The Effect of Sesamoid Mobilization and Flexor Hallucis Strengthening on Reducing Pain and Improving Function in the Great Toe

Jennifer Shamus
Lynn University

Follow this and additional works at: http://spiral.lynn.edu/etds
Part of the Physical Therapy Commons

Recommended Citation
http://spiral.lynn.edu/etds/172

This Dissertation is brought to you for free and open access by SPIRAL. It has been accepted for inclusion in Student Theses, Dissertations and Projects by an authorized administrator of SPIRAL. For more information, please contact lliadarola@lynn.edu.
Sponsoring Committee: Dr. Rita Nacken Gugel, Chairperson
Dr. Bernard Brucker
Dr. Cindy Skaruppa

The Effect of Sesamoid Mobilization and Flexor Hallucis Strengthening on Reducing Pain and Improving Function in the Great Toe

Jennifer Shamus, PhD, PT, CSCS

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Graduate Studies
Lynn University

2001
The Effect of Sesamoid Mobilization and Flexor Hallucis Strengthening on Reducing Pain and Improving Function in the Great Toe

Shamus, Jennifer L., Ph.D., PT, CSCS
Lynn University, 2001

Copyright 2001, by Shamus, Jennifer L. All Rights Reserved
Acknowledgements

The investigator wishes to thank the members of her dissertation committee, Dr. Rita Nacken Gugel, Chairperson, for her guidance and meaningful comments, Dr. Bernard Brucker, for his collaboration on research design and statistical analysis, and Dr. Cindy Skaruppa, for her feedback and continuous support. In addition, the investigator is grateful to Dr. Augustine Bollo for his assistance in referring subjects to the study. A special thanks to Dr. Eric Shamus for the encouragement to pursue this topic.
Table of Contents

Chapter 1 ........................................................................................................ 1
  Introduction .............................................................................................. 1
  Need for the Study ........................................................................ 1
  Conceptual Framework ................................................................. 2
  Significance of the Study ................................................................. 5
  Definition of Terms ........................................................................ 5
  Hypotheses .......................................................................................... 7
    Hypothesis I .................................................................................... 7
    Hypothesis II ............................................................................... 7
    Hypothesis III ............................................................................. 7
    Hypothesis IV .............................................................................. 7
    Hypothesis V .............................................................................. 7
    Hypothesis VI ............................................................................. 7
    Hypothesis VII ............................................................................ 7
    Hypothesis VIII .......................................................................... 7
    Hypothesis IX ............................................................................ 8

Chapter 2 ........................................................................................................ 9
  Review of the Literature ....................................................................... 9
    Anatomy .......................................................................................... 9
    Biomechanics of the Sesamoids ................................................. 11
    Injury ............................................................................................... 12
    Biomechanics of the First Metatarsophalangeal Joint .............. 14
    Joint Mobilization and Strengthening ..................................... 16

Chapter 3 ........................................................................................................ 20
  Methods .............................................................................................. 20
List of Tables and Figures

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Summary of Participants' Biographical Data</td>
</tr>
<tr>
<td>2</td>
<td>Comparing T-Test Pre and Post Data for First MPJ Ext. PROM</td>
</tr>
<tr>
<td>3</td>
<td>ANCOVA of First MPJ Extension PROM</td>
</tr>
<tr>
<td>4</td>
<td>Comparing T-Test Pre and Post Data for Flexor Hallucis Strength</td>
</tr>
<tr>
<td>5</td>
<td>ANCOVA of Flexor Hallucis Strength</td>
</tr>
<tr>
<td>6</td>
<td>Comparing T-Test Pre and Post Data for Subjective Pain Level</td>
</tr>
<tr>
<td>7</td>
<td>ANCOVA of Subjective Pain Levels</td>
</tr>
<tr>
<td>8</td>
<td>T-Test of Mean Diff. in Dorsiflexion ROM Before &amp; After Treatment</td>
</tr>
<tr>
<td>9</td>
<td>T-Test of Mean Difference in Age</td>
</tr>
<tr>
<td>10</td>
<td>T-Test of Mean Difference in Time Elapsed Since Injury</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Pre and Post Data for First MPJ Extension PROM</td>
</tr>
<tr>
<td>C2</td>
<td>Pre and Post Data for Flexor Hallucis Strength Values</td>
</tr>
<tr>
<td>D3</td>
<td>Pre and Post Data for Subjective Pain Level</td>
</tr>
</tbody>
</table>
Abstract

The purpose of this study was to determine the effect of standard physical therapy when combined with sesamoid mobilization, flexor hallucis strengthening and gait training for reducing pain and increasing function in the first metatarsophalangeal joint (MPJ) in persons with functional hallux limitus. Sprains of the first MPJ are common in athletics. Push off, forward drive and running can be significantly impaired after this injury. More importantly, MPJ sprains can also result in persistent pain and loss of range of motion. Given the debilitating nature of this injury, it is important to determine the most effective treatment for hallux limitus.

The participants in this study consisted of twenty individuals with pain, a loss of motion of twenty degrees or more and weakness of at least five pounds in the first MPJ. Subjects were randomly assigned to two groups. Measurements of first MPJ range of motion and strength were performed on the first and last visits. Subjects were also asked to rate their pain level on a scale of zero to ten on those visits. Both groups received whirlpool, ultrasound, first MPJ mobilizations, calf and hamstring stretching, marble pick up, cold packs and electrical stimulation. The experimental group also received sesamoid mobilizations, flexor hallucis isometrics and isotonics and gait training. Treatment was provided three times a week for one month.

Analysis of the results revealed that the experimental group achieved significantly greater range of motion and strength and had significantly lower pain levels as compared to the control group (p<.001). The results were also clinically significant in that all subjects in the experimental group achieved greater than sixty five degrees of hallux extension, which is needed for normal gait. In addition, strength of the involved first MPJ was equal to or exceeded the
strength of the uninvolved toe. Finally, the pain levels in the experimental group decreased to a zero or one out of ten upon completion of the therapy.

These results indicate that sesamoid mobilization, flexor hallucis strengthening and gait training should be included in the plan of care when treating an individual with hallux limitus.
Chapter 1

Introduction

Need for the Study

Sprains of the great toe metatarsophalangeal joint (MPJ) are common in athletics, including football, soccer, running and basketball. They are often referred to as turf toe injuries and are ranked third for lost time from athletics (Adelaar, 1997). Statistics show that more games are missed by players with turf toe injuries than ankle sprains (Coker, Arnold, & Weber, 1978). Push off, forward drive and running can be significantly impaired after this injury (Clanton & Ford, 1994). Injuries to the great toe can also result in long term sequelae such as persistent pain and loss of range of motion. Limited range of motion makes the joint susceptible to jamming, which can cause dorsal impingement (Adelaar, 1997; Lichniak, 1997). Bony proliferation and articular degeneration often develop and can be painful and debilitating. The joint may eventually ankylose. Some of the most famous athletes affected by this injury in the past two years include Steve McNair of the Tennessee Titans, Jack Lambert of the Pittsburgh Steelers, Deion Sanders of the Washington Redskins, Chuck Smith of the Atlanta Falcons, Jeff Kent of the San Francisco Giants, Antowain Smith of the Buffalo Bills, Ricky Williams of the New Orleans Saints, and Brett Favre of the Green Bay Packers (Battista, 2000; Deion, 1999; Gaudhan, 1999; Ledbetter, 1998; McNair, 2000; Strom & Allee-Walsch, 1999; “Toe”, 1999; Trotter, 2000).

The treatment for acute MPJ sprains is fairly universal. While the condition is in the acute stage, rest, ice, compression and elevation are recommended (Adelaar, 1997; Bruckner & Khan, 1993; Canavan, 1998; Clanton & Ford, 1994; Clanton, Butler, & Eggert, 1986; Cohn & Kanat, 1984; Hawkins & Haddad, 1988; Lichniak, 1997; Malone, McPoil, & Nitz, 1997;
Prentice, 1999). These authors also discuss that the use of non-steroidal antiinflammatory drugs (NSAIDs) may be indicated. Protection of the joint is important and can be achieved through the use of taping, shoe modifications and/or an orthotic. Several authors advocate the application of modalities such as ultrasound, electrical stimulation and iontophoresis (Bruckner & Khan, 1993; Canavan, 1998; Cohn & Kanat, 1984; Prentice, 1999). Once in the subacute phase, some authors stress the importance of mobilization of the MPJ to restore range of motion (Adelaar, 1997; Canavan, 1998; Cohn & Kanat, 1984; Clanton & Ford, 1994; Malone et al., 1997). Only a few advocate strengthening of the great toe flexors and use of the bike, swimming or the upper body ergometer to maintain cardiovascular fitness in these athletes. These authors also suggest that good strength and range of motion should be achieved before sport specific exercises and drills are introduced (Adelaar, 1997; Canavan, 1998). Given the debilitating nature of this injury, it is important to determine the most effective treatment for this injury.

**Conceptual Framework**

Hallux limitus is one of the more common conditions occurring in the great toe (Lichniak, 1997). This includes turf toe injuries which are frequently sustained by football and soccer players but can affect runners and other athletes as well. When dorsiflexion range of motion is restricted at the MPJ, abnormal biomechanics lead to degenerative changes and bony proliferation. Dorsal exostoses, marginal osteophytes and erosion of cartilage can occur and eventually cause ankylosis. These conditions can limit an athlete's performance secondary to the limited ability to push off, drive, sprint and cut (Clanton & Ford, 1994).

It is known that normal first MPJ function depends on the capacity of the
first metatarsal to plantarflex and normal sesamoid mobility (DeLauro, 1989; Donatelli, 1996). Research conducted by Shereff, Bejjani, & Kummer (1986) on the kinematics of the first MPJ and the articulation of the sesamoids supports this statement. This research revealed that the specimens with hallux rigidus had scarring of the conjoined tendon and plantar capsule that limited motion of the fibular sesamoid. This scarring is hypothesized to be a contributing factor in the loss of MPJ range of motion. Knowing that the sesamoids may become scarred down, mobilization of the sesamoids to prevent adhesions may be warranted in the treatment of hallux limitus. None of the literature reviewed suggested sesamoid mobilizations as a part of the plan of care when treating hallux limitus.

Sesamoid mobilization in the great toe is comparable to that of mobilization of the patella after a knee injury. The patella is also a sesamoid bone, housed in the tendon of the quadriceps. The effect of adhesions on the kinematics of the patella was explored by Ahmad, Kwak, Ateshian, Warden, Steadman, & Mow (1998). Significant increases in joint reaction forces and a decrease in the effective moment arm of the extensor mechanism were found when adhesions were present. In addition, the kinematics and contact areas of the joint were altered. This can be a source of pain after knee injury or surgery. Furthermore, patellar mobilization is advocated to restore knee range of motion and function (Kisner & Colby, 1990). Mobilization is typically performed if restrictions in gliding are noted during an evaluation for patellofemoral syndrome, or after arthroscopic knee surgery, anterior cruciate ligament reconstruction or a total knee replacement (Puniello, 1993; Veltri, 1997).

The amount of sesamoid movement that occurs in a healthy individual has been quantified for both the patella and the hallux sesamoids (Fithian,
Mishra, Balen, Stone, Daniel, 1995; Scranton & Rutkowski, 1980, Shereff et al., 1986). Knowing that a relationship has been found between hallux rigidus and decreased fibular sesamoid mobility, sesamoid mobilization could potentially play a role in the restoration of movement in the MPJ. It could also improve contact areas and joint kinematics, thereby lessening the long term sequelae of these injuries.

It is also known that the flexor hallucis longus and brevis assist in stabilizing the first metatarsal during push off (Donatelli, 1996; Lichniak, 1997). Yet, very few authors recommended strengthening the toe flexors after a turf toe injury. Strengthening is a component of the preferred practice pattern for this type of injury ("Impaired", 1997). However, the specific muscles to strengthen are not identified. Furthermore, it has been identified that injury to the sesamoids can impair great toe flexor function (Aper, Saltzman, & Brown, 1996, 1994; Donatelli, 1996; Lichniak, 1997). The flexor hallucis longus and brevis stabilize the first MPJ against the ground during walking or running. Injury to these muscles could contribute to an inefficient gait cycle (Donatelli, 1996; Lichniak, 1997). Therefore, strengthening the flexor hallucis and brevis in individuals with hallux limitus should be included in the plan of care for all health professionals treating this population.

Treatment for an acute turf toe injury commonly includes the use of rest, ultrasound, ice, electrical stimulation, taping/orthotics or shoewear modifications (Adelaar, 1997; Bruckner & Khan, 1993; Canavan, 1998; Churchill & Donley, 1998; Clanton & Ford, 1994; Malone et al., 1997; Prentice, 1999). Mobilization of the MPJ can also promote increased range of motion (Adelaar, 1997; Canavan, 1998; Edmond, 1993; Kisner & Colby, 1990; Prentice, 1999; Tomberlin & Saunders, 1994; Wadsworth, 1988). However, there appear to be
no published studies that support the mobilization of the sesamoids to increase MPJ range of motion. Several authors have described the movement of the sesamoids as the MPJ dorsiflexes and plantarflexes and that the motion of the lateral sesamoid decreased after injury secondary to intense scar formation (Adelaar, 1997; Shereff et al., 1986; Scranton & Rutkowski; 1980). It is widely accepted that mobilization of the patella is important to prevent adhesions and promote knee joint range of motion. Considering these findings, it important to investigate if mobilization of the great toe sesamoids and flexor hallucis strengthening in addition to standard therapy can reduce pain and improve function in the great toe.

The purpose of this study was to determine the effect of sesamoid mobilization and flexor hallucis strengthening in reducing pain and increasing function of the first MPJ in persons with functional hallux limitus.

Significance of the Study

If sesamoid mobilizations and great toe flexor strengthening are found to reduce pain and improve function, there are several implications. First, it could shorten the duration of care needed to restore function. This in turn, would lead to fewer follow-up visits with the physician and physical therapist. It could also mean that there would be fewer chronic cases. If function is restored, the need for surgery is eliminated. Overall, it would lead to a reduction in health care costs.

Definitions of Terms

Ankylose - the abnormal union of the bones of a joint (Thomas, 1989).

Articular degeneration - deterioration in the cartilage that lines the opposing surfaces of all joints (Thomas, 1989).

Bony proliferation - rapid and repeated reproduction of new bone
Dorsiflexion - movement of a part at a joint so as to bend the part toward the dorsum of the body (Thomas, 1989).

Flexor hallucis longus and brevis strength - the average amount of force generated during three trials by the great toe in 30 degrees of extension as measured by a pinch gauge (Crosby, 1994).

Hallux limitus/rigidus - restricted or loss of motion of the joint connecting the great toe to the metatarsal (Thomas, 1989).

Iontophoresis - introduction of various ions into tissues through the skin by means of electricity (Thomas, 1989).

Kinematics - the branch of biomechanics concerned with movement of the body (Thomas, 1989).

MPJ range of motion - the range of motion of the first metatarsal in relationship to the first phalanx starting from foot flat to maximum heel rise as measured by a goniometer (Hopson, McPoil, & Cornwall, 1995).

Plantarflexion - extension so that the forepart of the foot is depressed with respect to the tibia and fibula (Thomas, 1989).

Sesamoid bone - an oval nodule of bone or fibrocartilage in a tendon playing over a bony surface (Thomas, 1989).

Sesamoid mobilization - Grade three joint mobilizations of the great toe sesamoids that reach the end range of motion but do not exceed it and stretches into the tissue resistance (Kisner and Colby, 1990).

Strengthening - five sets of eight repetitions with 12 seconds of rest in between sets with the Physical Therapist providing manual resistance through the range of motion that is just short of stopping the motion (Baechle, 1994).

Subacute phase - between acute (initial, severe phase) and chronic (of
long duration) but with some acute features (Thomas, 1989).

**Hypotheses**

The following hypotheses were investigated with this research.

**Hypothesis I.** There will be a significant increase in first MPJ extension passive range of motion with the standard physical therapy interventions.

**Hypothesis II.** There will be a significant increase in first MPJ extension passive range of motion when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training.

**Hypothesis III.** There will be a significantly greater increase in first MPJ extension passive range of motion when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training as compared to standard physical therapy interventions alone.

**Hypothesis IV.** There will be a significant increase in strength of the flexor hallucis with standard physical therapy interventions.

**Hypothesis V.** There will be a significant increase in strength of the flexor hallucis when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training.

**Hypothesis VI.** There will be a significantly greater increase in strength of the flexor hallucis when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training as compared to standard physical therapy interventions alone.

**Hypothesis VII.** There will be a significant reduction in subjective pain level with standard physical therapy interventions.

**Hypothesis VIII.** There will be a significant reduction in subjective pain
level when standard physical therapy is combined with sesamoid mobilizations, flexor hallucis strengthening and gait training.

**Hypothesis IX.** There will be a significantly greater reduction in subjective pain level when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training as compared to standard physical therapy interventions alone.

The remainder of this dissertation will include an extensive review of the literature, methodology, results, discussion, references and appendixes.
Chapter 2

Review of the Literature

As previously mentioned in the conceptual framework section, there is little research on mobilization of the sesamoids. Consequently, this review of literature will address several related areas. First, there will be a review of anatomical studies on the sesamoids. Then, the biomechanics of the great toe will be presented. Next, research on turf toe as well as current treatment techniques will be presented. Literature on joint mobilization will conclude this review.

Anatomy

Sesamoids develop where changes of direction in the pull of a tendon occur. They provide protection to the tendon and increase its mechanical advantage (Helal, 1981; Dennis & McKinney, 1990; Oloff & Schulhofer, 1996; Scranton & Rutkowski, 1980). The great toe sesamoids and the patella both fit this description. Sesamoids also possess an articular surface and are stabilized by the tendon in which they lie (Jahss, 1981). In addition, they are intracapsular, true synovial joints with hyaline cartilage interfaces (Oloff & Schulhofer, 1996). As such, they are both susceptible to intra-articular disease and trauma (Jahss, 1981).

Understanding the anatomy of the great toe sesamoids is crucial to understanding their closed chain function. The first metatarsal head articulates with the tibial and fibular sesamoids on its plantar aspect. There are two shallow grooves in the plantar surface of the metatarsal head in which the sesamoids glide. The two sesamoids are separated by a bony ridge. The abductor hallucis tendon joins the medial head of the flexor hallucis brevis tendon at the proximal edge of the tibial sesamoid to form the conjoined tendon.
The fibular sesamoid receives the insertion of the lateral head of the flexor hallucis brevis and adductor hallucis transverse and oblique heads. These two tendons form the lateral conjoined tendon that extends to the plantar lateral aspect of the proximal phalanx. The transverse intermetatarsal ligament serves to attach the fibular sesamoid to the neck of the second metatarsal. The two sesamoids are bound together by the intersesamoidal ligament which anchors them to the base of the first metatarsal. The plantar fascia also attaches to the nonarticular surfaces of both sesamoids. It is this complex combination of muscles, ligaments and the capsule that gives the first MPJ stability (Adelaar, 1997; Churchill & Donley, 1998; Dennis & McKinney, 1990; Jahss, 1981; Oloff & Schulhofer, 1996; Richardson, 1987).

Many authors have studied the sesamoid bones of the first metatarsal. Rosenbaum de Britto (1982) examined cadaver specimens of fifty adult and fifty children’s feet to better describe the metatarso-sesamoid joint. The joint is defined by the concave plantar aspect of the head of the first metatarsal which contains an intersesamoid ridge and the convex articular surface of the tibial and fibular sesamoids. Each sesamoid has an elliptical shape and is included in a fibrocartilaginous formation which anchors it to the base of the proximal phalanx of the hallux. The bones are intracapsular and move forward and backward as the hallux moves.

Scranton and Rutkowski (1980) also studied cadaveric and freshly amputated feet to study this joint. They calculated the angular excursion for the sesamoids at 71.9 +11 degrees. It was also noted that subluxations, chondromalacia and degenerative spurring was present in eleven of the thirty-five cases. They drew an analogy to the patella in which condylar anatomic variations exist which predispose an individual to subluxations and
chondromalacia.

Biomechanics of the Sesamoids

The biomechanical function of the sesamoids of the first MPJ are not fully understood. Their role appears to include protecting the flexor hallucis longus and metatarsal head, distributing force to the medial forefoot, and working as a pulley mechanism to increase strength of the toe flexors (Adelaar, 1997). David, Delogoutte and Renard (1989) dissected six cadaveric specimens to investigate the mechanical function of the sesamoid apparatus. They defined the intersesamoidal ligament as a trilateral girder, formed by three divergent wings. This design allows it to support the forces that converge upon it, but at the same time permits the two sesamoids to function independently while being part of the whole. The horizontal position of the sesamoids was found to be critical to their function. It assists in the development of a catapult effect in which they play the role of the sling.

The role of the sesamoids was further analyzed during the four stages of loading the foot: suspension, fixation, coordination and propulsion. The anatomy of the sesamoids was found to promote their influence as a guide to direct and orient the foot for heel contact. They also serve as a propellant, allowing the foot to be removed from the ground at the terminal phase of weight bearing. All of the forces that are placed on the five metatarsals are coordinated by the sesamoids (David et al., 1989).

The effect of the removal of the sesamoids has been studied extensively by Aper et al. (1996/1994). The effective tendon moment arm of the flexor hallucis brevis was studied under three conditions: a distal hemiresection, a complete resection and resection of both sesamoids. Statistical analysis in the first study indicated a profoundly diminished mechanical advantage with the
excision of both sesamoids. Their latest study conducted in 1996 found significant decreases in the effective tendon moment arms of the flexor hallucis longus with full medial or lateral sesamoid resection in addition to the resection of both sesamoids.

Injury

Injuries to the sesamoids can be highly debilitating for the recreational or competitive athlete. Conditions such as sesamoiditis, bursitis, tendinitis, synovitis and chondromalacia are usually the result of repetitive stress. Osteochondritis can occur individually or as the result of repetitive trauma. Stress fractures are also reported. The medial sesamoid appears to be at greater risk as it endures greater forces during ambulation (Dietzen, 1990; McBryde & Anderson, 1988; Richardson, 1987).

Sprains of the first MPJ, more commonly called turf toe, are also a problem for athletes. This injury is usually the result of hyperextension of the great toe. Rodeo, O'Brien, Warren, Barner, Wickiewicz, & Dillingham (1990) surveyed eighty professional football players who had sustained turf toe injuries. Questions covered items such as the position played on the field, mechanism of injury, playing surface and shoe type when injured, treatment received and playing time missed. Additionally, each player participated in a foot and ankle evaluation. The incidence of injury was 36 of 80 players or 45%. Artificial turf was the playing surface in 83% of the cases. Ankle dorsiflexion was found to be significantly related to the incidence of turf toe. After the injury, there was a significant decrease in the plantarflexion and dorsiflexion range of motion of the first MPJ.

The trauma sustained during a hyperextension injury depends on the severity of the injury. In a low grade injury, there is tearing of the plantar
capsule and occasionally the plantar plate. In severe cases, there can be a compression injury to the dorsal articular surfaces (Churchill & Donley, 1998; Rodeo et al., 1990). The result of this injury is the athlete’s inability to bear weight normally on the medial aspect of the forefoot. There is severe pain and tenderness, marked swelling and ecchymosis and severe limitations in first MPJ range of motion (Churchill & Donley, 1998; Clanton & Ford, 1994). First MPJ range of motion needs to be restored to avoid soft tissue hallux limitus that is caused by scar formation as the capsuloligamentous structure heals (Adelaar, 1997).

Several weeks after the injury, symptoms can linger. Push off can be greatly impaired and forward running and drive are compromised (Clanton & Ford, 1994). Unpublished observations by Clanton included that 50% of the athletes studied had persistent symptoms five years after the initial injury.

Adelaar (1997) describes two clinical presentations of chronic first MPJ injuries that contribute to hallux limitus. Hallux limitus is any loss of dorsiflexion range of motion at the first MPJ. The first reason for this loss of motion can be adhesive capsulitis, caused by intense scar formation. The second reason for restricted motion can be a bony restriction. Over time, this loss of range of motion leads to faulty biomechanics which in turn can lead to the formation of dorsal exostoses, marginal osteophytes, erosion of articular cartilage and possible ankylosis (Cohn & Kanat, 1984; Lichniak, 1997). If the symptoms are severe enough, the involved toe may require arthroscopic surgery (Adelaar, 1997). Additional research by Clanton, Butler, & Eggert (1986) found hallux valgus and hallux rigidus as long term sequelae of first MPJ sprains as well.

Adelaar's (1997) clinical observations are supported by research conducted by Shereff et al. (1986). Fifteen cadaveric specimens were x-rayed
and examined. Six feet were normal, six displayed hallux valgus and three had hallux rigidus. In the feet with hallux valgus and hallux rigidus, the center of rotation moved outside of the metatarsal head. This was proposed to be a contributing factor in the degenerative changes that were identified. Furthermore, a significant difference was found in the MPJ range of motion in these specimens. The lateral sesamoid range of motion was decreased in the specimens with hallux rigidus more so than the medial sesamoid. Scarring of the conjoined tendon and plantar capsule was identified as the source of this limitation. This loss of sesamoid mobility was hypothesized to contribute to the overall loss of range of motion at the first MPJ.

**Biomechanics of the First MPJ**

The biomechanical role of hallux extension on the foot during ambulation has been reviewed extensively (Boissonnault & Donatelli, 1984). A minimum of 60-65 degrees of first MPJ extension is required for normal ambulation. This range is attained when the hallux is stabilized against the ground and the heel rises off the ground. The first metatarsal head glides plantarly upon the hallux and posteriorly in relationship to the sesamoids. This motion pulls the plantar aponeurosis tight, thus decreasing the distance between the calcaneus and the first MPJ. This is the mechanism by which the arch of the foot is raised and is often called the windlass mechanism. The mobility of the sesamoids is important to the normal mechanism of the first MPJ (DeLauro, 1989; Donatelli, 1996).

Dananberg (1986) utilized an Electrodynogram system to further study this phenomenon. This technology helped confirm that it is the inability of the great toe to extend, not the ineffectiveness of the windlass mechanism, that is responsible for the failure of the arch to be raised. This phase in the
biomechanics of gait is essential to the foot becoming a rigid lever for propulsion. It also enables the hallux and first MPJ to support the body's weight and provide an optimal length tension relationship of the flexor hallucis longus (Boissonnault & Donatelli, 1984). Decreased hallux extension decreases the ability of the flexor hallucis longus to function properly in its role as a hallux stabilizer during ambulation secondary to the decreased mechanical advantage (DeLauro & Positano, 1989).

It is important after a first MPJ injury to restore range of motion and great toe flexor strength so that the normal biomechanics of the joint can be achieved. However, there is little research to support this theory. There is a general consensus on how a first MPJ sprain or sesamoid injury should be treated in the early stages. Rest, ice, compression, elevation and the use of NSAIDs is recommended by most authors (Adelaar, 1997; Bruckner & Khan, 1993; Canavan, 1998; Churchill & Donley, 1998; Clanton & Ford, 1994; Dietzen, 1990; Malone et al., 1997; McBryde & Anderson, 1988; Prentice, 1999; Richardson, 1987). In addition, these authors describe the need to protect the joint from further damage by utilizing taping, a stiffer soled shoe, an orthotic or other accommodations. The use of modalities such as ultrasound, electrical stimulation and iontophoresis is purported to be beneficial (Bruckner & Khan, 1993; Canavan, 1998; Cohn & Kanat, 1984; McBryde & Anderson, 1988; Prentice, 1999). Mobilization of the first MPJ is suggested by a few authors, in order to restore range of motion to the joint (Canavan, 1998; Clanton & Ford, 1994; Cohn & Kanat, 1984; Malone et al., 1997). Adelaar (1997) and Canavan (1998) have the most comprehensive approach; they recognize that after the injury, not only does the range of motion need to be restored, but the strength of the great toe flexor must be addressed as well. For the athlete, cardiovascular
fitness must also be maintained while they are unable to run and participate in their sport. Once adequate range of motion and strength are achieved, sport specific drills are initiated to facilitate a return to play.

The preferred practice patterns for an individual with impaired joint mobility, motor function, muscle performance and range of motion associated with capsular restrictions have been developed by the American Physical Therapy Association (Impaired, 1997). Based on these practice patterns, the expected number of visits per episode of care is 6 to 36. Treatment can include but is not limited to therapeutic exercise and manual therapy techniques. This includes strengthening via manual resistance and joint mobilization including joint traction. The goals of this treatment include improved gait, locomotion and balance, decreased joint restriction, increased motor function, increased strength, power and endurance, and increased tolerance to positions.

Clanton and Ford (1994) report that surgery is rarely indicated for first MPJ sprains. If these injuries are managed properly, the prognosis is excellent. However, if the injury does not resolve with conservative care, surgical intervention is an option. It is when the symptoms persist and the kinematics are altered that hallux limitus can advance into hallux rigidus. Surgery may be necessary at that time to remove loose bodies, dorsal exostoses and other forms of spurring (Churchill & Donley, 1998). Many professional athletes such as Jerris McPhail, Deion Sanders and Steve McNair have undergone surgeries of the great toe.

Joint Mobilization and Strengthening

Restoring range of motion to the first MPJ is essential for restoration of function (Clanton & Ford, 1994). Joint mobilization is a widely utilized technique in the physical therapy profession to promote range of motion and
function. It is a manual therapy technique that involves, slow, passive movement of articulating surfaces. It is used to regain normal active range of motion, to restore normal passive motions, to reposition or realign a joint, to regain a normal distribution of force about the joint and to decease pain. The overall result is increased function (Prentice, 1999). By this definition, MPJ mobilization is indicated in the treatment of first MPJ sprains. Taking into account the cadaveric studies that revealed scarring of the sesamoids and the plantar plate as a result of this injury, mobilization of the hallux sesamoids could potentially be beneficial as well.

A pilot study conducted by Dijs, Roofthooft, Driessens, DeBock, Jacobs, & Van Acker (2000) examined the effects of joint mobilization on limited joint mobility of the foot in diabetic patients. Ten therapy sessions resulted in a significant improvement of joint mobility. No serious adverse effects were noted during the treatment. One limitation of this study was the small sample size of eleven patients.

The concept of specifically mobilizing a sesamoid to increase joint range of motion is not new. It is a widely accepted practice for the patella, which is housed in the quadriceps tendon of the knee joint. Patellar mobilization is advocated after anterior cruciate ligament reconstructions and total knee replacements to restore range of motion (Veltri, 1997; Kisner & Colby, 1990).

The effect of adhesions on the kinematics of the patella was explored by Ahmad et al. (1998). Five cadaveric knees were studied in which adhesions of the patellar tendon were simulated. These adhesions decreased the amount of translation of the patella, increased its flexion angle, changed the articular contact area and increased the joint reaction forces. The authors concluded that adhesions can have a profound effect on function and progressive
Determining the proper direction for the glide applied in a joint mobilization is based on a concept called the convex-concave rule (Kisner & Colby, 1990). This rule states that if the surface of the moving bony partner is convex, the treatment glide is in the opposite direction in which the bone swings. If the surface of the moving bony partner is concave, the treatment glide should be in the same direction. Techniques for mobilizing the patella commonly include four glides. Inferior glides are purported to increase knee flexion range of motion, superior glides are for knee extension and medial/lateral glides are performed to assist with tracking (Bruckner & Khan, 1993; Canavan, 1998; Edmond, 1993; Kisner & Colby, 1990; Prentice, 1999; Tomberlin & Saunders, 1994; Wadsworth, 1988).

When mobilizing the first MPJ, three to five techniques are commonly utilized. Distraction is good for general tightness, a dorsal glide is for increased extension and a plantar glide is for increased flexion (Canavan, 1998; Edmond, 1993; Kisner & Colby 1990; Prentice, 1999; Tomberlin & Saunders, 1994; Wadsworth, 1988). Medial and lateral glides are reported to assist with abduction and adduction range of motion respectively (Canavan, 1998; Edmond, 1993; Wadsworth, 1988). To determine the proper mobilization technique for the hallux sesamoids, the convex-concave rule would also apply. The metatarsal head is convex and the sesamoids are concave. Therefore, to promote first MPJ extension, the sesamoids will be mobilized in a superior direction.

Given the degree of disability that can arise after a turf toe injury, it is important that an athlete receive appropriate treatment. If motion at the first MPJ and toe flexor strength are not restored, push off during ambulation and running
can be greatly limited. Furthermore, degenerative changes in the joint can take place. In persons of all ages, this simple injury can lead to long term disability. Clanton & Ford (1994) reported a 50% incidence of persistent symptoms after turf toe injury. Determining if sesamoid mobilization and resistive training of the great toe flexors can reduce pain and improve function could potentially prevent the long term sequelae of this injury.
Chapter 3

Methods

This research utilized a two-group pretest-posttest design. A control and experimental group were formed by random assignment. It compared standard physical therapy interventions (control group) to standard therapy combined with sesamoid mobilizations, flexor hallucis strengthening and gait training. Selection bias was controlled with the random assignment of subjects to groups. History, maturation, testing and instrumentation effects were expected to affect both groups equally (Portnoy & Watkins, 1993).

Subjects

Twenty subjects with a mean age of 32.8 years old (S.D. = 5.8) were referred to the study and consented to participate. See Table 1 for participants' biographical data. Subjects were referred to the study by a local Podiatrist on the basis of diagnosis. Subjects presented with functional hallux limitus from trauma, overuse or surgery. The injuries were subacute or chronic in nature. This Podiatrist was responsible for taking x-rays to rule out bony proliferation and hallux abductovalgus greater than 20 degrees. In addition, NSAIDs were not prescribed if the individual was to participate in the study.

Individuals were instructed to contact the investigator by their Podiatrist and an appointment was made for a physical therapy screening. All screenings and treatments were provided at an outpatient orthopaedic facility in Broward County, Florida by a licensed physical therapist.

In order to select the subjects, a physical therapy screening was performed. This included taking a brief history. Individuals who had received previous treatment for the injury or who were participating in any aggressive recreational activities at the time that could interfere with treatment were
excluded from the study. In addition, individuals were not permitted in the study if they had a history of rheumatoid arthritis or diabetes. No individuals with litigation or injuries sustained at work were included in the sample as well. Measurements of first MPJ extension range of motion, flexor hallucis strength, hamstring flexibility and subjective pain level were obtained. For individuals to qualify, they had to have at least a twenty degree limitation in great toe extension passive range of motion and at least a four pound difference in flexor hallucis strength as compared to the opposite side. A minimum of 45 degrees of hamstring flexibility was required to participate. The individuals also needed a subjective pain level of at least three out of ten.

Qualified subjects were randomly assigned to two groups using the last digit of their day of birth. Subjects with even numbers were part of the control (standard therapy) group and those with odd numbers were part of the experimental (standard therapy combined with sesamoid mobilization, flexor hallucis and gait training) group. Once one group had ten subjects, the remaining subjects were placed in the other group such that both groups contained ten subjects, twenty total. The mean age of the control group was 33.6 years old (S.D. = 5.42) and they had a mean time of 8.4 months post injury (S.D. = 2.16). The control group was composed of three males and seven females. The mean age of the experimental group was 32.0 years old (S.D. = 6.32) and they had a mean time of 7.9 months post injury (S.D. = 1.97). The experimental group was composed of two males and eight females.
# Table 1

## Summary of Participants' Biographical Data

<table>
<thead>
<tr>
<th>Participant Limitation</th>
<th>Age</th>
<th>Sex</th>
<th>Time Since Injury</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>M</td>
<td>0/2</td>
<td>Running</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
<td>F</td>
<td>1/4</td>
<td>Walking</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>F</td>
<td>0/1</td>
<td>Walking</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>M</td>
<td>0/6</td>
<td>Running</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td>F</td>
<td>0/8</td>
<td>Running</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>F</td>
<td>0/3</td>
<td>Soccer (Running)</td>
</tr>
<tr>
<td>7</td>
<td>29</td>
<td>M</td>
<td>1/1</td>
<td>Running</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>F</td>
<td>1/3</td>
<td>Walking</td>
</tr>
<tr>
<td>9</td>
<td>32</td>
<td>F</td>
<td>1/7</td>
<td>Walking</td>
</tr>
<tr>
<td>10</td>
<td>39</td>
<td>F</td>
<td>0/1</td>
<td>Walking</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>32</td>
<td>F</td>
<td>0/1</td>
<td>Running</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
<td>M</td>
<td>1/1</td>
<td>Football (Running)</td>
</tr>
<tr>
<td>13</td>
<td>35</td>
<td>F</td>
<td>1/3</td>
<td>Walking</td>
</tr>
<tr>
<td>14</td>
<td>26</td>
<td>F</td>
<td>0/5</td>
<td>Running</td>
</tr>
<tr>
<td>15</td>
<td>29</td>
<td>F</td>
<td>1/0</td>
<td>Walking</td>
</tr>
<tr>
<td>16</td>
<td>43</td>
<td>F</td>
<td>1/6</td>
<td>Walking</td>
</tr>
<tr>
<td>17</td>
<td>23</td>
<td>M</td>
<td>0/8</td>
<td>Running</td>
</tr>
<tr>
<td>18</td>
<td>32</td>
<td>F</td>
<td>0/4</td>
<td>Running</td>
</tr>
<tr>
<td>19</td>
<td>34</td>
<td>F</td>
<td>0/1</td>
<td>Walking</td>
</tr>
<tr>
<td>20</td>
<td>26</td>
<td>F</td>
<td>0/2</td>
<td>Soccer (Running)</td>
</tr>
</tbody>
</table>
Instruments

A six inch plastic goniometer was utilized to take the first MPJ and dorsiflexion range of motion measurements. The scale on the goniometer was marked in one degree increments. For the MPJ measurements, a pen was used to draw lines bisecting the first metatarsal and hallux and to mark the estimated MPJ joint center. This technique was described by Hopson et al. (1995) and was found to be reliable.

A standard, calibrated pinch gauge (B&L Engineering, Santa Fe, CA) was utilized to measure flexor hallucis longus and brevis strength. The scale was marked in one pound increments. Calibration was performed the week prior to testing and the same device was used throughout testing. The pinch gauge has been found to be a reliable and valid way to measure strength (Mathiowitz, Weber, Volland, & Kashman, 1984).

Procedure

Prior to collecting data, all subjects signed an informed consent. Subjects were asked what the date of injury was and if they were experiencing any functional limitations at the present time. All data were recorded on the data collection form (see Appendix A). The subjects were identified on this form only by their birth date. Dorsiflexion active range of motion was then measured to assure there was no significant difference between the groups.

Goniometric measurement of ankle joint dorsiflexion. The subject was supine with the knee extended and the ankle joint in the anatomical position. The axis was placed over the lateral malleolus of the fibula, the stationary arm was placed parallel to the lateral midline of the fibula and the moving arm was placed parallel to the lateral midline of the calcaneus (Palmer & Epler, 1990). The patient was asked to actively pull the toes and ankle back toward them,
subtalar joint neutral was maintained by the therapist. At that point, the therapist read the degrees off of the goniometer and it was recorded on the data collection form.

Next, the three dependent variables were quantified: first MPJ extension passive range of motion (PROM), flexor hallucis strength and subjective pain level.

**Static weight bearing measurement of MPJ extension range of motion.**

With the subject in a supine position, a line bisecting the first metatarsal and a line bisecting the first phalanx was drawn. A dot was placed on the MPJ joint center. This was done on both feet. Then the subject was positioned on table paper on the floor and was instructed to take eight steps. The purpose of this footprint template was to replicate the subject’s step length during walking. The subject was asked to stand on the template with the involved foot positioned behind the uninvolved foot on the respective foot prints. The subject was then asked to raise the heel of the involved foot, extending the first MPJ as far as possible while maintaining step length and hallux contact with the floor. Measurements were taken by placing the goniometer on the skin markings made during the static non-weight bearing preparation. The subject returned to a foot flat position between each measurement. Three measurements were taken, with the subject returning the heel to the ground in between measurements. The highest of the three numbers was recorded.

**Isometric strength measurement.** The subject was seated as far back in a chair as possible with the foot flat on the ground in subtalar joint neutral. The pinch gauge was placed under the great toe, with the end directly underneath the distal crease of the MPJ. The gauge was stabilized with one hand by the tester. The subject was asked to push their great toe down as hard as they
could for 3 seconds without the heel rising from the floor. The subject was not allowed to lean the trunk forward during the procedure. The tester utilized the free hand to ensure that the foot did not move out of the neutral position. After each measurement, the foot pounds were read and the dial was returned to zero by the tester. The measurement was repeated 3 times in a row, with less than 5 sec allowed between repetitions. The average of the three trials was calculated and recorded.

**Subjective pain level.** Subjects were asked, “rate the pain that you experienced while walking into the clinic today on a scale of zero to ten, with zero being no pain and ten being the worst pain that that you can imagine.”

The subjects in both groups received treatment three times a week for four weeks, except for two individuals from the experimental group who were discharged sooner. Both groups received a hot whirlpool treatment (102 degrees) for fifteen minutes. This was followed by a standing gastrocnemius stretch with the foot in subtalar joint neutral and a supine hamstring stretch with a strap, keeping both knees extended. Three repetitions of each stretch were performed for a thirty second hold. For the first six treatments, subjects also received 3MHz, 50% pulsed ultrasound to the volar surface of the first MPJ at 1.0 w/cm² for 8 minutes. The whirlpool, ultrasound and stretches were used for a more complete treatment approach because joint mobilizations are rarely performed in isolation (Henricson, Fredriksson, Persson, Pereira, Rostedt, & Westlin, 1984; Wiktorsson-Moller, Oberg, Ekstrand, & Gillquist, 1983; Williford, East, Smith, & Burry, 1986). The whirlpool and ultrasound were selected to warm up the joint to improve soft tissue mobility and the stretches were selected secondary to their impact on sagittal plane motion. After the stretches were completed, the physical therapist performed passive range of motion exercises.
to the first MPJ for one minute and Grade III dorsal glides and distraction of the MPJ for one minute to promote extension range of motion. The subjects then performed thirty marble pickups. The session was concluded with premodulated electrical stimulation at 1-150 Hz combined with ice for fifteen minutes to the dorsal and volar surfaces of the MPJ. Subjects were instructed in a home exercise program of seated heel raises for 30 repetitions, three times a day. In addition to the aforementioned therapy, the experimental group also received sesamoid joint mobilizations, flexor hallucis strengthening and gait training.

**Sesamoid joint mobilizations.** The Physical Therapist performed grade three joint mobilizations on the medial and lateral sesamoids of the affected first MPJ. Superior glides were performed by placing one thumb on the inferior aspect of the sesamoid and applying an upward force that caused the sesamoid to reach the end range of motion but not exceed it and stretched into the tissue resistance (Kisner & Colby, 1990). The grade three mobilizations were performed with large-amplitude rhythmic oscillations. No greater than ten degrees of movement of the MPJ was allowed during the technique. Oscillations were performed for one minute on each sesamoid at a rate of two full glides per second. Care was taken not to compress the sesamoid into the metatarsophalangeal head.

**Flexor hallucis strengthening.** During the first three visits, ten isometric contractions were performed for a ten second hold. The tester provided the resistance manually with the MPJ in neutral. During the last nine visits, five sets of eight repetitions were performed on the involved toe with 12 seconds of rest between each set. The Physical Therapist provided manual resistance throughout the range of motion that was just short of stopping movement of the
great toe (Baechle, 1994). The isometric contractions were assigned to the experimental subjects’ home exercise program to be performed three times a day.

Gait training. In order to reinforce functional use of the great toe flexors, the subjects received gait training for 50 feet. The following verbal cues were provided as the heel on the involved side began to rise from the ground: “Push your big toe down into the ground now and propel yourself forward.” The word “push” was repeated each time the foot passed through terminal stance.

On the twelfth visit, or upon discharge if sooner, identical testing as described prior was performed.

Data Analysis

In order to test hypotheses I, II, IV, V, VII, and VIII, a paired t-test was performed on the pre and post data individually for the control and experimental groups for each of the three dependent variables. In order to test hypotheses III, VI, and IX, an analysis of covariance was conducted using treatment condition as one factor and testing occasion as the other (Portnoy & Watkins, 1993). This statistical test was selected because it was of specific interest to compare initial scores on each dependent variable (range of motion, strength and pain).

An unpaired t-test was also utilized to determine if there was a significant difference between the two groups in the initial and final measurements of dorsiflexion range of motion, in subjects’ age and time elapsed since injury. For all tests, the alpha value was set at .05.
Chapter 4

Results

In order to test hypothesis I, which states that there will be a significant increase in first MPJ extension passive range of motion with standard physical therapy interventions, a paired t-test was computed. This analysis compared the pretest and posttest measurements of first MPJ extension passive range of motion within the control group. The mean difference after treatment was 14.4 degrees. The results of the analysis are reported in Table 2 and show a significant difference (t = -2.01, p<.001). This indicates that the standard physical therapy interventions resulted in a significant increase in first MPJ extension passive range of motion.

In order to test hypothesis II, which states that there will be a significant increase in first MPJ extension passive range of motion when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training, a paired t-test was utilized. This analysis compared the pretest and posttest measurements of first MPJ extension passive range of motion within the experimental group. The mean difference after treatment was 42.7 degrees. The results of the analysis are reported in Table 2 and show a significant difference (t = -11.17, P<.001). This indicates that the standard physical therapy interventions combined with sesamoid mobilization, flexor hallucis strengthening and gait training resulted in a significant increase in first MPJ extension passive range of motion.

In order to test hypothesis III, which states that there will be a significantly greater increase in first MPJ extension passive range of motion when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening, and gait training as compared to standard physical
therapy interventions alone, an analysis of covariance was utilized. This analysis compared the pretest and posttest measurements of first MPJ extension passive range of motion between the control and experimental groups (see Appendix B). The results of the analysis are reported in Table 3 and show a significant difference (F = 354.99, p<.001). This indicates that the standard physical therapy intervention when combined with sesamoid mobilization, flexor hallucis strengthening and gait training were more effective at increasing first MPJ extension passive range of motion than standard physical therapy interventions alone.

In order to test hypothesis IV, which states that there will be a significant increase in strength of the flexor hallucis with standard physical therapy interventions, a paired t-test was computed. This analysis compared the pretest and posttest strength scores within the control group. The mean difference was 1.6 foot pounds. The results of the analysis are reported in Table 4 and are not significant (t = -1.04, p >.05). This indicates that the standard physical therapy interventions did not significantly increase flexor hallucis strength.

In order to test hypothesis V, which states that there will be a significant increase in strength of the flexor hallucis when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training, a paired t-test was computed. This analysis compared the pretest and posttest strength scores within the experimental group. The mean difference was 7.8 foot pounds. The results of the analysis are reported in Table 4 and show a significant difference (t = -5.92, p<.001). This indicates that the standard physical therapy interventions when combined with sesamoid mobilization, flexor hallucis strengthening and gait training significantly increased strength of the flexor hallucis muscles.
In order to test hypothesis VI, which states that there will be a significantly greater increase in strength of the flexor hallucis when standard physical therapy interventions are combined with sesamoid mobilization, flexor hallucis strengthening and gait training as compared to standard physical therapy interventions alone, an analysis of covariance was computed. This analysis compared the pretest and posttest strength scores between the control and experimental groups (see Appendix C). The results are reported in Table 5 and show a significant difference between the groups (F = 108.28, p<.001). This indicates that standard physical therapy when combined with sesamoid mobilization, flexor hallucis strengthening and gait training is more effective at increasing flexor hallucis strength than standard physical therapy interventions alone.

In order to test hypothesis VII, which states that there will be a significant reduction in subjective pain level with standard physical therapy interventions, a paired t-test was computed. This analysis compared the pretest and posttest subjective pain levels within the control group. The mean difference was -2.6. The results of the analysis are reported in Table 6 and reveal a significant decrease (t = 4.28, p<.001). This indicates that standard physical therapy interventions are effective in reducing the subjective pain level.

In order to test hypothesis VIII, which states that there will be a significant reduction in the subjective pain level with standard physical therapy interventions when combined with sesamoid mobilization, flexor hallucis strengthening and gait training, a paired t-test was computed. This analysis compared the pretest and posttest subjective pain levels within the experimental group. The mean difference was -6.4. The results of the analysis are reported in Table 6 and reveal a significant decrease (t = 12.39, p<.001).
This indicates that standard physical therapy when combined with sesamoid mobilization, flexor hallucis strengthening and gait training were effective in reducing the subjective pain level.

In order to test hypothesis IX, which states that there will be a significantly greater reduction in subjective pain level when standard physical therapy interventions are combined with sesamoid mobilizations, flexor hallucis strengthening and gait training as compared to standard physical therapy interventions alone, an analysis of covariance was computed. This analysis compared the pretest and posttest subjective pain levels between the control and experimental groups (see Appendix D). The results are reported in Table 7 and show a significant difference between the groups (F = 332.72, p<.001). This indicates that the standard physical therapy interventions when combined with sesamoid mobilization, flexor hallucis strengthening and gait training are more effective at reducing the subjective pain level than standard physical therapy interventions alone.

**Additional Analyses**

Secondary to the biomechanical influence that tight calf musculature can have on the first MPJ, two unpaired t-test analyses were performed to individually compare the dorsiflexion measurements taken on the first visit and on the last visit between the two testing conditions. The results are reported in Table 8 and show that there was no statistical difference between the groups on the first visit (t = -0.42, p>.05) or on the last visit (t=-.76, p>.05). This indicates that dorsiflexion active range of motion was not significantly different between the two groups at the initiation of treatment or at the completion of the study.

An additional unpaired t-test was performed to determine if there was a significant difference between the mean age of the two groups. The results are
reported in Table 9 and show that there was no statistically significant difference in the mean age of the two groups \((t=.61, \ p>.05)\). This indicates that age was not significantly different between the two groups.

The amount of time that had elapsed since the initial injury could have influenced the results of this study. Consequently, an unpaired t-test was performed to determine if there was a significant difference between the mean time after injury for the two groups. The results are reported in Table 10 and show that there was no statistically significant difference between the two groups \((t=.17, \ p>.05)\). This indicates that time elapsed after the injury was not significantly different between the two groups.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th>Experimental</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Mean Diff.</td>
<td>Pre</td>
</tr>
<tr>
<td>Mean</td>
<td>39.7</td>
<td>54.1</td>
<td>14.4</td>
<td>41.2</td>
</tr>
<tr>
<td>S.D.</td>
<td>18.7</td>
<td>12.7</td>
<td>(t = -2.01^{***})</td>
<td>10.3</td>
</tr>
</tbody>
</table>

\(***p<.001, \ n = 10\) for all groups
Table 3
ANCOVA of First MPJ Extension PROM

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td>9030.03</td>
<td>1</td>
<td>9030.03</td>
<td>130.01***</td>
</tr>
<tr>
<td>Between</td>
<td>116532.0</td>
<td>1</td>
<td>116532.0</td>
<td>354.99***</td>
</tr>
<tr>
<td>Interaction</td>
<td>2449.23</td>
<td>1</td>
<td>2449023</td>
<td>350.26***</td>
</tr>
</tbody>
</table>

***p<.001

Table 4
Comparing T-test Pre and Post Data for Flexor Hallucis Strength

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Mean</td>
<td>5.9</td>
<td>7.5</td>
</tr>
<tr>
<td>S.D.</td>
<td>3.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

***p<.001, n = 10 for all groups
Table 5
ANCOVA of Flexor Hallucis Strength

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td>223.26</td>
<td>1</td>
<td>223.26</td>
<td>158.76***</td>
</tr>
<tr>
<td>Between</td>
<td>2153.56</td>
<td>1</td>
<td>2153.56</td>
<td>108.28***</td>
</tr>
<tr>
<td>Interaction</td>
<td>94056</td>
<td>1</td>
<td>94.56</td>
<td>67.24***</td>
</tr>
</tbody>
</table>

***p<.001

Table 6
Comparing T-test Pre and Post Data for Subjective Pain Level

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Mean</td>
<td>6.8</td>
<td>4.2</td>
</tr>
<tr>
<td>S.D.</td>
<td>1.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

***p<.001, n = 10
Table 7
**ANCOVA of Subjective Pain Levels**

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td>202.50</td>
<td>1</td>
<td>202.50</td>
<td>293.95***</td>
</tr>
<tr>
<td>Between</td>
<td>828.10</td>
<td>1</td>
<td>828.10</td>
<td>332.72***</td>
</tr>
<tr>
<td>Interaction</td>
<td>36.10</td>
<td>1</td>
<td>36.10</td>
<td>52.40***</td>
</tr>
</tbody>
</table>

***p<.001

Table 8
**T-test of Mean Difference in Dorsiflexion ROM Before and After Treatment**

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Exp.</td>
</tr>
<tr>
<td>Mean</td>
<td>2.2</td>
<td>4.6</td>
</tr>
<tr>
<td>S.D.</td>
<td>10.45</td>
<td>7.64</td>
</tr>
</tbody>
</table>

n = 10 for all groups
Table 9

**T-test of Mean Difference in Age**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>33.60</td>
<td>32.00</td>
<td>1.60</td>
</tr>
<tr>
<td>S.D.</td>
<td>5.42</td>
<td>6.32</td>
<td></td>
</tr>
</tbody>
</table>

\[ t = .607 \text{ N.S.} \]

\[ n = 10 \text{ for all groups} \]

Table 10

**T-test of Months Elapsed Since Injury**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.4</td>
<td>7.9</td>
<td>.5</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.16</td>
<td>1.97</td>
<td></td>
</tr>
</tbody>
</table>

\[ t = .171 \text{ N.S.} \]

\[ n = 10 \text{ for all groups} \]
Chapter 5

Discussion

The results of this study indicate that standard physical therapy interventions for the treatment of functional hallux limitus are effective in increasing range of motion and reducing subjective pain level. They also indicate that the standard physical therapy interventions when combined with sesamoid mobilization, flexor hallucis strengthening and gait training are effective in increasing first MPJ extension passive range of motion and flexor hallucis strength and reducing subjective pain level. Furthermore, the results of this study indicate that standard physical therapy when combined with sesamoid mobilization, flexor hallucis strengthening and gait training result in statistically greater increases in range of motion and strength and a greater reduction in pain level as compared to standard physical therapy interventions alone. There were no statistical differences between the experimental and control groups in regard to age, dorsiflexion range of motion and time elapsed since the injury.

Even more important than the statistical significance of this data is the clinical significance. The increase in extension passive range of motion of the first MPJ in the experimental group has clinical significance. A minimum of 60 to 65 degrees of first MPJ extension is needed for normal ambulation (Boissonnault & Donatelli, 1984). All ten subjects in the experimental group achieved at least 74 degrees of first MPJ extension. Four of the ten achieved 90 degrees of first MPJ extension passive range of motion which is considered full range of motion. Only one subject in the control group achieved greater than 65 degrees of first MPJ extension passive range of motion. Despite increase in range of motion of the control group, it was not enough for normal ambulation in
seven out of the ten participants. This may be one reason why the control group continued to experience higher pain levels than the experimental group during ambulation.

The greater increase in range of motion in the experimental group is thought to be the effect of the MPJ and sesamoid mobilizations combined. The initial trauma that caused the injury most likely led to scar tissue formation in the capsuloligamentous structures surrounding the first MPJ as well as the sesamoid mechanism. This is supported by the writings of Adelaar (1997) and Shereff et al. (1986) who both described scarring of the conjoined tendon and plantar capsule that limited motion of the sesamoids. To restore functional range of motion to the first MPJ, the normal biomechanics of the MPJ and its sesamoid mechanism must be restored. This can be accomplished through the use of joint mobilization in the absence of bony proliferation in the joint.

The experimental group also performed better strength of the hallux flexors. The experimental group all achieved equal or greater strength as compared to the opposite great toe after all treatments were completed. Although there was an increase in strength in the control group, it was not statistically significant and none of the subjects achieved equal strength as compared to the opposite side.

There are several explanations for this difference. First, it is known that strength gains made during the first two weeks of strength training are secondary to improved neural efficiency (Baechle, 1994). It is possible that the marble pick up exercise is not specific enough to improve the efficient recruitment of muscle fibers. In addition, specificity of training must be considered. The experimental group trained isometrically in the testing position for the first three treatments and continued the exercise at home. Consequently,
the experimental group should perform better. Furthermore, the hallux underwent strength training for four weeks. This in itself should produce strength gains. This is consistent with research conducted by Unger and Wooden (2000). Subjects underwent six weeks of foot intrinsic resisted strength training in one leg, and the opposite leg served as the control. The side that received the strengthening exercises had significantly greater strength increases than the control side. In addition, the vertical jump height and horizontal jump distance for the experimental side were significantly greater. In this study, all of the experimental subjects were able to return to their recreational activities. The marble pick up exercise alone may not provide enough of an overload to the muscles to result in strength gains.

There are yet other explanations for the increase in strength in the experimental group. Strength can be inhibited by pain. The pain levels of the control group were at least a three on a scale of zero to ten at the conclusion of treatment. It is possible that pain was continuing to inhibit performance.

Lastly, it is possible that by restoring the mobility of the sesamoids, the pulley mechanism for the toe flexors was restored. Research conducted by Adelaar (1997) and Aper et al. (1996, 1994) supports this concept. In their research, limited motion or removal of the sesamoids damaged the pulley mechanism and lead to decreased hallux flexion strength. For all of the reasons mentioned above, sesamoid mobilization and flexor strengthening can cause a significant increase in hallux flexion strength.

Pain levels were also significantly influenced by the experimental treatments. All of the subjects in the experimental group had their pain levels drop to one or zero by the end of the treatment sessions. Over half of the subjects were painfree after completing the course of treatment. None of the
subjects in the control group were able to achieve painfree status.

The reason for this reduction in pain in the experimental group can be explained by several factors. First, the great toe biomechanics, including the sesamoid mechanism, was most likely restored. This enabled the first MPJ to move through unrestricted ROM during ambulation. Then, not only was the strength of the great toe flexors restored, but they were reeducated on how to function in a closed chain manner. The sesamoids were able to assist in force distribution during midstance and the increased strength of the great toe allowed the toe to be stabilized during heel rise. In this scenario, there are no abnormal stresses to irritate tissues and cause pain.

**Limitations**

There are a few limitations of this study. First, the findings only relate to those individuals ages 26 to 43 who sustained their injuries less than two years ago and have no other complications. It is difficult to predict how these techniques would affect someone who had sustained their injury over two years ago. There could potentially be too much scarring to see an effect of treatment. Those who are older than 43 could potentially have poor joint health. They are more likely to have arthritis or bony proliferations that would limit range of motion. Consequently, the results of this study may not hold true for an elderly population or for individuals who sustained their injuries over two years ago.

The small sample size is a limitation. Small sample sizes threaten statistical power. However, it is not uncommon in clinical research to see small samples utilized.

Finally this study was not designed to investigate the effect of joint mobilization of the sesamoids, flexor hallucis strengthening and gait training alone. Conclusions cannot be drawn about the effectiveness of sesamoid
mobilizations performed in isolation. If these findings are taken out of context, they may not have good predictive validity.

Recommendations for Practice

For health professionals working with individuals age 26 to 43 who have a painful but functional hallux limitus, standard physical therapy combined with sesamoid mobilization, flexor hallucis strengthening and gait training can be very effective. More specifically, this treatment should include standard modalities such as the whirlpool, ultrasound, ice and electrical stimulation. It should also include first MPJ and sesamoid mobilization, flexor hallucis strengthening and gait training for great toe stabilization and push off. This treatment, if provided for twelve visits will result in a significant reduction in pain, increased range of motion, strength and function. Individuals should be able to return to their prior level of function with little or no pain. Surgery should not be the treatment of choice in the absence of bony proliferation on x-ray.

Recommendations for Future Research

Further research should be conducted to investigate the effectiveness of these techniques in additional populations. This could include individuals with rheumatoid arthritis and diabetes. It could also include persons with injuries over two years old. Research should also examine the effectiveness of sesamoid mobilization, flexor hallucis strengthening and gait training in the absence of modalities. Several studies could be performed to determine which treatment interventions are essential in effectively treating individuals with this impairment. If all treatment interventions were not necessary, it would reduce treatment time and costs.
References


Appendix A

Data Collection Form

Birth date:

New treatment group         Standard treatment group

Date of Injury:

Pain Level (0-10):  Visit 1 _______  Visit 6 _______  Visit 12 _______

Functional Limitations:  Visit 1
                         Visit 6
                         Visit 12

<table>
<thead>
<tr>
<th>DF AROM</th>
<th>1st MPJ PROM</th>
<th>1st MPJ strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

Visit 1
Visit 6
Visit 12
Appendix B

Figure B1. Pre and post data for first MPJ extension PROM

Control Group
Experimental Group
Appendix C

Figure C2. Pre and post data for flexor hallucis strength

![Bar graph showing pre and post data for flexor hallucis strength for control and experimental groups.](image)
Appendix D

Figure D3. Pre and post data for subjective pain level