

THE RELATIONSHIP BETWEEN LOWER LEG LEAN TISSUE, FUNCTIONAL  
INDEX SCORES AND TRICEPS SURAE ENDURANCE IN ATHLETES

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## INTRODUCTION

Anterior shin pain is a common pathology among elite and novice athletes. Anterior shin pain is a broad term similar to "low back pain." This term is used to describe the result of many etiological factors. Often clinicians look to a single underlying cause to attribute to its onset. However, a multitude of risk factors can play a role in its development.<sup>1</sup> The purpose of this study was to identify the role, if any, lean calf girth and lower leg endurance have in the occurrence of anterior shin pain.

Minimal research has been conducted to include lean calf girth measurements within its data collection. Furthermore, little research has been done to examine the ratio distribution of muscle mass between the plantar flexors of the lower leg and its effect on the development of anterior shin pain. There is still plenty of research to be done and the benefits of determining any correlation will aid in reducing the risk of anterior shin pain development through the modification of training techniques.

Among the few studies that have been conducted in this area, researchers Burne et al<sup>2</sup> and Schinkel-Ivy et al<sup>3</sup> found similar results, indicating decreased lean muscle mass as a possible contributory factor to the lower leg's incapacity to adapt to loading forces and withstand injury. Interestingly, both studies found females to suffer higher rates of injury than their male counterparts. The study conducted by Burne et al revealed that 25% of female cadets could not complete the Australian Defense Force Academy training requirements due to early onset exertional medial tibial pain. However, 95% of male cadets passed the running component. Schinkel-Ivy et al concluded that females in the study presented with lower lean tissue mass than their male counterparts resulting in greater acceleration response of the tibia following impact, predisposing them to greater risk of musculoskeletal disorders.

This study used the Lower Limb Functional Index<sup>4</sup> to analyze the effect of anterior shin pain among varsity athletes at California University of PA and used questions that assessed their ability to perform their respective sport. A study conducted by Wikstrom et al<sup>5</sup> used the Foot and Ankle Disability Index questionnaire to determine the diagnostic utility of a self-assessed disability questionnaire. Its results demonstrated perceptual

disability had the greatest diagnostic accuracy in comparison to mechanical and sensorimotor indicators. Anterior shin pain accounts for 10.7% of injuries in men and 16.8% of injuries in women and as a result decreases the athletes' participation in practice and competition.<sup>6</sup>

The focus of this study was to determine any relationship between lean calf girth and anterior shin pain. The results of this study will aid in narrowing down the possible risk factors associated with anterior shin pain. Any association between variables may result in further investigation to reduce or increase lean mass composition in the lower leg among athletes to decrease the implications of anterior shin pain on performance.

## METHODS

The primary purpose of this study was to determine any relationship between lean calf girth, lower leg muscular endurance measurements and Lower Limb Functional Index scores. The methods section includes the following subsections: (1) Research Design, (2) Subjects, (3) Instruments, (4) Procedures, (5) Hypotheses, and (6) Data Analysis.

### Research Design

This research was a correlational design. The variables were lean calf girth, lower leg muscular endurance scores and Lower Limb Functional Index scores (LLFI). A measurement of lean calf girth was correlated to lower leg muscular endurance scores to objectively determine if lean calf girth size corresponded to muscular endurance scores. Lean calf girth was then correlated to Lower Limb Functional Index scores to determine if excessive or limited amounts of lean calf girth correlated to self-reported injury. Lower leg muscular endurance

scores were then correlated to Lower Limb Functional Index scores to determine any relationship existing between endurance testing and self-reported injury. The group used for testing was volunteers from varsity sports involving repetitive lower extremity impact that completed at least one competitive season from California University of Pennsylvania, or another collegiate program, without current lower extremity injuries. A Preliminary Questionnaire was used to eliminate athletes from inclusion in the study currently suffering from lower leg injury. The study examined the relationship between lean calf girth measurements, lower leg muscular endurance scores and LLFI scores, which could potentially identify lean calf girth as a diagnostic tool for possible injury and permanently alter training techniques.

### Subjects

The subjects used for this study were volunteer male and female varsity athletes involved in football, volleyball, and men and women's soccer at California University of Pennsylvania. All subjects completed at least one season of their competitive sport. All subjects took the Preliminary Questionnaire to determine inclusion

within the study. Individuals currently suffering from any lower leg injury at the time the survey was distributed were eliminated from the study due to the potential inflammation of the lower leg during the healing process. Each subject was required to participate in calf girth measurements, lower leg skin fold measurements, lower leg muscular endurance screening, height, weight, Bioelectrical Impedance Analysis and Lower Limb Functional Index screening. The study was approved by the Institutional Review Board (Appendix C2) at California University of PA. Each participant's identity remained confidential and was not included in the study.

#### Preliminary Research

A pilot survey was conducted with this research project. The Lower Limb Functional Index was given to the surveyors to be modified to assess the severity of previous anterior shin pain among individuals participating within the study. Subjects involved in completing the pilot survey passed the BOC exam, obtained Athletic Training Licensure, were currently practicing as Athletic Trainers, and therefore had the qualifications to recognize the signs and symptoms of anterior shin pain. This ensured the

subjects were qualified to assess the validity of the modified Lower Limb Functional Index to diagnose anterior shin pain pathology and make further modifications as needed. The researchers conducting the study agreed upon the final product of the Lower Limb Functional Index.

### Instruments

The instruments used in this study included a Sammons Preston Rolyan flexible tape measure, Lange skinfold caliper, hand-held dynamometer Model 01163, OMRON hand-held bioelectrical impedance analysis device Model HBF-306CN (HBF-306-Z5), weight scale Model 884 7021099, National Football Scouting height measurement tool, flexible height measurement tool, metronome, goniometer, surgical tubing and two parallel uprights.

### Procedures

#### Lower Limb Functional Index Scores

Subjects answered the questions on the survey separately for both legs. Subjects could answer yes, no or maybe if the questions pertained to symptoms they had experienced in the past. Each answer was correlated to a



number value, yes=1 point, no=0 points, and maybe=1/2 point. The total points for each leg were multiplied by four and then divided by the total number of possible points to determine the percentage.<sup>4</sup>

### Height and Weight Measurement

Height was measured using a National Football Scouting height measurement tool or a standard flexible height measurement tool based on availability. The subjects were required to remove their shoes. The subject stood upright, both feet flat on the floor and heels touching. The heels, midbody and upper body parts remained touching the wall. The subject's head remained in neutral position relative to the chin while looking straight ahead. An electronic scale was used to take weight measurements. Subjects were instructed to void the bladder within the hour prior to testing and asked to remove excessive outerwear if they were comfortable doing so. Subjects' weight measurements were taken before noon in order to make accurate comparisons among measurements.<sup>7</sup>

### Bioelectrical Impedance Analysis

Subjects were required to take their height and weight measurements in order to enter the correct demographic data into the BIA to determine body fat percentage. Subjects held the handheld dynamometer with both arms extended away from their bodies until the reading was done. America's College of Sports Medicine suggests the hydration status of the subjects be controlled for prior to testing. Subjects should not consume alcohol forty-eight hours prior to testing and products containing diuretic properties in the previous twenty-four hours before the test. The subjects should not exercise up to twelve hours before testing and avoid eating or drinking anything within four hours prior to the test. Finally, the bladder should be completely voided within thirty minutes of the test.<sup>7</sup> It would be extremely unrealistic to ask subjects to meet these standards prior to testing. Instead, subjects were asked to avoid eating anything within one hour of testing and void the bladder within thirty minutes of testing. Testing was completed in the morning prior to subjects working out.

### Calf Girth Measurements

The subject stood with both feet 20 cm apart. A flexible tape measure was placed horizontally around the

maximum circumference of the calf between the knee and ankle. The tape measure was placed on the skin's surface without compressing the subcutaneous adipose tissue. Duplicate measurements were taken once the skin returned to normal texture. A third measurement was taken if the previous measurements were not within five millimeters of one another. The measurements were averaged for the individual's calf girth measurement.<sup>7</sup>

#### Skinfold Measurements

The skinfold measurement was taken on the side undergoing testing while the subject remained standing upright. The skinfold measurement was taken at the maximal circumference of the calf on the midline of its medial border. The researcher used the index finger and thumb to pinch the skin and underlying adipose tissue away from the deeper layers of muscle. This pinch was maintained for one to two seconds before reading the caliper. The caliper was placed perpendicularly on the skin, 1 cm away from the thumb and index finger and halfway between the crest and base of a vertical fold. Once the skin returned to its normal texture and thickness this measurement was repeated to ensure validity of the measurement. A third measurement was taken if duplicate measures were not within two

millimeters of one another. The measurements were averaged for the individual's calf skinfold measurement.<sup>7</sup>

#### Muscular Endurance Screening

Subjects stood barefoot between two parallel uprights fitted perpendicularly with surgical tubing. The subject's foot was placed in their neutral position and then measured using a goniometer (the angle between the lateral midline of the fibula and lateral fifth metatarsal). Subjects stood on one foot and raised their heel to their end range of plantar flexion so that the height of the surgical tubing could be adjusted to make contact with the dorsal side of the foot during testing. The subject's weight-bearing plantar flexion was documented. Heel raises were performed to a metronome at a ratio of one heel raise every two seconds by raising the heel to make contact with the surgical tubing and lowering the heel to the ground. Repetitions were counted each time the dorsal side of the foot made contact with the surgical tubing. The knee remained straight in the leg undergoing testing and the same side upper extremity remained relaxed. The subject's forward lean was controlled with the use of a handheld dynamometer in the upper extremity opposite to the leg being tested. Maximal forward lean was equivalent to 2% of

the subject's body weight. Subjects were shown an example of an acceptable calf raise. They were also given the opportunity to practice calf raises to the metronome if they chose to. Subjects were given the opportunity to use the dynamometer to get a feeling of the amount of pressure they were allowed to apply during the test. Two investigators determined termination of the test by monitoring if the subject exhibited a forward lean greater than 2% of their body weight, the subject's knee flexed, became too fatigued to continue or did not make contact with the surgical tubing for three consecutive repetitions.<sup>8</sup>



**Figure 1.** Muscular Endurance Screening

## Hypotheses

The following hypotheses were based on previous research and a review of the literature.

1. There will be a relationship between calf girth and functional index scores.
2. There will be a positive relationship between calf girth and muscular endurance scores.
3. There will be a relationship between functional index scores and muscular endurance scores.

## Data Analysis

The data was analyzed through the use of Pearson Product Correlations. The three variables correlated included lean calf girth, muscular endurance scores and Lower Limb Functional Index Scores. The Additional Findings subsection used Independent-Samples *t* Tests and a Scatter plot.

## RESULTS

The purpose of this study was to determine any relationship between lean calf girth and lower leg endurance on anterior shin pain. Subjects' Lower Limb Functional Index scores, muscular endurance scores and lean calf girth measurements were analyzed through Pearson Product Correlations and an Independent-Samples *t* Test. The mean LLFI score, muscular endurance score and lean calf girth measurement of subjects' right and left legs were analyzed using Pearson correlations. Two additional Pearson correlations were analyzed using the same three variables, but isolated for subjects' dominant and non-dominant legs. Finally, a *t* Test was performed between the group of individuals that scored a 0% on the LLFI and the group of individuals that scored greater than 0% on the LLFI to determine any correlation between the muscular endurance scores and lean calf girth measurements between the two independent samples. The following section contains the data collected in this study and is divided into three subsections: Demographic Information, Hypotheses Testing, and Additional Findings.



## Demographic Information

Data collection was taken for nineteen subjects; however, five were excluded from statistical analysis. Four were excluded due to the fact one leg had been injured within the past 6 months. Therefore we could not compare lean tissue girth, muscular endurance score or LLFI score between their dominant and non-dominant leg and chose to discard them altogether. The final subject never identified dominance and therefore a similar issue came about. The subjects used in this study (N=14) were volunteer student-athletes from California University of Pennsylvania. The subjects included athletes from volleyball, football and Men and Women's soccer. The subjects included ten females and four males. The subjects' ages ranged from 18-22 years. At the time of data collection athletes were in their off-season.

**Table 1.** Demographics of Subjects According to Sport

<b>Sport</b>	<b>Number of Subjects</b>	<b>Age (# of subjects)</b>
Volleyball	5	19(4), 20
Football	2	21, 22
Women's Soccer	5	18, 19(2), 20, 21
Men's Soccer	2	19, 20

## Hypothesis Testing

The following hypotheses were tested in this study. All hypotheses were tested with a level of significance set at  $\alpha \leq 0.05$ . Pearson Product Correlations were calculated for the effect of lean calf girth on anterior shin pain.

Hypothesis 1: There will be a relationship between calf girth and functional index scores.

Conclusion: A Pearson correlation was calculated for the relationship between participants' average LLFI score and average lean calf girth. A moderate correlation that was not significant was found ( $r(12)=-0.517, p>.05$ ). A Pearson correlation was calculated examining the relationship between participants' lean calf girth and LLFI score in their dominant leg. A moderate correlation that was not significant was found ( $r(12)=-0.527, p>.05$ ). A Pearson correlation was calculated examining the relationship between participants' lean calf girth and LLFI score in their non-dominant leg. A moderate correlation that was not significant was found ( $r(12)=-0.494, p>.05$ ).

**Table 2.** Pearson Product Correlation of Subjects' Mean Muscular Endurance Score, Lean Tissue Girth and LLFI Score

<b>Group</b>	<b>Muscular Endurance Score (Correlation)</b>	<b>Lean Tissue, mm (Correlation)</b>	<b>LLFI Score, percentage (Correlation)</b>
Muscular Endurance Score	1	0.187	-0.098
Lean Tissue	0.187	1	-0.517
LLFI Score	-0.098	-0.517	1

**Table 3.** Pearson Product Correlation of Subjects' Muscular Endurance Score, Lean Tissue Girth and LLFI Score in their Dominant Leg

<b>Group</b>	<b>Muscular Endurance Score (Correlation)</b>	<b>Lean Tissue, mm (Correlation)</b>	<b>LLFI Score, percentage (Correlation)</b>
Muscular Endurance Score	1	0.237	-0.070
Lean Tissue	0.237	1	-0.527
LLFI Score	-0.070	-0.527	1

**Table 4.** Pearson Product Correlation of Subjects' Muscular Endurance Score, Lean Tissue Girth and LLFI Score in their Non-Dominant Leg

<b>Group</b>	<b>Muscular Endurance Score (Correlation)</b>	<b>Lean Tissue, mm (Correlation)</b>	<b>LLFI Score, percentage (Correlation)</b>
Muscular Endurance Score	1	0.120	-0.071
Lean Tissue	0.120	1	-0.494
LLFI Score	-0.071	-0.494	1

Hypothesis 2: There will be a positive relationship between calf girth and muscular endurance scores.

Conclusion: A Pearson correlation coefficient was calculated for the relationship between participants' average muscular endurance score and average lean calf girth. Table 2 illustrates a weak correlation that was not significant was found ( $r(12)=0.187, p>.05$ ). A Pearson correlation was calculated examining the relationship between participants' muscular endurance score and lean calf girth in their dominant leg. Table 3 illustrates a weak correlation that was not significant was found ( $r(12)=0.237, p>.05$ ). A Pearson correlation was calculated examining the relationship between participants' muscular endurance score and lean calf girth in their non-dominant leg. Table 4 shows a weak correlation that was not significant was found ( $r(12)=0.120, p>.05$ ).

Hypothesis 3: There will be a relationship between functional index scores and muscular endurance scores.

Conclusion: A Pearson correlation was calculated for the relationship between participants' average muscular endurance score and average LLFI score. Table 2

illustrates a weak correlation that was not significant was found ( $r(12)=-0.098, p>.05$ ). A Pearson correlation was calculated examining the relationship between participants' muscular endurance score and LLFI score in their dominant leg. Table 3 reveals a weak correlation that was not significant was found ( $r(12)=-0.070, p>.05$ ). A Pearson correlation was calculated examining the relationship between participants' muscular endurance score and LLFI score in their non-dominant leg. Table 4 illustrates a weak correlation that was not significant was found ( $r(12)=-0.071, p>.05$ ).

#### Additional Findings

A supplementary test was performed to determine if muscular endurance scores and lean tissue girth varied among subjects that reported a history of anterior shin pain and subjects that reported no history of anterior shin pain. Subjects scoring a zero on the Lower Limb Functional Index confirmed no history of anterior shin pain. Any subjects scoring above zero on the Lower Limb Functional Index were identified as having a past history of anterior shin pain.

An independent-samples  $t$  test comparing the mean scores of the subjects with a history of anterior shin pain and the subjects without a history of anterior shin pain found a significant difference between the means of the two groups when comparing lean calf girth ( $t(16.716) = 3.972, p = .001$ ). The mean lean girth of the subjects with a history of anterior shin pain was significantly lower ( $m = 334.7, sd = 14.42$ ) than the mean girth of the subjects without a history of anterior shin pain ( $m = 337.6, sd = 37.73$ ).

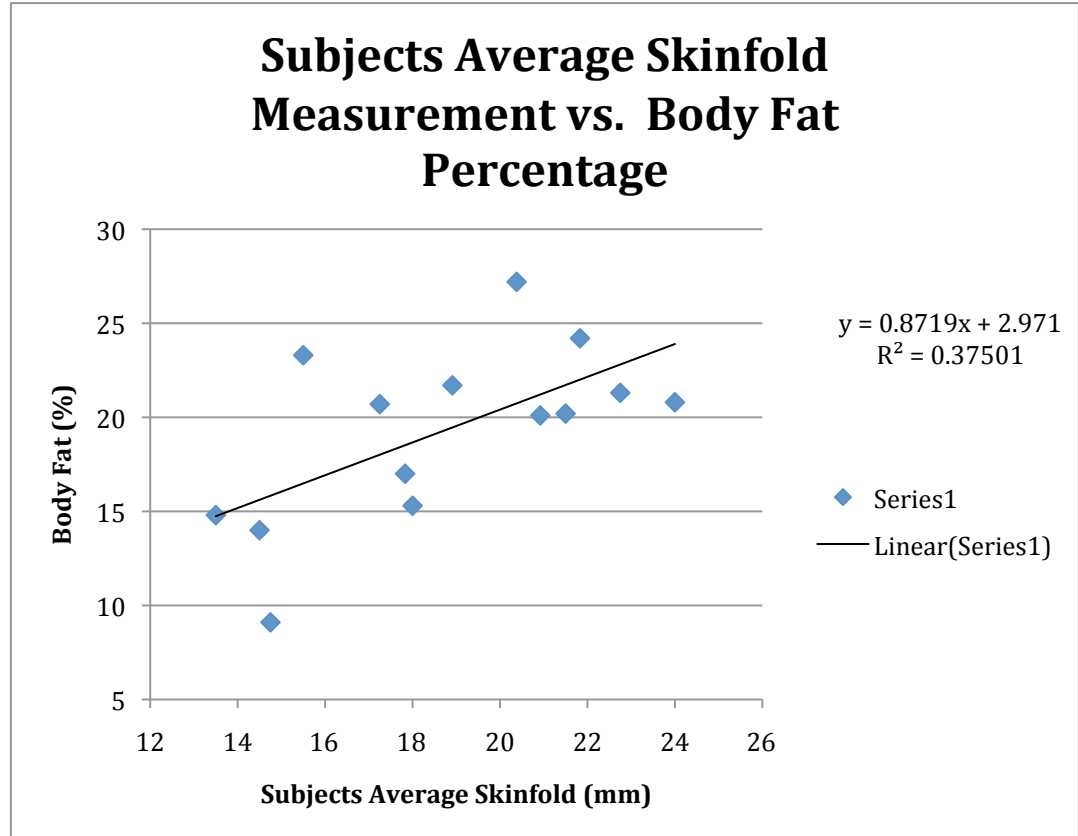
**Table 5.** Independent-Samples  $t$  Test Comparing the Mean Muscular Endurance Score and Mean Lean Tissue Girth in Subjects with History of Anterior Shin Pain and Subjects without History of Anterior Shin Pain

<b>Group</b>	<b>Muscular Endurance Score Mean (SD)</b>	<b>Lean Tissue, mm Mean (SD)</b>
History of Shin Pain	27.7 (10.67)	334.7 (14.42)
No History of Shin Pain	33.1 (18.81)	337.6 (37.73)

An independent-samples  $t$  test was calculated comparing the mean scores of the subjects with a history of anterior shin pain and the subjects without a history of anterior shin pain. Table 5 illustrates no significant difference was found between the means of the two groups when comparing mean muscular endurance scores ( $t(20.582) = .939, p > .05$ ). The mean muscular endurance score of the

subjects with a history of anterior shin pain ( $m = 27.7$ ,  $sd = 10.67$ ) was not significantly different from the mean score of the subjects without a history of anterior shin pain ( $m = 33.1$ ,  $sd = 18.81$ ).

Bioelectrical Impedance Analysis was used to calculate Body Fat percentage among subjects in order to determine any relationship between their prospective skinfold measurements. The purpose of collecting Body Fat percentage was to determine standardization and accuracy of the skinfold measurements collected. Subjects with larger Body Fat percentages were hypothesized to have larger skinfold measurements, resulting in less lean calf tissue. Greater or lesser amounts of lean calf tissue were hypothesized to have an effect on the development of anterior shin pain. A Scatter plot comparing subjects average skinfold measurement to Body Fat percentage revealed an  $R^2$  value of 0.375. There was not a strong correlation between subjects' calculated skinfold measurement and Body Fat percentage.



**Figure 2.** Scatter plot of Subjects' Average Skinfold Measurement and Body Fat Percentage



## DISCUSSION

The purpose of this research study was to determine any relationship between lean calf girth and lower leg endurance on anterior shin pain. The following section is divided into three subsections: Discussion of Results, Conclusions, and Recommendations.

### Discussion of Results

Anterior shin pain is a broad injury caused by many etiological risk factors.<sup>1</sup> Researchers have not yet been able to isolate one risk factor that has more prevalence on the development of anterior shin pain in comparison to others. Limited research has examined lean calf girth as a possible contributory factor. The focus of this study was to determine the role, if any, lean calf girth and muscular endurance plays in the development and severity of anterior shin pain.

Burne et al<sup>2</sup> conducted research to determine the role of lean calf girth among other variables on the sudden development of Exertional Medial Tibial Pain (EMTP) through a prospective study in Australian Defense Force cadets over

the course of a twelve month training period. The results of this study revealed decreased lean muscle mass as a possible contributory factory to the lower leg's incapacity to adapt to loading forces and withstand injury. This incapacity contributed to 25% of female cadets not being able to complete training requirements and only 95% of male cadets completing the fitness test.

It was hypothesized that there would be a relationship between calf girth and functional index scores. Statistical analysis of three Pearson Product Correlations revealed no significant relationship. The subjects' average LLFI score was not related to the average lean girth measurement. Subjects' lean tissue girth was not related to LLFI score in the dominant leg. Subjects' lean girth measurement was not related to LLFI score in their non-dominant leg.

It was hypothesized that there would be a positive correlation between calf girth and muscular endurance scores. Statistical analysis of three Pearson Product Correlations revealed no significant relationship. Subjects' average muscular endurance score was not related to their corresponding average lean tissue girth. Subjects' muscular endurance score was not related to lean calf girth in the dominant leg. Subjects' muscular

endurance score was not related to subjects' lean calf girth in their non-dominant leg.

It was hypothesized that there would be a relationship between functional index scores and muscular endurance scores. Statistical analysis of three Pearson Product Correlations revealed no significant relationship. Subjects' average muscular endurance score was not related to average LLFI score. Subjects' muscular endurance score was not related to LLFI score in the dominant leg. Subjects' muscular endurance score was not related to LLFI score in their non-dominant leg.

In addition there was an Independent Samples t Test performed comparing the mean muscular endurance scores of the subjects with a history of anterior shin pain and the subjects without a history of anterior shin pain. No significant difference was found between the means of the two groups when comparing muscular endurance scores.

An Independent Samples t Test comparing mean girth measurement of subjects with a history of anterior shin pain and without a history of anterior shin pain was found significant. Subjects with a history of anterior shin pain had a significantly lower mean girth than the subjects without a history of anterior shin. The results of this

statistical analysis were similar to those reported by Burne et al<sup>2</sup> and Shinkel-Ivy et al<sup>3</sup>.

The results of the statistical analysis of the three Pearson Product Correlations and Independent Samples t Test comparing mean muscular endurance scores of subjects with a history of anterior shin pain and subjects without a history of anterior shin pain were not similar to those reported by Burne et al and Schinkel-Ivy et al. There are possible explanations for the results of this study differing from the literature.

This study used the Lower Limb Functional Index as a tool to determine subjects' past experience with anterior shin pain.<sup>4</sup> Subjects were not currently suffering from anterior shin pain at the time of data collection. It is possible subjects' past experience with anterior shin pain was so long ago that the lean calf girth calculated at the time of the study was not the same value as when they were suffering from anterior shin pain. For example, subjects may have increased or decreased their lean calf girth due to varying training regimens over time. One of the preliminary requirements of the study disqualified any subject that suffered from any lower extremity injury within six months of data collection to prevent residual swelling from interfering with the accuracy of the data.

It is possible that the number of subjects had a negative effect on the statistical significance. Due to time constraints, subjects' class schedules and the rigid testing parameters, it was difficult to recruit a large sample size. Perhaps with a greater subject pool results may have differed. Furthermore, there were an unequal number of males and females that participated in this study (f=10, m=4). Given a greater number of male participants, it may have proven beneficial for gender comparison of muscular endurance score, lean calf girth and LLFI score due to past research by Burne et al and Shinkel-Ivy et al. Both studies revealed a greater number of females suffering from injury than their male counterparts.

Subjects included within this study were not required to have suffered from anterior shin pain in the past. This particular study included subjects without a history of anterior shin pain because of limited volunteers and time constraints. After statistical analysis of an Independent Samples t Test comparing the mean girth of subjects with a history of anterior shin pain and subjects without a history of anterior shin pain revealed significance, it may have been beneficial to strictly include subjects with a history of anterior shin pain. I hypothesize subjects without a history of anterior shin pain will have lean

girth measurements that remain stable over time due to lack of history. Perhaps the three Pearson Product Correlations would have shown statistical significance if only subjects that experienced anterior shin pain participated in data collection. Based on the results of this study, I believe it is worthwhile to investigate further whether lean girth plays a role in anterior shin pain on subjects with a previous history.

### Conclusions

The relationship between subjects' lean calf girth, muscular endurance scores and Lower Limb Functional Index scores were not proven statistically significant. However, additional findings revealed subjects with a history of anterior shin pain had a lower mean girth than subjects without a history of anterior shin pain. This is similar to current literature findings.<sup>2, 3</sup> The additional findings included within this study are important to propel further research and insight into the role of lean calf girth on anterior shin pain.

## Recommendations

Athletic trainers, strength and conditioning professionals and coaches must work closely together to aid in the rehabilitation process of injured and healthy athletes. It is important to realize the possible implications of lesser or greater amounts of lean calf girth in the development of anterior shin pain. The sports professionals must collaborate to develop training regimens to ensure athletes are not over or under-worked. The rehabilitative exercises, lifting sessions and repetitive drills at practice may require modification to prevent or aid in Triceps Surae lean mass gains.

Further research to determine the role, if any that lean calf girth plays in the development of anterior shin pain is suggested.

- 1) A greater population of subjects would create a larger sample population to examine for statistical significance. In addition to data collected from volleyball, football and men and women's soccer at California University of PA, it would be beneficial to include as many varsity teams that are willing to participate.

- 2) An equal number of male and female subjects from athletic teams would create a more equal distribution. For instance, including ten subjects from men's soccer would require ten subjects from women's soccer. For sports teams that do not have a male or female counterpart (ie. football and volleyball) the number of subjects from each team should remain equal to confirm an equal number of males and females included within the study.
- 3) It is recommended that strictly subjects with a history of anterior shin pain are included in data collection. I hypothesize subjects without a history of anterior shin pain should not have altered lean calf girth measurements due to lack of previous injury. Therefore, subjects with a history of anterior shin pain should be exclusively used in this study to determine any relationship between lean calf girth and previous anterior shin pain.
- 4) It is recommended that BIA is not included in further research of the relationship between lean calf girth and history of anterior shin pain. Simply collecting height and weight measurements to calculate Body Mass Index would be appropriate to standardize skinfold measurements to determine accuracy of lean calf girth



measurements.

## REFERENCES

1. Craig, DI. Medial tibial stress syndrome: current etiological theories part 1-background. *Athl Ther Today*. 2008;13(1):17-20.
2. Burne SG, Khan KM, Boudville PB, et al. Risk factors associated with exertional tibial pain: a twelve months prospective clinical study. *Br J Sports Med*. 2004;38(4):441-5.
3. Schinkel-Ivy A, Burkhart T, Andrews D. Leg tissue mass composition affects tibial acceleration response following impact. *J Appl Biomech*. 2012;28(1):29-40.
4. Gabel C, Melloh M, Burkett B, Michener L. Lower limb functional index: development and clinimetric properties. *Phys Ther*. 2012;92(1):98-110.
5. Wikstrom E, Tillman M, Chmielewski T, Cauraugh J, Naugle K, Borsa P. Discriminating between copers and people with chronic ankle instability. *J Athl Train*. 2012;47(2):136-142.
6. Clement DB, Taunton JE, Smart GW et al. A survey of overuse running injuries. *Phys Sportsmed*. 1981;9:47-58.
7. Kaminsky, LA. *Body Composition: ACSM's Health-Related Physical Fitness Assessment Manual*. 3<sup>rd</sup> ed. Baltimore, MD: Lippincott Williams & Wilkins, a Wolters Kluwer business;2010.
8. Ross M, Fontenot E. Test-retest reliability of the standing heel-rise test. / Fiabilite du test du talon leve en position debout, effectue a deux reprises. *J Sport Rehabil*. 2000;9(2):117-123.

## APPENDICES

APPENDIX A  
Review of Literature

## INTRODUCTION

The purpose of this Review of Literature is to enlighten the reader about conflicting data regarding the etiology of anterior shin pain. Clement et al found that Medial Tibial Stress Syndrome accounted for 10.7% of injuries in men and 16.8% of injuries in women suggesting it is a common pathology. Clement draws attention to the fact that relatively little is known about its causes suggesting the need for further investigation.<sup>1</sup> It is widely accepted that musculoskeletal and neuromuscular adaptations result from exercise. The aim of this review is to determine the role, if any, lean calf girth has on the prevalence of anterior shin pain. This will be accomplished in the following sections: Etiology of Anterior Tibial Pain, Leg Soft Tissue Composition, Body Mass Index Determination, the use of Disability Indexes and Triceps Surae Strength Testing. The literature review will end with a summary of the research performed to date.

## Etiology of Anterior Tibial Pain

Previous research has revealed multiple etiological factors that contribute to the development of Medial Tibial Stress Syndrome (MTSS) and 'shin splints', which encompass the broad diagnosis of anterior shin pain. The most recent evidence reveals a multitude of biomechanical factors that lead to the development of anterior shin pain, contributing to the vagueness of this injury.<sup>2</sup> A study conducted by Johnell et al<sup>3</sup> discredited the theory that anterior shin pain had a single underlying cause through the assessment of tissue biopsy from patients suffering from medial tibial pain post-exercise.

A study conducted by Moen et al<sup>4</sup> aimed to examine multiple theorized risk factors for medial tibial stress syndrome and through their identification increase their diagnostic value. Among the most popular theorized etiologies to date, the study focused on hip internal and external ranges of motion, knee flexion and extension, dorsal and plantar ankle flexion, hallux flexion and extension, subtalar eversion and inversion, maximal calf girth, lean calf girth, standing foot angle and navicular drop test. The multivariate regression analysis performed

within this study confirmed significant association between decreased hip internal rotation, increased plantar flexion and a positive navicular drop test and the presence of MTSS. Moen et al theorized decreased internal hip range of motion negatively influenced running economy in such a manner that the tibia became abnormally loaded. Overall, greater plantar flexion range of motion found in MTSS subjects is theorized to predispose forefoot landing as opposed to initial heel strike during normal running mechanics leading to overcompensation by unequipped structures of the lower leg. Abnormal navicular drop measurements in MTSS subjects can be attributed to genetic structural differences and has proven to have a negative effect on functional movement.

A twelve-month prospective clinical study conducted by Burne et al investigated anthropometric and intrinsic biomechanical risk factors to exertional medial tibial pain (EMPT) within the Australian Military Defense Force Academy. Lean calf girth measurements were recorded and analyzed among the seven intrinsic variables investigated in this study. Following twelve-months of military training, twenty-three of one-hundred fifty-six military cadets met the diagnostic standards defined in this study for exertional medial tibial pain. Although both male and

female cadets were examined in the study, results varied between the sexes. A possible contributory factor for statistical significance correlating lean calf girth and the presence of EMTP found solely for male cadets is the greater prevalence of males than females in the academy. Furthermore, twenty-five percent of the female cadets did not compete in the running component of the physical fitness testing because of diagnosed exertional medial tibial pain.<sup>5</sup>

Interestingly, male cadets suffering from EMTP had a right lean calf girth that was 4.2% less than NON-EMTP male cadets. Although not statistically significant, it should be noted that male cadets suffering from EMTP tended to have a lesser lean calf girth in their left leg in comparison to NON-EMTP male cadets. Burne et al attributes decreased lean muscle mass as a possible contributory factor to the lower leg's incapacity to adapt to loading forces and withstand injury.<sup>5</sup>

Schinkel-Ivy et al conducted a study that is closely related to the research question of this project. The aim of this article was to determine the effect of body composition and leg tissue masses on the acceleration response of the tibia succeeding impact.<sup>6</sup> Few studies have



attempted to examine the effect of localized anthropometric measurements on overall function.

The peak acceleration, time to peak acceleration and acceleration slope measurements were found to be statistically significant when normalized for measurements of leg tissue mass. Peak acceleration and acceleration slope values decreased with increased leg lean mass and bone mineral content. Schinkel-Ivy et al suggest that greater lean and bone mass provide protection to tibial shock. Furthermore, the females in this study presented with lower lean mass and bone mass than their male counterparts resulting in greater peak acceleration and acceleration slope values. The data suggests that localized tissue make-up is a factor in injury susceptibility and that individuals with less lean mass and bone mass run a greater risk of musculoskeletal disorders.<sup>6</sup>

Researchers have shown various relationships associated with the development of anterior shin pain. Little investigation has been done to isolate the role of excessive or sparse amounts of lean calf girth in the progression of musculoskeletal damage. This particular study will determine any relationship between lean calf girth and anterior shin pain.

### Leg Soft Tissue Composition

The literature review includes the examination of the lean mass and fat mass of the lower leg in order to determine if an optimal ratio exists to absorb impact forces adequately. The purpose of the present study is to determine if abnormal amounts of muscle tissue predispose subjects to anterior shin pain. Several anthropometric measurements can be taken and further manipulated in order to determine a crude lean mass value of the lower leg and multiple researchers have done so.

The study conducted by Moen et al took maximal calf girth and skin-fold measurements to determine lean calf girth. The corrected lean calf girth was calculated by subtracting the skin-fold thickness (fat tissue composition) using a skin-fold caliper from the maximal calf girth (absolute tissue composition) of the relaxed calf obtained through use of a tape measure at the greatest circumference of the muscle belly between the ankle and knee joints.<sup>4</sup>

Although calf girth measurements using a tape measure is accepted as the sole determinant of isolated girth

measurements, there are multiple, accurate methods to take skin-fold measurements. A study conducted by Selkow et al compared the validity of skin-fold calipers to ultrasound imaging techniques based on the assumption that there is greater risk of human error using skin-fold calipers to determine subcutaneous fat thickness.<sup>7</sup>

This study aimed to determine a relationship between thigh fat-thickness using both methods at four sites. The results indicate ultrasound imaging and skin-fold caliper values were strongly correlated among individuals with less subcutaneous fat-thickness. However, measurements taken manually on individuals with overall greater subcutaneous fat thicknesses tended to overestimate the values in comparison to the ultrasound imaging technique. The results indicate greater room for human error with the calipers used on individuals with greater subcutaneous fat.<sup>7</sup>

There are several variations and limitations within this study. The study conducted their experiment on 'healthy adults.'<sup>7</sup> We can assume an even greater validity of the calipers used on elite athletes because of their increased physical fitness level and generalized lower BMI values in contrast to the average adult. Therefore, a basic assumption of this experimental procedure is that the elite subjects will have decreased subcutaneous fat in

comparison to the "healthy adult". Therefore, measurements of localized subcutaneous fat thickness using the skin-fold calipers on elite athletes is even less likely to overestimate subcutaneous fat thicknesses. Furthermore, the site location will vary between the studies. The lower leg has a smaller circumference than the thigh and therefore has fewer adipose cells to store subcutaneous fat. The skin-fold calipers will provide greater validity measuring locations with less area to store fat deposits. The use of a skin-fold caliper would be a valid measurement tool to determine isolated subcutaneous fat of the lower leg.

#### Body Mass Index Determination

This research design will also include whole Body Mass Index measurements using a hand-held BMI digital analyzer. The purpose of the BMI measurement within this experiment is to standardize calf girth measurements between athletes of various body fat percentages.

Body Mass Index is a type of body composition analysis commonly used as a determinant of an individual's health status. Body Mass Index is a measure of a person's weight (kg) relative to their height ( $m^2$ ). Adult BMI measurements

are put into categories according to the Center for Disease Control and Prevention as a predictor of disease and longevity. Reed et al. believes that BMI should be a supplement to other simple measures of body composition and body fat distribution due to its limitations. The review conducted by Reed et al highlights findings from multiple studies that BMI is not a suitable predictor of health, disease and mortality for individuals in the midrange of BMI measurements. Therefore, an additional method will be used in order to determine body composition of the individuals in this study.<sup>8</sup>

Body Mass Index can be determined through a multitude of techniques. As expected, some methods produced greater validity. The gold standard for measuring body composition is hydrostatic weighing (HW). However, this method is time consuming, expensive and can cause undue stress to subjects compared to alternative methods. Unick et al compared the accuracy of more readily available body composition analyzers, specifically bioelectrical impedance analysis (BIA) to skin-fold and hydrostatic weighing techniques.<sup>9</sup>

Unick et al found significant correlations between BIA and skin-fold values in comparison to hydrostatic weighing for male and female high school aged participants. However, females did show less validity among measurements

of fat free mass (FFM) between both bioelectrical impedance analysis and hydrostatic weighing. Males showed a significant difference between FFM through skin-fold measurements alone compared to HW. In its entirety, BIA is a valid measurement tool for assessing body composition when compared to the gold standard. Unick et al suggests further investigation into the assessment of mean FFM amongst high school aged females.<sup>9</sup> Bioelectrical impedance analysis will be used in this research design to determine body mass index.

Bioelectrical impedance analysis conducts a small amount of electrical current through the body. The amount of resistance to the flow of the current generated by the device reveals whole body fat percentage. The electrical current flows more easily through bodily tissues saturated with water due to the increased presence of electrolytes. Lean tissue contains large amounts of water in comparison to fat tissue allowing for easier conduction of the current. As a result, the BIA differentiates between lean and fat tissue content. The percentage of body fat revealed through BIA is a measurement of the total resistance to the electrical current.<sup>10</sup>

## Disability Indexes

Researchers often use a Disability Index as a form of diagnostic tool to categorize subjects into various groups. Wikstrom et al used scores on the Foot and Ankle Disability Index (FADI) to group individuals currently suffering from chronic ankle instability based on lingering residual symptoms from individuals who suffered acute injury with no current instability.<sup>11</sup> The Disability Index questionnaire such as the FADI has proven to be a valid diagnostic tool. Wikstrom et al found a high correlation between patients' perceptual disability scores using the FADI and objective measurements involving radiographic images and the single-legged hop stabilization test.<sup>11</sup> Disability Indexes have been established as a valid tool in conducting research.

The Lower Limb Functional Index (LLFI) is a type of Disability Index used to determine the extent of lower limb deficiencies in activities of daily living based solely on patient reporting. Gabel et al assessed the limitations of the LLFI in comparison to the Lower Extremity Functional Scale (LEFS) because of its established validity.<sup>12</sup>

The validity of the two scales was assessed on floor and ceiling effects, missing responses and criterion validity. The LLFI findings presented no floor or ceiling effects based on visual examination, missing responses left no questionnaires invalid in comparison to 10% of the LEFS questionnaires and construct validity between disability indexes was high. Furthermore, Gabel et al found that the LLFI questionnaire was completed and scored more quickly and slightly more readable. The increased efficiency of the LLFI in comparison to the LEFS made the decision to use this Disability Index a logical choice.<sup>12</sup>

#### Triceps Surae Strength Testing

It is often assumed that larger muscle size is positively correlated to increased muscular strength. As previously discussed, researchers attempted to increase accuracy of lean calf tissue calculations by subtracting skin-fold measurements from circumferential measurements.<sup>4</sup> Once a crude measurement of lean tissue mass is obtained one can compare these values with measurements of muscular strength to determine an objective relationship based on quantitative data.



The researchers cannot assume that subjects with increased lean calf mass are definitively stronger than subjects with smaller measurements. Ross et al investigated the test-retest reliability of the Standing Heel-Rise Test through a repeated-measures analysis of variance. Subjects performed end range of motion plantar flexion of the ankle joint, also standardized for individual range of motion, to the rhythm of a metronome until standards were no longer met to continue on. In order to account for additional support through forward leaning during the test, subjects held a hand dynamometer against the wall on the opposite side of the leg being tested. Pressure from forward leaning was standardized between subjects allowing no greater than 2% of the individual's body weight. All subjects underwent two testing sessions separated by seven days in order to compare the maximal standing heel-rise repetitions performed.<sup>13</sup>

ANOVA analysis showed high test-retest reliability, indicating that the Standing Heel-Rise Test can be used as a sufficient measure of calf muscular endurance.<sup>13</sup> Both the gastrocnemius and soleus muscles are stressed by this test. Svantesson et al suggests the potential of The Standing Heel Rise Test to determine which plantar flexor reaches

fatigue first by the type of contraction performed within the test. The activation of the gastrocnemius and soleus can be isolated during the concentric and eccentric components of plantar flexion. The Standing Heel Rise Test may aid in identifying which plantar flexor requires additional muscular strengthening exercises to improve athletic performance.<sup>14</sup> The Standing Heel Rise Test has the capability to quantify isolated calf muscular endurance as well as differentiate between plantar flexors reaching their prospective failure point.<sup>13, 14</sup>

#### Summary

The literature review provides evidence of a relationship between lean calf girth and anterior shin pain that deserves further investigation. The high prevalence of anterior shin pain among the athletic population warrants research into any possible contributing factor. The strengths and weaknesses of previously conducted research will guide this particular study. The literature review will aid in the development of a concise procedure that identifies any relationship between lean calf girth and anterior shin pain. This particular study will control for potential variables in order to focus solely on the

implications of lean calf girth on anterior shin pain. The findings of this particular study will contribute to further research into this relationship or narrow down the possible risk factors associated with anterior shin pain. The results of this study may require changes in training techniques to reduce or increase the lean tissue composition of the lower leg.

## APPENDIX B

## The Problem

## STATEMENT OF THE PROBLEM

The purpose of the study was to examine the relationship between lean calf girth, calf strength and anterior shin pain. It is important to examine this relationship because anterior shin pain affects a large percentage of athletes and inhibits their ability to perform at their best. If we know excessive or reduced amounts of lean calf girth can lead to the development of anterior shin pain we can modify training techniques to counteract its development.

Definition of Terms

The following definitions of terms are defined for this study:

## 1) Anterior Shin Pain

Pain on the distal medial 1/3 of the anterior tibia.

## 2) Lean Calf Girth

The average calf girth (mm) minus the average calf skin-fold (mm).

## 3) Lower Leg Functional Index

The tool used in this study to determine the presence and severity of anterior shin pain among subjects.

4) Single Leg Heel Rise Test

The tool used in this study to assess lower leg muscular endurance by performing as many single leg calf raises to the beat of a metronome until reaching fatigue, becoming out of synch with the metronome, flexing of the knee joint or excessive forward lean.

5) Dominant Leg

The leg the subject would use to kick a soccer ball.

6) Muscular Endurance

Performing high repetitions at a sub-maximal effort.

Basic Assumptions

The following are basic assumptions of this study:

- 1) The subjects were honest when they completed their Lower Limb Functional Indexes.
- 2) The subjects performed to the best of their ability during the Single Leg Heel Rise Test.
- 3) Subjects did not eat or drink within the hour and voided their bladder thirty minutes prior to calculating their BMI.
- 4) Researchers were consistent and trained properly in performing calf girth measurements, skin fold measurements and Single Leg Heel Rise testing.

### Limitations of the Study

The following are possible limitations of the study:

- 1) An unequal number of males and females to complete all phases of testing.
- 2) Human error related to taking skin-fold measurements.
- 3) The inability to extrapolate results found in this study of Division II athletes at California University of PA to all athletes.
- 4) Inability to control the training level of the subjects at the time of testing.

### Delimitations of the Study

- 1) California University of Pennsylvania NCAA Division II athletes that completed at least one season of their prospective sport were included in the study.
- 2) Subjects did not suffer lower extremity injury six months prior to the time this study was conducted.
- 3) Calf girth measurements were standardized for subjects using BMI analysis.
- 4) Subjects included in this study participate in athletics that require lower extremity impact forces.
- 5) Subjects confirmed maintaining hydration guidelines prior to BIA.

### Significance of the Study

The findings of this study did not reveal a relationship between lean calf girth, muscular endurance scores and Lower Limb Functional Index scores. None of the hypotheses proved to be statistically significant. However, subjects with a history of anterior shin pain did reveal a lower mean lean calf girth than subjects without a history of anterior shin pain. This finding suggests further research be conducted to determine the relationship between lean calf girth and anterior shin pain. Further study can be performed to determine if an appropriate ratio of lean muscle mass exists between the plantar flexors for optimal efficiency. The athlete will benefit the most from greater understanding of risk factors to anterior shin pain.



## APPENDIX C

## Additional Methods

APPENDIX C1  
Informed Consent Form

# The Relationship Between Lower Leg Lean Tissue, Functional Index Scores and Triceps Surae Endurance in Athletes



## California University of Pennsylvania

### Informed Consent Form

1. Caitlin Kamide, who is a Graduate Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at California University of Pennsylvania. The title of the research is *The Relationship Between Lower Leg Lean Tissue, Lower Leg Functional Index Scores and Triceps Surae Endurance in Athletes*.

2. I have been informed that the purpose of this study is to determine any relationship between the variables: lean calf tissue mass, Lower Limb Functional Index Scores and Triceps Surae endurance scores. I understand that I must be 18 years of age or older to participate. I understand that I have been asked to participate along with other varsity athletes participating on the football, volleyball, Men's and Women's soccer and basketball teams and track and field at California University of Pennsylvania. I understand that I must have completed at least seventy-five percent of one competitive season of my sport at the collegiate level. I understand that to participate in data collection I can confirm I am not currently suffering from and have had no lower extremity injury in the 6 months prior to the time of testing. I confirm that I am not currently pregnant and in the event I do become pregnant I will immediately notify the Primary Researcher. I understand that the Principal Investigator will terminate my participation if circumstances such as unexpected pregnancy arise due to the potential risk to the unborn child.

3. I have been invited to participate in this research project. My participation is voluntary and I can choose to discontinue my participation at any time without penalty or loss of benefits. My participation will involve calf girth measurements, calf skin fold measurements, height and weight measurements, providing demographic information pertinent to Body Mass Index calculation such as age and gender, Bioelectrical Impedance Analysis using a hand-held dynamometer, the Standing Heel Rise Test for Triceps Surae endurance calculation and completion of the Lower Limb Functional Index. First, the subjects will complete their individual Lower Limb Functional Index. Once subjects are deemed eligible for participation all anthropometric measurements will be taken during one meeting. On the final day of testing, subjects will complete the

## The Relationship Between Lower Leg Lean Tissue, Functional Index Scores and Triceps Surae Endurance in Athletes

Standing Heel Rise Test. All testing materials will be completed over the course of three days.

4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. I understand that there is risk of soft tissue damage, muscle soreness, muscle cramping, loss of balance, falling and the possibility of experiencing fatigue during testing. With participation in a research program such as this there is always the potential for unforeseeable risks, such as a subject experiencing exaggerated fatigue due to sickness at the time of testing. I understand that the Lower Limb Functional Index requires that I am honest to my best knowledge in its completion. I understand that demographic information will be required to calculate Body Mass Index using the hand-held Bioelectrical Impedance Analyzer. I understand that calf skinfold measurements and calf girth measurements will be required as part of the data collection and temporary tissue alteration is a possible risk. I understand the Principal Investigator will inform me of any significant new findings developed during the research that may affect me and influence my willingness to continue participation.

5. I understand that, in case of injury, I can expect to receive treatment or care in Hamer Hall's Athletic Training Facility. This treatment will be provided by the researcher, Caitlin Kamide, under the supervision of the CalU athletic training faculty, all of whom can administer emergency care.<sup>1</sup> Additional services needed for prolonged care will be referred to the attending staff at the Downey Garofola Health Services located on campus. I understand, in case of prolonged stress, there is on campus counseling services available in Carter Hall Room G-53.

6. There are no feasible alternative procedures available for this study.

7. I understand that the possible benefits of my participation in the research is the better understanding of etiological factors contributing to chronic or acute bouts of anterior shin pain and that my participation may aid in the alteration of training techniques to reduce the likelihood of its future development in athletes.

8. I understand that the results of the research study may be published but my name or identity will not be revealed. Only aggregate data will be reported. In order to maintain confidentiality of my records, Caitlin Kamide will maintain all documents in a secure location on campus and password protect all electronic files so that only the student researcher and research advisor can access the data. Each subject will be given a specific subject number to represent his or her name so as to protect the anonymity of each subject.

## The Relationship Between Lower Leg Lean Tissue, Functional Index Scores and Triceps Surae Endurance in Athletes

9. I have been informed that I will not be compensated for my participation nor will there be any costs incurred on my behalf.

10. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by:

Caitlin Kamide, LAT, ATC  
STUDENT/PRIMARY RESEARCHER  
KAM5655@calu.edu  
203-592-6353

Dr. Edwin Zuchelkowski  
RESEARCH ADVISOR  
Zuchelkowski@calu.edu  
(724) 938-4202

11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

12. I have read the above information and am electing to participate in this study. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. I understand the Principal Researcher may terminate my participation at any time without warning. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

13. This study has been approved by the California University of Pennsylvania Institutional Review Board.

14. The IRB approval dates for this project are from: 02/15/13 to 02/14/14.

Subject's signature: \_\_\_\_\_

Date: \_\_\_\_\_

Witness signature: \_\_\_\_\_

Date: \_\_\_\_\_

The Relationship Between Lower Leg Lean Tissue,  
Functional Index Scores and Triceps Surae Endurance in  
Athletes

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Reference:

1. Prentice, WE. *Arnheim's Principles of Athletic Training: A Competency Based Approach*. 13<sup>th</sup> ed. New York, New York: The McGraw-Hill Companies, Inc; 2009.

## APPENDIX C2

Institutional Review Board Approval-  
California University of Pennsylvania

Institutional Review Board  
California University of Pennsylvania  
Morgan Hall, Room 310  
250 University Avenue  
California, PA 15419  
instreviewboard@calu.edu  
Robert Skwarecki, Ph.D., CCC-SLP, Chair

Dear Ms. Kamide:

Please consider this email as official notification that your proposal titled "The relationship between lower leg lean tissue, functional index scores, and triceps surae endurance in athletes" (Proposal #12-024) has been approved by the California University of Pennsylvania Institutional Review Board as amended.

The effective date of the approval is 2-15-2013 and the expiration date is 2-14-2014 .  
These dates must appear on the consent form .

Please note that Federal Policy requires that you notify the IRB promptly regarding any of the following:

- (1) Any additions or changes in procedures you might wish for your study (additions or changes must be approved by the IRB before they are implemented)
- (2) Any events that affect the safety or well-being of subjects
- (3) Any modifications of your study or other responses that are necessitated by any events reported in (2).
- (4) To continue your research beyond the approval expiration date of 2-14-2014 you must file additional information to be considered for continuing review. Please contact instreviewboard@calu.edu

Please notify the Board when data collection is complete.

Regards,  
Robert Skwarecki, Ph.D., CCC-SLP  
Chair, Institutional Review Board



APPENDIX C3

Preliminary Questionnaire

**NAME and EMAIL:** \_\_\_\_\_

**DATE:** \_\_\_\_\_

**Please answer the following preliminary questions before completing the Lower Limb Functional Index.**

- 1. What is your class rank? (i.e. freshman, sophomore etc.)**
  
- 2. What varsity sport do you participate in?**
  
- 3. Are you currently in season?**
  
- 4. Have you suffered any lower extremity injury within the last 6 months?  
Identify the affected leg/side.**
  
- 5. Have you experienced a lower extremity injury more than 6 months ago?  
Briefly explain “Yes” answers by indicating type of injury and severity.  
Identify the affected leg/side.**
  
- 6. How many seasons at the collegiate level have you actively participated in (at  
least 75% of the season)?**

## APPENDIX C4

## LOWER LIMB FUNCTIONAL INDEX

**LOWER LIMB FUNCTIONAL INDEX**

**NAME:** \_\_\_\_\_

**DATE:** \_\_\_\_\_

**PLEASE COMPLETE:** Your leg/s may have suffered anterior shin pain and made it difficult to do some things you normally did. This list contains sentences athletes commonly use to describe themselves when suffering from anterior shin pain.

**If an item describes your past injury, mark the line with a letter “Y”. If not, mark the line with a letter “N”. Please answer each question separately for left (L) and right (R) legs.  
If an item partly describes your past injury-Use a letter “M” Mark.**

**DUE TO MY LEG/S:**

**L      R**

- |     |     |  |
|-----|-----|--|
| ___ | ___ | 1. Outside of school and athletics I stayed at home most of the time.    |
| ___ | ___ | 2. I changed position frequently for comfort.                            |
| ___ | ___ | 3. I avoided heavy jobs involving heavy lifting.                         |
| ___ | ___ | 4. I rested more often.  |
| ___ | ___ | 5. I got others to do things for me.                                     |
| ___ | ___ | 6. I had the pain/problem almost all the time.                           |
| ___ | ___ | 7. I had difficulty lifting and carrying. (eg, backpacks, shopping bags) |
| ___ | ___ | 8. The pain was so distracting that it had affected my appetite.         |
| ___ | ___ | 9. My walking or normal recreation or sporting activity was affected.    |
| ___ | ___ | 10. I had difficulty with normal home or family duties and chores.       |
| ___ | ___ | 11. I slept less well.   |
| ___ | ___ | 12. I had discomfort with personal care (eg, washing, hygiene).          |

**L**      **R**

- \_\_\_ \_\_\_ 13. My regular daily activities (work, school, college life) were affected.
- \_\_\_ \_\_\_ 14. I was more irritable and/or bad tempered.
- \_\_\_ \_\_\_ 15. I felt weaker and/or stiffer.
- \_\_\_ \_\_\_ 16. My transport independence was affected (driving, public transport).
- \_\_\_ \_\_\_ 17. I had discomfort with dressing (eg, trousers/pants/shoes and socks).
- \_\_\_ \_\_\_ 18. I had difficulty changing directions, twisting or turning.
- \_\_\_ \_\_\_ 19. I was unable to move as fast as I would wish.
- \_\_\_ \_\_\_ 20. I had difficulty with prolonged or extended standing.
- \_\_\_ \_\_\_ 21. I had difficulty bending, squatting, and/or reaching down.
- \_\_\_ \_\_\_ 22. I had difficulty with long or extended walks.
- \_\_\_ \_\_\_ 23. I had difficulty with steps and stairs.
- \_\_\_ \_\_\_ 24. I had difficulty with sitting for prolonged or extended times.
- \_\_\_ \_\_\_ 25. I had problems with my balance on uneven surfaces and/or with  
unaccustomed footwear.

## Appendix C5

## Individual Data Collection Sheet

## Data Collection Sheet

Name: \_\_\_\_\_

R Leg      L Leg

## Skinfold Measurement

Athlete	Skinfold #1	Skinfold #2	Skinfold #3	Average

## Calf Girth Measurement

Athlete	Girth #1	Girth #2	Girth #3	Average

## Bioelectrical Impedance Analysis

Athlete	Gender	Age	Height	Weight	BMI

## Single Heel Rise Test

Athlete	Degrees Plantar Flexion	2% Body Weight	Height of Surgical Tubing	# Heel Rises

## REFERENCES

1. Clement DB, Taunton JE, Smart GW et al. A survey of overuse running injuries. *Phys Sportsmed*. 1981;9:47-58.
2. Craig, DI. Medial tibial stress syndrome: current etiological theories part 1-background. *Athl Ther Today*. 2008;13(1):17-20.
3. Johnell O, Rausing A, Wendeberg B, Westlin N. Morphological bone changes in shin splints. *Clin Orthop Relat Res*. 1982;(167):180-184.
4. Moen M, Bongers T, Backx F, et al. Risk factors and prognostic indicators for medial tibial stress syndrome. *Scand J Med Sci Sports*. 2012;22(1):34-39.
5. Burne SG, Khan KM, Boudville PB, et al. Risk factors associated with exertional tibial pain: a twelve months prospective clinical study. *Br J Sports Med*. 2004;38(4):441-5.
6. Schinkel-Ivy A, Burkhart T, Andrews D. Leg tissue mass composition affects tibial acceleration response following impact. *J Appl Biomech*. 2012;28(1):29-40.
7. Selkow N, Pietrosimone B, Saliba S. Subcutaneous thigh fat assessment: a comparison of skinfold calipers and ultrasound imaging. *J Athl Train*. 2011;46(1):50-54.
8. Reed J, Buck S, Gronbech C. Questioning body mass index. *Illinois Journal For Health, Physical Education, Recreation & Dance*. 2010;65:45-51.
9. Unick J, Utter A, Schumm S, McInnis T. Evaluation of leg-to-leg BIA in assessing body composition in high-school-aged males and females. *Res Sports Med*. 2006;14(4):301-313.
10. Kaminsky, LA. *Body Composition: ACSM's Health-Related Physical Fitness Assessment Manual*. 3<sup>rd</sup> ed. Baltimore, MD: Lippincott Williams & Wilkins, a Wolters Kluwer business; 2010.
11. Wikstrom E, Tillman M, Chmielewski T, Cauraugh J, Naugle K, Borsa P. Discriminating between copers and



- people with chronic ankle instability. *J Athl Train*. 2012;47(2):136-142.
12. Gabel C, Melloh M, Burkett B, Michener L. Lower limb functional index: development and clinimetric properties. *Phys Ther*. 2012;92(1):98-110.
  13. Ross M, Fontenot E. Test-retest reliability of the standing heel-rise test. / Fiabilite du test du talon leve en position debout, effectue a deux reprises. *J Sport Rehabil*. 2000;9(2):117-123.
  14. Svantesson U, Osterberg U, Thomee R, Grimby G. Muscle fatigue in a standing heel-rise test. *Scand J Rehabil Med*. 1998;30:67-72.

## ABSTRACT

Title: THE RELATIONSHIP BETWEEN LOWER LEG LEAN TISSUE, FUNCTIONAL INDEX SCORES AND TRICEPS SURAE ENDURANCE IN ATHLETES

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Research Type: Master's Thesis

Context: Minimal research has been conducted to determine the relationship between lean calf girth and anterior shin pain. Research has revealed decreased lean muscle mass as a possible contributory factor to the lower leg's incapacity to adapt to loading forces and withstand injury.

Objective: The purpose of this study was to identify the role, if any, lean calf girth and lower leg endurance have in the occurrence of anterior shin pain.

Setting: The testing was done in Hamer Gymnasium and Dance Studio on the campus of California University of Pennsylvania.

Participants: Fourteen student-athletes from volleyball, football and men and women's soccer at California University of PA volunteered for this study (10 females, 4 males).

Intervention: Subjects completed a preliminary questionnaire, followed by a Lower Limb Functional Index, height, weight, BIA, calf girth, calf skinfold and muscular endurance measurements.

**Main Outcome Measures:**

Three Pearson Product Correlations were conducted for statistical analysis. The three variables included subjects' lean calf girth, muscular endurance scores and LLFI scores. Two Independent-Sample t Tests were conducted to compare muscular endurance scores and lean calf girth measurements between subjects that identified and did not identify a history of anterior shin pain.

**Results:**

The Pearson Product Correlation comparing subjects' average muscular endurance score, average LLFI score and average lean calf girth found no significance among the three variables. The Pearson Product Correlations comparing muscular endurance score, LLFI score and lean calf girth in the dominant leg and non-dominant leg found no significance among the three variables. An independent-samples *t* test comparing the mean scores of the subjects with and without a history of anterior shin pain found a significant difference between the means of the two groups comparing lean calf girth ( $t(16.716) = 3.972, p = .001$ ). An independent-samples *t* test comparing the mean scores of the subjects with and without a history of anterior shin pain illustrated no significant difference between the means of the two groups comparing mean muscular endurance scores ( $t(20.582) = .939, p > .05$ ).

**Conclusion:**

This study revealed subjects with a history of anterior shin pain have a significantly lower mean lean calf girth than subjects without a history of anterior shin pain. However, comparing average lean calf girth, average LLFI score and average muscular endurance score among subjects there is no statistical significance between the three variables. There was no significance found between LLFI score, muscular endurance score and lean calf girth among subjects when looking at the dominant or non-dominant leg.

Word Count: 441