from the general public who are suffering from plantar fasciitis. Each volunteer will complete a Volunteer Screening Questionnaire, and we will determine their eligibility for participation in this study. If a volunteer satisfies the inclusion and exclusion criteria, we will then obtain written consent for participation. (See attached **Consent Form**)

3. *If your planned recruitment process involves emailing Texas State students, staff, faculty or other individuals using their active Texas State email address, provide details in the Synopsis. (In addition, the IRB will require a draft of your recruitment*

email, using the enclosed template and formatted as illustrated in the example in this document, submitted in addition to other required documents.

We will recruit participants specifically from the Department of Human Health and Performance. We will target athletic training, biomechanics, exercise physiology, health, physical education, recreation, physical fitness wellness, and special population students. Please refer to the attached recruitment email template.

4. *If you plan to distribute a survey to collect information directly from individuals who comprise a significant proportion of one or more Texas State affiliation groups, as defined in Section 04 of UPPS No. 04.01.02, Information Resources Identity and Access Management, you must follow the review and approval procedures outlined in UPPS No. 01.03.05, Administrative Surveys, and provide information in your Synopsis regarding review and approval.*

We will not employ surveys as part of the data collection for this study.

5. *Describe the project's methodology in detail. If applicable, detail the data collection procedures, the testing instruments, the intervention(s), etc. If using a survey, questionnaire, or interview, please provide a copy of the items or questions.*

This study will employ a cross-sectional, case-control experimental design to identify variables associated with the diagnoses of plantar fasciitis in competitive and recreational runners. Volunteers who have been previously diagnosed with plantar fasciitis will be assigned to the case group. Runners who qualify for inclusion in the study who do not have symptoms of plantar fasciitis will be assigned to the control group.

The two independent variables for this study will be Group (participants with plantar fasciitis, participants without a plantar fasciitis diagnosis), and Limb (involved limb and uninvolved limb). For those participants in the non-injured group, the dominant limb will be coded as the "involved" limb for purposes of comparison.

The primary outcome measures for this study will be active and passive ankle dorsiflexion range of motion, the tarsal navicular drop test, the longitudinal arch angle test, body mass index, foot length, lower leg length, and the score on the self-reported Foot Function Index-Revised questionnaire.

Pilot Study

Prior to formal data collection, we will conduct a pilot study with 20 physically-active volunteers to establish the intra-rater reliability of the principal investigator (MJM) on all of the clinical outcome measures. According to Shrout and Fleiss (1979), intraclass correlation coefficients ($ICC_{3,1}$) values $\geq$ 0.75 are indicative of "excellent" intra-rater reliability. Values between 0.40 and 0.74 are considered "good and fair" reliability, while values $\leq$ 0.39 are viewed as "poor" reliability. We will aim to achieve intraclass correlation coefficients ($ICC_{3,1}$) values $\geq$0.75 or higher prior to commencing with the formal assessment of the 80 participants to be recruited to this study.

Factorial MANOVA

A 2 x 2 MANOVA approach will be used to identify differences between the case/control groups and the involved/uninvolved limbs ($\alpha = 0.05$). Eight outcome measures— active dorsiflexion ROM, passive dorsiflexion ROM, body mass index (BMI), navicular drop test (NDT), longitudinal arch angle (LAA), foot length, lower leg length, and the patient-centered Foot Function Index-revised (FFI-R) score— will be analyzed for significant main effects and interactions.

Conditional Logistic Regression

The increased risk of PF associated with 5 risk factors will be estimated by calculating odds ratios with the use of conditional logistic regression. In this way we will be able to describe the odds that a participant with plantar fasciitis has been exposed to the risk factor, e.g., reduced active dorsiflexion ROM, divided by the odds that a control subject had been exposed to that same risk factor, after adjusting for all other variables in the model. For 5 of our 7 clinician-based outcome measures, the relationship between that risk factor and the risk of plantar fasciitis will be tested for trend analysis, e.g., linear, quadratic, cubic.

In order to have direct comparisons with the work of Riddle et al. we will analyze 5 continuous variables (active and passive ankle dorsiflexion, BMI, NDT, LAA) through the creation of categorical tertiles or quartiles as indicated below:

- Active ankle dorsiflexion = quartiles ($> 10^o$, 6-10^o, 1-5^o, $\leq 0^o$)
- Passive ankle dorsiflexion = quartiles ($> 10^o$, 6-10^o, 1-5^o, $\leq 0^o$)
- BMI = tertiles (BMI $\leq$ 25, BMI 25-30, BMI > 30)
- NDT = tertiles (pes planus, normal arch, pes cavus)
- LLA = quartiles related to pronated/supinated feet to be determined through pilot data collection and analysis)

We will use IBM SPSS software (version 22) for all statistical tests.

6. *Describe any potential risks — physical, psychological, social, legal or other — and state their likelihood and seriousness. Describe alternative methods, if any, that were considered and why they will not be used.*

There are no significant risks associated with these testing procedures.

7. *Describe the procedures for protecting against or minimizing any potential risks and include an assessment of the likely effectiveness of those procedures. Include a discussion of confidentiality safeguards, where relevant, and arrangements for providing mental health or medical treatment, if needed.*

All participating athletes will sign a HIPAA waiver allowing the research team access to their medical history during the course of the study. Volunteer screening, consent, and demographic questionnaires will be completed. Previous medical history screening will be completed as a component of the demographic form.

8. *Describe and assess the potential benefits to be gained by the subjects, as well as the benefits that may accrue to society in general as a result of the proposed study.*

Our study is one that can help identify key risk factors pertinent to the diagnosis of plantar fasciitis, as well as assist in the development of new clinical decision rules that could improve clinical practice for this chronic condition. This study will provide useful clinical insights so that preventative measures can be implemented. The results of this project may allow athletic trainers and other health care providers to enhance their clinical practices by increasing their understanding of the risk factors that predispose a physically-active person to plantar fasciitis.

9. *Clearly describe any compensation to be offered/provided to the participants. If extra credit is provided as an incentive, include the percentage of extra credit in relation to the total points offered in the class. Also, if extra credit is provided, describe alternatives to participation in your research for earning extra credit.*

Completion of all aspects of this study will require one (1) visit to our research laboratory for screening, consent and subsequent data collection. The total time commitment to complete this study will be between 60 and 90 minutes. As an incentive for participation, we have proposed a $25 gift card from a popular regional grocery store chain (HEB) as appropriate compensation. With 80 participants to be recruited, the total cost of these gift cards will be $2,000.

10. *Discuss the risks in relation to the anticipated benefits to the subjects and society.*

The data collected from this study will provide benefits to the athletic community and health care system that outweigh any risks. Plantar fasciitis is a debilitating injury for runners and this study will provide insight on appropriate diagnostic tools.

11. *Identify the specific sites/agencies to be used as well as approval status. Include copies of approval letters from agencies to be used (note: these are required for final approval). If they are not available at the time of IRB review, approval of the proposal will be contingent upon their receipt.*

This research study will be conducted in the Biomechanics/Sports Medicine Laboratory, a 2,700 square foot multi-disciplinary research and teaching center in Jowers Center that focuses on biomechanics, physical medicine, and strength and conditioning research.

12. *If you are a student, indicate the relationship of the proposal to your program of work and identify your supervising/sponsor faculty member.*

The principal investigator and lead author is a graduate student in the Master of Science degree program in Athletic Training at Texas State University. This

project is being completed as a master's thesis and my supervising faculty member is Dr. Rod Harter.

Dr. Jeff Housman and Dr. Kyung Min Kim are members of my original thesis committee at my proposal, held in June 2015. Since that time, Dr. Kim has left Texas State University for a faculty position at the University of Miami. Due to the logistics associated with his departure, I have decided to replace Dr. Kim with Dr. Marie Pickerill, a new Department of Health and Human Performance graduate faculty member.

13. *In the case of student projects, pilot studies, theses, or dissertations, evidence of approval of Supervising Professor or Faculty Sponsor should be included. Thesis and dissertation proposals must be approved by the student's committee before proceeding to the IRB for review.*

A formal thesis proposal meeting was held on June 22, 2015, at which time my committee members approved my thesis proposal as written, and signed the required Graduate College form.

14. If the proposed study has been approved by another IRB, attach a copy of the letter verifying approval/disapproval and any related correspondence. If the proposed study has not been reviewed/approved by another IRB, please state this explicitly.

Not applicable. This research proposal is only being submitted to the Texas State University IRB.

15. *Identify all individuals who will have access, during or after completion, to the results of this study, whether they be published or unpublished.*

The following individuals will have access to the results of this study: Matthew J. McNamee, Dr. Rod Harter, Dr. Jeff Housman and Dr. Marie Pickerill.

16. Provide date of completion of the required CITI training on the protection of human subjects. Applicants must provide training dates for themselves and for supervising faculty member. All training must be current and not expired.

Matthew McNamee	Biomedical Research Medical Students Course Passed on 11/30/2014, Expiration date 11/30/2016 Reference ID: 14681214
Rod A. Harter	Biomedical Research Investigator Refresher Course/2 Passed on 02/14/2014, Expiration date 02/11/2016 Reference ID: 7054667

Recruitment Email Message Template

Replace the red and bracketed [ ] text below, with text appropriate for your approved research.

To: [Use this line for individual addresses or your own address if BCC line is used]
From: mjm274@txstate.edu
BCC: [Use this line when sending the same email message to multiple addresses]
Subject: Research Participation Invitation: Subject: Research Participation Invitation: Plantar Fasciitis Study

This email message is an approved request for participation in research that has been approved or declared exempt by the Texas State Institutional Review Board (IRB).

Researchers in the Biomechanics/Sports Medicine Laboratory at Texas State University are seeking adult volunteers between the ages of 18 and 35 who have been previously diagnosed with plantar fasciitis. We hope to identify risk factors for plantar fasciitis among running athletes to determine which outcome measures are most predictive.

During this study, both of your feet will be evaluated and a series of clinical measurements will be taken. The study will only require one visit to our laboratory that will last approximately 60 to 90 minutes. Your participation will be kept confidential, and you will be compensated with a $25 gift card from HEB if you complete study.

> This project [2015D3162] was approved by the Texas State IRB on [10/30/15]. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Jon Lasser (512-245-3413 - lasser@txstate.edu) and to Becky Northcut, Director, Research Integrity & Compliance (512-245-2314 - bnorthcut@txstate.edu).

Questions about this research should be addressed to [Matthew J. McNamee, Graduate Student Researcher, at: mjm274@txstate.edu]. I can also be reached via cell phone at 646-463-9328.

Consent Form to Be in a Research Study

(In this form "you" means a person 18 years of age or older who is being asked to volunteer to participate in this study. In this form "we" means the researchers and staff involved in running this study at Texas State University.)

Principal Investigator:
Matthew McNamee, ATC, LAT
Track and Field Graduate Assistant AT
Department of Athletics
601 University Drive
San Marcos, TX 78666
mjm274@txstate.edu
(c) 646-463-9328

Rod Harter, PhD, ATC, LAT, FNATA
Professor of Athletic Training
Department of Health and Human Performance
A132 Jowers Center
San Marcos, TX 78666
rod.harter@txstate.edu
512-245-2972

What is the purpose of this form?
This form will help you decide if you want to participate in the research study. You need to be informed about the study, before you can decide if you want to be involved. You do not have to be in the study if you do not want to. You should have all your questions answered before you give your permission to be involved in the study.

Please read this form carefully. If you choose to participate in the study, you will need to sign this form. You will receive a copy of this signed form.

Why is this research being done?
The primary purpose of this study will be to identify key anatomical and biomechanical risk factors that predispose physically-active persons to plantar fasciitis, a common condition involving the foot. We are seeking volunteers between the ages of 18 and 35 who are either intercollegiate or recreational runners who are interested in helping us answer this research question. If you run 5 miles or more per

week, you may qualify for participation in this study, regardless of whether you have plantar fasciitis or not.

How long will this study take?
Your participation in this study will require one (1) laboratory visit lasting approximately 60 to 90 minutes. After you have read and signed this consent form, your participation in the study will begin at Texas State University's Biomechanics/Sports Medicine Laboratory. You will be asked to complete a participant demographic form and a paper-and pencil questionnaire known as the Foot Functional Index. Once completed, we will then assess your height and weight in order to calculate your body mass index (BMI). Finally, we will measure your foot length, lower leg length, ankle joint range of motion, arch angle and navicular drop – a test of how much your navicular, one of the key bones in your foot, moves when you stand in weight-bearing position.

What will happen if you are in the study?
If you volunteer to participate in this study, you will be screened for eligibility to participate in this study by completing a volunteer screening form that will ask about your general health and foot conditions. If you meet all of the inclusion criteria and agree to participate, you will need to sign this Consent Form before any study procedures take place.

During data collection, you will first be asked to step on the scale so that your weight can be measured. We will also measure your height, and use these two values to calculate your body mass index (BMI).

Next, we will measure your ankle range of motion by having you lie on your back on an examination table and ask you to move your ankle joint 3 times so that range of motion measurements (known as plantar flexion and dorsiflexion) can be taken.

To measure passive ankle range of motion, we will have you lay prone on the examination table with the hip extended and knee and ankle flexed to 90°. A 10 pound (4.5 kg) ankle weight will be strapped on the bottom of your foot so that a consistent load is applied to all study participants. This measurement will be taken 3 times.

To measure the amount of downward movement of one of the key bones of your foot (the navicular) while in a weight-bearing stance, we will perform the navicular drop test. While you are in a non-weight bearing position we will put a mark on the navicular tuberosity. While your foot is still in contact with the ground but non-

weight bearing, we will make a mark on a 3" x 5" index card corresponding to the level of the navicular tuberosity. We will then ask you to stand with the body weight evenly distributed between your two feet. We will mark the new level of the navicular tuberosity with the index card. We will perform the navicular drop test 3 times on each foot.

We will next use an anthropometer to measure the length of both your feet, as well as both of your lower legs between the knee and ankle joints. We will take 3 measurements for each of these orthopedic tests.

Lastly, we will assess the static foot posture of the long (medial) arch of both of your feet. We will draw two lines on your foot using a water-based ink marker. These intersecting lines will form an angle, which is known as your longitudinal arch angle. We will repeat this measurement 3 times on each foot.

What are the benefits of being in the study?

There are minimal benefits associated with participation in this study. However, you will learn about your current body mass index, as well as other clinical orthopedic information about your foot and arch types, and relative stability of your feet.

What are the risks of being in this study?
There are no risks associated with being in this study. The techniques being performed are standard, non-invasive, passive clinical orthopedic tests.

What if you are hurt in this study?
Please be advised that medical treatment is available upon the event of physical injury resulting from the study. Medical treatment will be limited to first aid and ice. In the event that you sustain an injury needing medical treatment beyond that of first aid and ice, you will need to seek appropriate medical attention. Texas State University students may choose to go to the Student Health Center free of charge. Please call 512-245-2161 to schedule an appointment or speak to a health care provider at the Student Health Center. We will report any adverse events per institutional policy. In the event that you believe you have suffered injury not apparent immediately after testing, please contact the IRB chairperson Dr. Jon Lasser at 512-245-3413, who will review the matter with you and identify any other resources that may be available to you.

Will you be compensated/helped for being in this study?
You will receive a $25 HEB gift card if you complete all aspects of this study during your one visit to our research laboratory. In addition to being compensated for your

time in the study, you will learn more about your foot structure and posture, and how it might impact your risk of future orthopedic injury.

Who funds the study?
The study will be funded by a $500 grant from Texas State University's College of Education Graduate Student Research Grant program.

Who will see your information?
Your participation in this study is confidential. Only the investigators will have access to your personal identifiers and to any information that may be linked with your identity. All information that you provide will be assigned an identification number rather than your name to ensure your confidentiality. All coded data will be stored in a locked filing cabinet in Texas State University's Biomechanics/Sports Medicine Laboratory for up to 3 years following the conclusion of this study before being destroyed. In the event of this study being published, none of your personal identifying information will be disclosed.

If you want to know about the results before the study is done:
We cannot disclose any information about your results to you until the end of the study, after all results have been analyzed. At that point, we will be happy to discuss and interpret your individual clinical findings, and the overall results of this study with you.

Right to ask questions:
You may ask questions about the research procedures at any time and will receive immediate responses. If you have any further questions, please direct these to Matthew McNamee (graduate student) at mjm274@txstate.edu or Dr. Rod Harter (thesis supervisor) at rod.harter@txstate.edu.

Voluntary Participation
Your participation in this study is completely voluntary. You may withdraw from this study at any time without any negative consequences from anyone associated with this study.

What if you have concerns about a study?
This project 2015D3162 was approved by the Texas State IRB on 10/30/15. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Jon Lasser (512-245-3413 - lasser@txstate.edu) and to Becky Northcut, Director, Research Integrity & Compliance (512-245-2314 - bnorthcut@txstate.edu

What does your signature mean?
Before you sign this form, please ask questions about any part of this study that is not clear to you. Your signature below means that you understand the information given to you about the study and in this form. If you sign the form, it means that you agree to participate in the study.

You have been given an opportunity to ask any questions that you may have and all have been answered to your satisfaction.

You must be 18 years of age or older to consent to this study. If you consent to participate in this study and to the above state terms, please sign your name and date below.

You will be given a copy of this consent form for your records.

_____
Participant Name (please print in all caps)

_____ _____
Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

_____ _____
Investigator Signature Date

Volunteer Screening Questionnaire

Volunteer Number _____ Date: _____

1) Are you currently between the ages of 18-35?

   Yes No

2) Do you currently have pain and symptoms of plantar fasciitis?

   Yes No

3) Do you currently run a minimum of 5 miles per week?

   Yes No

4) Have you had any stress fractures of the bones in the foot within the last year?

   Yes No

5) Have you had any previous lower extremity traumatic fractures?

   Yes No

6) Have you had any previous lower extremity surgeries?

   Yes No

7) Have you been previously diagnosed with Type I or Type II diabetes?

   Yes No

Volunteer qualifies for study??

Yes_____ No_____

Plantar fasciitis group? ___

Control group? ___

Participant Demographic Questionnaire

To be completed by all study participants who have been determined to be eligible to participate in this study, and have provided consent.

Today's Date: _____ ID Number: _____

Date of Birth: _____ Contact Phone: _____

Sex: F___ M ___ Email: _____

1. Please estimate your average weekly running mileage over the past 3 months

___ Less than 5 miles per week
___ 5 to 15 miles/week
___ 16 to 25 miles/week
___ 26 to 35 miles/week
___ 36 to 45 miles/week
___ More than 45 miles per week. If "yes", how many miles/week on average?

Please estimate your average minutes per week of physical activity.

___ < 120 Minutes (< 2 hours)
___ 120 – 240 Minutes (2 – 4 Hours)
___ 240 – 360 Minutes (4 – 6 Hours)
___ 360 – 480 Minutes (6 – 8 Hours)
___ 480 – 600 Minutes (8 – 10 Hours)
___ 600 – 720 Minutes (10 – 12 Hours)
___ More than 720 (12 hours) minutes. If "yes", how many minutes/week on average? ____

2. Typical pace per mile: _____ (min:sec)

3. Have you run in competitive road races? Yes___ No___

If "yes", what is your best ("PR") 5K time? _____
10K time? _____
Half marathon time? _____
Marathon time? _____

4. Have you been previously diagnosed with plantar fasciitis? Yes___ No ___

If your answer to Q4 is "yes", what type of medical professional diagnosed your injury?

___ Athletic trainer (AT)
___ Chiropractor (DC)
___ Occupational therapist (OT)
___ Nurse practitioner (NP)
___ Physical therapist (PT)
___ Physician (MD, DO)
___ Physician assistant (PA)
___ Registered nurse (RN)

If your answer to Q4 is "yes", when was your plantar fasciitis diagnosed?

_____
month/day/year

Please circle the number that reflects the category that best describes what you currently experience with your plantar fasciitis:

1 No pain or soreness

2 Stiffness or mild soreness after exercise activity. Pain is usually gone in 24 hours.

3 Mild stiffness and soreness before activity which disappears with warm up. No pain during activity, but mild soreness after activity that disappears within 24 hours.

4 Same as above with mild pain during activity which does not alter activity, disappearing in 24 to 48 hours.

5 Mild to moderate pain before, during, and after exercise which alters the exercise or activity. Activities of daily living are affected.

6 Moderate or greater pain before, during, and after exercise or activity, forcing the patient to discontinue the exercise. Pain is experienced during activities of daily living.

7 Pain disrupts activities of daily living; many activities have to be eliminated.

8 Pain causes lack of sleep on a consistent basis. Pain is aching in nature and intensifies with activity.

For the following 6 questions, please put a vertical mark on each line to indicate your level of pain:

1. How much pain are you in today?

_____

No pain whatsoever — Worst pain imaginable

2. When your symptoms were their worst, how much pain were you in?

_____

No pain whatsoever — Worst pain imaginable

3. How much pain do you experience when taking the first steps of the day?

_____

No pain whatsoever — Worst pain imaginable

4. How much pain do you currently experience when participating in activities of daily living, e.g., standing, walking, stairs, gardening, maintaining personal hygiene?

_____

No pain whatsoever — Worst pain imaginable

5. How much pain do you currently experience during physical activity, e.g., yoga, Zumba, weight lifting, dancing?

_____

No pain whatsoever — Worst pain imaginable

6. How much pain do you currently experience when running?

_____

No pain whatsoever — Worst pain imaginable

Plantar Fasciitis Study Procedures Checklist

Participant Name_____ Participant Number_____

Volunteer Screening Complete_____ Ht._____ Wt._____

Demographic Questionnaire Complete_____ Age _____

1. Complete Foot Function Index-Revised

Completed: Yes No

2. Body Mass Index

BMI= mass(kg)/height(m)^2	Mass (lbs.)	Height (in.)
Trial 1		
Trial 2		
Trial 3		
Average	(Convert to kg)	(Convert to m^2)

3.

Talocrural Joint Dorsiflexion Range of Motion

Active dorsiflexion range of motion (ROM) will be assessed by having the participant lay in a prone position with the hip extended, and knee and ankle flexed to 90^o. The participant will be asked to maximally dorsiflex the talocrural joint three times and ROM measurements will be taken. The average of the three measurements will be calculated and analyzed.

Active Range of Motion	Dominant / Involved Limb	Non Dominant / Uninvolved
Trial 1		
Trial 2		
Trial 3		
Average		

To assess ankle passive dorsiflexion, the participant will be positioned prone on an examination table with their hip extended, and knee and ankle flexed to 90^o A 4.5 kg ankle

weight will be strapped over the plantar surface of the foot at a distance of 8 cm from the lateral malleolus. For each measurement, the ankle weight will suspend for 15 seconds. At 15 seconds, a measurement will be taken and the strap will be removed for 30 seconds before re strapping the weight on the foot. This procedure will be performed three times. The mean of all the measurements will be calculated and analyzed.

Passive Range of Motion	Dominant / Involved Limb	Non Dominant / Uninvolved
Trial 1		
Trial 2		
Trial 3		
Average		

4. Navicular Drop Test

The subtalar joint will be placed in a neutral position with the patient's foot flat against the ground, but non-weight bearing. We will place a dot over the navicular tuberosity. While the foot is still in contact with the ground but non-weight bearing, an index card will be positioned next to the medial longitudinal arch. A mark is made on the card corresponding to the level of the navicular tuberosity. The patient will be instructed to stand on one leg and slightly flex the knee putting all body weight on the one foot. The foot is allowed to relax into its natural position. The new level of the navicular tuberosity is identified and marked on the index card. The relative displacement of the navicular is determined by measuring the distance between the two dots in millimeters

Navicular Drop Test	Involved Limb	Uninvolved Limb
Trial 1		
Trial 2		
Trial 3		
Average		

5. Longitudinal Arch Angle

Assessing the static foot posture of the medial longitudinal arch; LAA from two vectors, the first vector passing through the midpoint of the medial malleolus to the navicular tuberosity and the second vector passing through the midpoint of the medial aspect of the first metatarsal head to the navicular tuberosity. The apex of the LAA is the navicular tuberosity.

Longitudinal Arch Angle	Involved Limb	Uninvolved Limb
Trial 1		
Trial 2		
Trial 3		
Average		

6. Foot and Lower Leg Length Inequalities

An anthropometer will be used to measure the length of both your feet, as well as both of your lower legs. In order to measure foot length, we will trace your foot on paper and then use the anthropometer to measure the length of your foot. Measurements will be taken and we will calculate a 3-trial average for each of these measurements.

Foot Length Inequalities (calcaneal tubercle to the longest justified toe)	Dominant / Involved	Non Dominant / Univolved
Trial 1		
Trial 2		
Trial 3		
Average		

Leg Length Inequalities (between distal tip of the medial malleolus and medial tibial plateau)	Dominant / Involved	Non Dominant / Univolved
Trial 1		
Trial 2		
Trial 3		
Average		

Review of Literature

Introduction

One of the most common foot disorders encountered by health care professionals is chronic plantar heel pain, also known as plantar fasciitis. [1] Plantar fasciitis is chronic pain on the plantar surface of the foot manifesting from the insertion of plantar fascia near the medial tubercle of the calcaneus. Typical complaints consist of pain under the medial heel during weight bearing activities especially in the morning and at the beginning of weight bearing activities such as walking. [1] This chronic pathology is a multifactorial musculoskeletal dysfunction with high prevalence and cost, difficult clinical diagnoses with debilitating symptomology.

Synonymous with the terms painful heel syndrome, and chronic plantar heel pain, plantar fasciitis has been reported to affect between 10% and 20% of injured athletes. [2] Irving et al., [1] reports plantar fasciitis accounts for 15% of all adult foot complaints requiring professional care and is prevalent in both athletic and non-athletic populations. Roughly 50-70% of the 25-30 million Americans who are running for their aerobic exercise will sustain injury during activity. [3] Chronic planter fasciitis due to cumulative stress is one of the most common painful foot conditions observed in runners both competitive and recreational. [3] The following is an overview of clinical diagnoses, typical signs and symptoms, injury incidence and cost, treatment, hypothesized intrinsic and extrinsic causative factors, and a review of literature of regarding recently published biomechanical influences and epidemiology related to plantar fasciitis.

Plantar fasciitis is the most common cause of plantar heel pain and affects as many as 10% of the population in the United States. Plantar fasciitis comprises approximately 25% of all foot injuries in runners and up to 8% of all injuries to people participating in sporting activities. [1,4,5] Currently, plantar fasciitis accounts for approximately 1 million physician visits per year with annual cost of treatments estimated between $192 and $376 million dollars. [6,7]

Running remains one of the most popular physical activities enjoyed around the world and the numbers of runners has grown substantially over the past decades. [4,5] Runners who train year-round average 208 days logging nearly 1,165 miles per year. [8] A recent systematic review of running-related musculoskeletal injuries found PF (incidence ranging from 4.5% to 10.0%; prevalence ranging from 5.2% to 17.5%) to be the third most frequently encountered pathology for running athletes. [5] Despite this prevalence, the etiology of plantar fasciitis is not well understood, particularly among physically-active populations.

Clinical Diagnoses, Signs & Symptoms

In an effort to better understand the etiology of lower extremity injuries, researchers have long studied the form and structure of the human foot. The foot is an anatomically complex structure whose functions include roles as a compliant shock absorber, static and dynamic base of support, and rigid lever arm. [1,6,9,10,11] The repetitive loads that the foot is subjected to in these and other biomechanical roles can lead to a variety of foot injuries and overuse conditions.

The plantar fascia divides into medial, central, and lateral bands that attach to the abductor hallucis, flexor abductor brevis, and abductor digiti minimi. [3] The windlass

mechanism of great toe extension transfers tension from the proximal attachment of the fascia to its insertion on the calcaneus. This mechanism causes the calcaneus to invert and turns the foot into a rigid lever. Repetitive stress causes the fascia to become inflamed or undergo degenerative changes, commonly called fasciosis. (12,13,14)

Plantar fasciitis presents as pain in the plantar heel at the medial calcaneal tubercle and is most noticeable with the first step in the morning. This pain intensifies with long periods of standing and may be exacerbated with plantar fascia stretching. Although the two may coexist, plantar fasciitis (or fasciopathy) should be differentiated from plantar fat pad atrophy (FPA), which presents as increased pain with weight-bearing and compression over the center of the heel.

Plantar fasciitis is a musculoskeletal disorder primarily affecting the facial enthesis. Pes planus foot types and lower limb biomechanics that result in a lower medial longitudinal arch are thought to create excessive tensile strength within the fascia producing microscopic tears and chronic inflammation. (2,15) Patients with heel pain reveal disorganization of collagen fibers and an increase in mucoid ground substance decreasing fibroblastic activity and inducing inflammation within the fascia (MacAuley 2007). The diagnosis of plantar fasciitis is usually based on clinical criteria, specifically pain localized on the medial tubercle of the calcaneus. Symptoms are typically the worst at first step in the morning and athletes participating in frequent running activities have a higher risk of developing this disorder.

Under ultrasonography, the plantar fascia in asymptomatic patients is 2-4 mm thick. In symptomatic patients, the plantar fascia is 6-10 mm thick. (4) Diagnostic

ultrasonography also typically demonstrates diffuse or localized thickening of the calcaneal tendon and plantar fascia or plantar aponeurosis. [15] The plantar aponeurosis is the investing fascia on the soul of the foot and forms a strong mechanical linkage between the calcaneus and the toes. [15] In a study performed by Wearing et al, [15] results concluded that individuals with heel pain were exposed to greater internal loading of the foot causing adaptive thickening of the plantar fasciitis so the body is able to tolerate the expressed tensile loads. This process causes pain in patients. A relationship exists between thicker fascial structures, lowered arched feet, and heel pain. The plantar fascia in the symptomatic limb was (6.1+/- 1.4mm) 48% thicker than that of its asymptomatic counterpart (4.2+/-.5mm). [2] This was 75%-79% thicker than the fascia of the matched control limbs. An interesting correlation was noted between the magnitude of pain and fascial thickness and the in relation to the patients CMT1 angle. As fascial thickness increased, CMT1 angle decreased causing pain to increase.

In diabetic patients, peripheral neuropathy induces foot deformities and alters gait patterns which in return, creates areas of high plantar pressure. [16] Limited joint mobility in the ankle, weakness of the tibialis anterior and vastus lateralis, and atrophy to the intrinsic muscles of the foot have led to increased mechanical stress of the foot. In a study performed by D'Arbogani et al., [16] an increase in thickness of the plantar fascia was seen in diabetic patients. Measurements taken from the calcaneus insertion of the plantar fascia were increased in patient groups compared to the control group. Diabetic patients had a reduction of MTP joint mobility (54.0+/-29.4). [16] This reduction is linked to the reduction of dorsiflexion in the diabetic group

compared to the control group (26.1+/- 12.4 to 64.2+/- 6.4). An inverse relationship was noted between thickness of the plantar fascia and limited joint mobility. This is interesting because when all three pathological groups were put together, a direct correlation was seen between thickness of the plantar fascia and absorbed vertical forces underneath the metatarsal heads.

Risk Factors

Risk factors for the development of plantar fasciitis have been previously hypothesized in the literature; however, evidence to support most of these theorized factors is limited or absent. [1] Plantar fasciitis risk factors identified in the literature include increasing age, increasing body mass index (BMI), height and weight gain. Anatomical risk factors for plantar fasciitis include limited ankle dorsiflexion, leg length discrepancy, heel pad thickness, increased plantar fascia thickness, pes planus (excessive pronation of the foot), pes cavus, muscle imbalance, limited first metatarsophalangeal joint (MPJ) range of motion (ROM), and calcaneal spurs. [1,9,10] I Previous studies have failed to look specifically at these factors in running athletes. Investigators have reported that more than 2 million patients are treated for plantar fasciitis every year, making it the most commonly encountered condition by foot and ankle surgeons. [6,7,11]

Several intrinsic and extrinsic risk factors have been associated with plantar fasciitis. Pes planus foot types and faulty lower limb biomechanics result in a lower medial longitudinal arch, creating excessive tensile strength within the fascia that produces microscopic tears and chronic inflammation. [17] Patients with chronic heel pain often present with disorganization of collagen fibers and an increase in mucoid

ground substance, decreased fibroblastic activity and inflammation within the fascia. [17]

Pronation of the foot has long been associated with a myriad of sport-related injuries and conditions, and these are not limited to plantar fasciitis, but also involve the shank, knee, hip and low back. [18] Excessive pronation as defined by Root et al., [19] is a condition of hypermobility that may lead to numerous injuries of the foot, ankle and lower leg. These authors assessed pronation by measuring the calcaneal position, the subtalar neutral position, and the range of motion at the subtalar joint. Their technique of measuring pronation remains in clinical use today despite the existence of several studies that have reported open kinetic chain goniometric subtalar measurements to be unreliable (inter-examiner) with ICC values ranging from 0.00 to 0.27. [20,21,22] As a result, closed chain techniques such as the navicular drop test (NDT) and longitudinal arch angle (LAA) have gained greater acceptance among clinicians. [23,24]

Limited evidence suggests that there may be an association between reduced ankle dorsiflexion and heel pain that increases due to a reduction of dorsiflexion. Of the 16 studies reviewed by Irving et al., [1] Riddle et al., [9] had the largest sample size (N=150). Their measurements of dorsiflexion were considered to be the most reliable and valid because of the two-way matching (sex and age) that was carried out. Riddle et al. found that the risk of plantar fasciitis increased as the range of ankle dorsiflexion decreased in a type of "dose-response" fashion. [9] These authors reported that patients with $\leq 0^{o}$ dorsiflexion have a 23.3 greater risk of incurring plantar fasciitis than those with more ankle dorsiflexion ROM. Riddle et al. [9]

concluded that limited ankle dorsiflexion was the most important of these risk factors--the greater the limitation in ankle dorsiflexion, the more the plantar fascia is loaded because of compensatory pronation, and the higher risk for the development of plantar fasciitis.

A recent systematic review by Irving et al. [1] found conflicting evidence regarding height, weight and BMI and their association with plantar fasciitis. In an earlier study, Riddle et al. [9] reported that those plantar fasciitis patients whose body mass index was >30 kg/m^2 had a 5.6 times greater risk of developing plantar fasciitis than those with a BMI less than 25. These mixed results indicate that further investigation of the relationship between BMI and PF is warranted.

Brody [25] is commonly credited as the original proponent of the navicular drop test (NDT). However, it was Schuster who in 1956 first proposed the concept of the NDT as a measure of foot pronation. [26] The NDT is a measure of the change in the height of the navicular relative to the ground when measured in static, closed kinetic chain non-weight bearing and full weight bearing positions. Brody et al., [25] considered NDT results greater than 15 mm to be "abnormal", while those $\leq$ 10 mm displacement were defined as "normal".

Previous research has established an association between plantar fasciitis and intrinsic foot muscle atrophy. Chang et al [27] found that forefoot muscle volume was significantly lower in the affected limbs of patients with unilateral plantar fasciitis than in the healthy limbs. In a similar study, Cheung et al., [28] found that rear foot intrinsic muscle volume was lower in experienced runners with chronic plantar fasciitis than in healthy runners. Kibler et al., [29] also found that runners with plantar

fasciitis had significantly worse ankle plantar flexion strength than healthy runners; this weakness could be related to muscle atrophy or to reflex inhibition with increased load on the plantar fascia. [29] Although intrinsic foot muscle atrophy has been studied, no studies exist confirming muscle atrophy as the cause of plantar fasciitis or support the notion that strengthening exercises will relieve symptoms. Research does suggest that intrinsic muscle activation from forefoot contact to toe off may reinforce ligamentous structures therefore supporting the plantar fascia. [30]

Conflicting evidence existing in regards to running pace and volume and the risk of injuries, including plantar fasciitis. [31,32] A study by Knobloch et al., [32] found that marathon runners have a lower risk of plantar fasciitis than runners of shorter distances, which suggests faster pace may be a risk factor and higher volume may be protective. [32] However, other prospective studies have linked lower extremity injuries, including plantar fasciitis, to higher running volume. [32]

More recent studies focusing on static foot posture and dynamic foot motion have been inconclusive despite the fact that pronated foot posture and over-pronation during gait are commonly cited as causative factors. [1] Evidence of static foot posture and dynamic foot motion was inconclusive and height, weight, and BMI in athletic populations were not associated with chronic plantar heel pain. On the basis of the results of a study by McPoil et al., [33] the longitudinal arch angles (LAA) obtained were highly predictive of dynamic foot posture and these results validate the use of the LAA as part of the foot and ankle examination. [33] The dearth of evidence regarding the relationship between LLA and plantar fasciitis merits for further investigation. The connection between foot structure and plantar fasciitis is unclear.

Researchers found a lower arch index with increased range of dorsiflexion in female runners with plantar fasciitis than in their healthy counterparts but others suggest this relationship is not easily defined due to the foot's adaptability to prevent injury. [33,34]. Nielsen et al found no increased risk of running-related injury in novice runners with moderately pronated feet. [31] Additional well-controlled randomized prospective studies of homogenous running groups are critical to furthering our understanding of these factors.

Injury Prevalence and Cost

Plantar fasciitis has been reported to affect between 10 and 20% of injured athletes. [7] In 2007, it was projected that the cost of plantar fasciitis treatment to third-party payers ranged from $192 to $376 million. [7] Investigators have reported that more than 2 million patients are treated for plantar fasciitis every year and it is the most commonly encountered condition by foot and ankle surgeons. [7]

The incidence of lower extremity injuries in runners is estimated to range from 4.5% to 10% and the prevalence from 5.2% to 17.5%. [5] Taunton et al [18] and Lopes et al [5] have noted the absence of prospective studies of running populations.

Taunton et al [5] however observed that a higher number of male runners (54%) than female runners (46%) injure the plantar fascia. In fact, plantar fascia injury is the third-most frequent complaint of runners visiting sports medicine clinics. Unfortunately, many relevant studies have not uniformly defined running injuries or running populations. [3]

Tong et al [7] combined 6 years of data to derive the incidence of ambulatory visits for plantar fasciitis in the United States. During these visits, the type of

treatments patients received was characterized as medicated or non-medicated therapy. During the 6-year study, 6,029,000 visits were accounted for plantar fasciitis. This is equivalent to 1,005,000 per year. Pain medication was prescribed to 381,000 (46.6%) of the 818,000 annual physician office visits and hospital outpatient department visits for patients with plantar fasciitis. Exercise counseling and physical therapy were provided to 210,000 (26.2%) and 154,000 (18.8%) of visits respectively. For the remaining 19.6% of patients, neither treatment was characterized. Mean unit cost of treatment was $48 per physician office and $93 per hospital outpatient department visit. Mean cost of ambulatory care visits were estimated to $51. Mean medication costs including NSAIDS were $591 per patient per year. Minimum costs were $131.13 and maximum costs were $2,868. Unit cost related to exercising or education and physical therapy were $47 and $50 respectively. Surgical interventions had the highest cost. Medicare for traditional fasciotomy procedures was on average $295 in 2007. In 2008, cost charged by physicians jumped to $897. Inpatient hospital reimbursement rates plantar fascia fasciotomy ranged from $4,568 to $8,662. When nerve decompression was involved, inpatient hospital reimbursement rates ranged from $4,568 to $8,662. [7]

Plantar fasciitis is a self-limited condition with different treatment options including conservative therapy, medication, therapy, extracorporeal shock wave therapy, and surgical intervention. Recovery from treatment for chronic plantar fasciitis tends to be lengthy and recurrence is common.

Treatment of Plantar Fasciitis

The distal attachment of the plantar fascia and on the proximal phalanges creates a windlass effect when the toes are extended, pulling the plantar fascia around the metatarsal heads. The American Physical Therapy Association's clinical practice guidelines for treatment of plantar fasciitis combine stretching, activity limitation, iontophoresis, night splints, and prefabricated or custom inserts. [34] The American College of Foot and Ankle Surgeons recommends initial treatment with ice, stretching, ergonomics, off-the-shelf arch supports, nonsteroidal anti-inflammatory drugs, and corticosteroid injections, with progression to custom foot orthoses and physical therapy if little or no improvement after six months. [11] Rest is likely to be helpful but no literature has been published to support this. Regardless of treatment intervention, 80-85% of patients will experience improvement in their symptoms within the first 6 months. [11]

Orthotics wear has been shown to reduce tension in the plantar fascia, as it would be expected that reducing tension would decrease pain. [15] The findings of Pfefffer et al [35] support the use of less rigid orthotic devices in patients with plantar fasciitis. Felt, silicone or rubber were more likely to be associated with symptom relief than more rigid devices. Research has demonstrated that orthotic devices are associated with positive kinematic effects. Mundermann et al [36] found a decrease in forefoot to rearfoot coupling angles with the use of foot orthoses. Another study showed a change in rearfoot eversion angle and eversion velocity in female distance runners. The authors also found that molded foot orthoses reduced vertical loading rates and ankle inversion moments in healthy runners. However, none of these

researchers concluded whether similar biomechanical effects can be expected in runners with plantar fasciitis, or to what extent those changes might affect patient symptoms. [36]

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