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Plantar Fasciitis: Etiology and Treatment

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PLANTAR FASCIITIS:
Etiology and Treatment

by

Todd M. Leingang
Bachelor of Science in Physical Therapy
University of North Dakota, 1993



An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1994

This Independent Study, submitted by Todd M. Leingang in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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PERMISSION

Title Plantar Fasciitis: Etiology and Treatment

Department Physical Therapy

Degree Master of Physical Therapy

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Date 4-24-94

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ABSTRACT

Plantar fasciitis is a repetitive injury which causes microtrauma to the attachment of the plantar aponeurosis at the medial calcaneous of the foot. This condition is most prevalent among athletes involved in running sports, but can also occur in a sedentary individual who is overweight. Traditional treatments for plantar fasciitis, including rest, ice, anti-inflammatory drugs, and passive modalities, are helpful in temporarily reducing inferior heel pain. However, recurrence of this condition is common because the potential biomechanical causes of plantar fasciitis are often left unidentified. The purpose of this study is to review the anatomical structures and the biomechanical functions of the plantar fascia, to describe mechanical and non-mechanical etiologic factors involved in plantar fasciitis, and to analyze the inflammatory tissue response of this fibrous connective tissue. Furthermore, the literature review outlines a comprehensive rehabilitation treatment plan, including a conservative course of treatment using therapeutic exercises, taping techniques, and orthotic devices as well as possible surgical procedures in the most severe cases.

INTRODUCTION

Painful heel syndrome is a relatively common clinical pathology encountered by many health care professionals who treat patients with foot complaints. Approximately 15% of all foot problems requiring professional medical care can be identified as calcaneal pain.¹ Planter fasciitis, an overuse injury involving the inferior aspect of the calcaneous, is frequently associated with this condition.

Plantar fasciitis is most prevalent among athletes involved in running sports, but can also occur in any sedentary individual who is overweight and who predominately stands on hard surfaces. The classic symptom of this condition is pain that occurs when first walking in the morning, after long periods of sitting, or at the beginning/end of a workout.^{2,3,4} The pinpoint, sharp, stabbing pain usually presents in the plantar aspect of the heel pad at the fascial origin.⁵ With chronic plantar fasciitis, the pain extends distally along the plantar aponeurosis and there is occasional thickening or nodularity of the fascia.⁶ The pain and stiffness noted with weight bearing activities is related to muscle spasm and to splinting of the fascia, which are secondary to repetitive microtrauma and an inflammatory response at the plantar fascial origin.

Because of this repetitive overload process, plantar fasciitis is classified as an overuse syndrome.

Although plantar fasciitis may be insidious in onset, the literature describes etiologic factors involved in the causation of the painful heel pathology.^{3,5,7} Presently, several research articles have shown that certain biomechanical and anatomical variables are the source of plantar fasciitis. Repetitive mechanical stresses, from alterations in normal biomechanical/anatomical structure and function, are generally the primary predisposing factors for the painful plantar heel. Kwong et al⁶ have shown that during the midstance of gait, excessive pronation causes an increase in tensile stress to the plantar fascial insertion. On the other hand, with a cavus foot (supination), the longitudinal arch is rigid and unable to assist in the dissipation and absorption of body and ground reaction forces. Therefore, the force attenuation occurs through the plantar fascia.⁶ An exostosis or bone spur arising from the medial aspect of the inferior calcaneous frequently exists in association with plantar fasciitis. Tanz⁸ reviewed roentgenograms of patients with inferior heel pain and found that 50% of the patients indeed had calcaneal plantar spurs. These bone spurs are primarily significant only when the inferior fat pad is worn. Direct repetitive microtrauma occurring at heelstrike can also irritate or entrap calcaneal nervous structures causing a painful plantar heel. In addition, other non-mechanical mechanisms, such as training errors and improper footwear, have been identified as reasons for the onset of plantar

fasciitis in recreational athletes.^{2,9,10} Finally, pathological states, such as metabolic diseases and systemic inflammatory diseases, have been implicated as causal factors of heel pain, although these conditions are usually bilateral and must be differentiated from local plantar heel pain and plantar fasciitis. For the intentions of this paper, planter fasciitis will be strictly defined as a repetitive microtrauma overload syndrome of the attachment of the plantar aponeurosis at the inferior aspect of the medial calcaneous, thus provoking an inflammatory response to the fascia and its associated structures.

The traditional common treatments for plantar fasciitis are based on the concept of tissue overload. Rest, ice, anti-inflammatory drugs, and passive therapeutic modalities decrease inflammation and pain symptoms during the acute stage.^{2,4,7} However, recurrence of the condition is common, secondary to the failure in identifying the primary etiologic factors and in correcting the maladaptive complications. Orthotics, therapeutic exercises, and surgical procedures are necessary to permit individuals with plantar fasciitis to return to normal pain-free activities.

The purpose of this paper is to review the anatomical structures and the biomechanical functions of the plantar fascia, to describe mechanical and non-mechanical etiologic factors involved in plantar fasciitis, and to analyze the inflammatory tissue response of the fibrous connective tissue. Furthermore, the paper will outline a comprehensive rehabilitation treatment plan, including a conservative course of treatment using therapeutic exercises, taping

techniques, and orthotic devices, as well as possible surgical procedures in the most severe cases.

ANATOMY

Plantar fasciitis is an inflammation of the plantar fascia and the perifascial structures. The plantar fascia is a multilayered fibrous aponeurosis divided into three distinct components: medial, central, and lateral (See figure 1). The central portion is the thickest and originates on the plantar surface of the posteromedial calcaneal tuberosity. Distally, the central portion divides into five tracts, forming superficial and deep components.^{4,7,11} According to Bojsen-Moller and Flagstag,¹² the superficial portion of the central plantar fascia anchors the skin and provides support from the shear forces during gait, while the deep portion of the digital band inserts to the proximal phalanxes via the fibrous flexor sheath and separates the fascia from the lumbricals. The medial component of the plantar fascia originates around the medial calcaneous and covers the abductor hallucis muscle; whereas, the lateral component originates from the lateral aspect of the medial calcaneal tubercle and extends distally to the fourth and fifth toes.¹¹ This lateral portion of the fascia also covers the abductor digiti minimi. Williams and Warwick,¹³ authors of Gray's Anatomy, believe the medial and lateral portions blend with the central portion as the course of the entire plantar fascia becomes more distal.

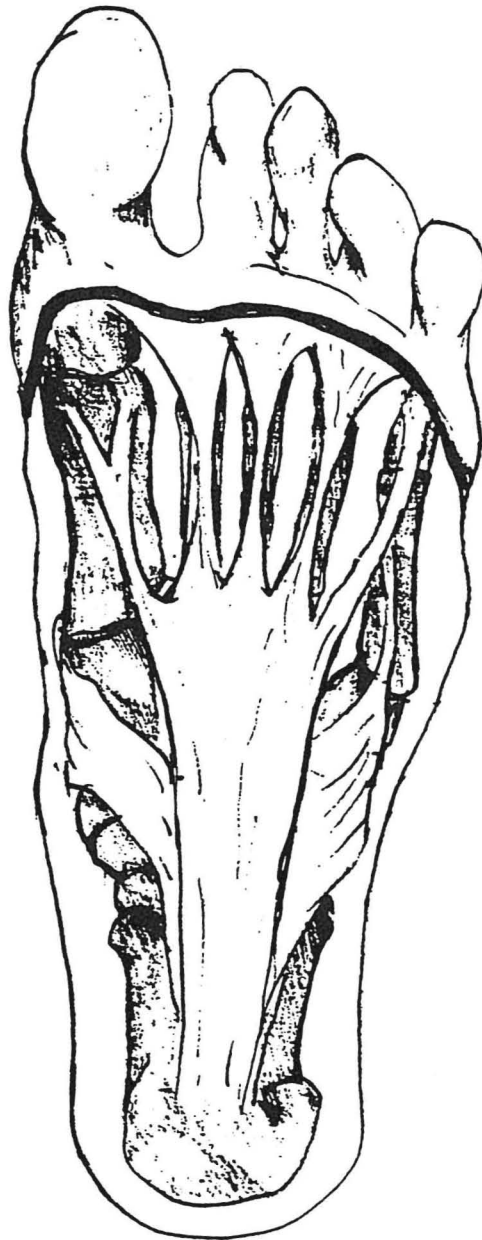


Figure 1. The plantar aponeurosis

Superficial and deep plantar muscles surround the plantar fascia. The three muscles of the superficial layer all attach to the calcaneal tuberosity. The abductor hallucis originates on the medial tuberosity and distally inserts on the tibial aspect of the base of the first phalanx of the great toe. The flexor digitorum brevis also arises from the medial calcaneal tuberosity and courses distally to attach on the middle phalanx of digits two through five, wrapping around the distal plantar fascia. Finally, the abductor digiti minimi originates from the lateral aspect of the calcaneal tuberosity and inserts at the base of the proximal phalanx of the fifth toe. Deep to the superficial musculature lies the quadratus plantae (flexor accessorius), which has two heads originating from the inferior calcaneous. The larger medial head originates from the medial concave inferior surface, just distal to the medial tuberosity; whereas, the lateral head arises from the lateral inferior aspect of the calcaneous. These two portions join distally to insert into the tendons of the flexor digitorum longus. Peak EMG studies indicate that these superficial and deep muscles maximally contract in the later part of stance phase, aiding with supination of the foot.¹⁴

The remaining perifascial structures concerned with plantar fasciitis include the longitudinal ligaments, the calcaneal nerve structures, and the subcutaneous plantar calcaneal bursa. The plantar calcaneocuboid ligament is a dense, thick, white structure consisting of two distinct layers. The long plantar ligament attaches to the inferior surface of the calcaneous and courses longitudinally to insert into the inferior aspect of the cuboid and the bases of the

third, fourth, and fifth metatarsals.¹³ The short plantar ligament routes from the anterior tubercle of the calcaneous to the plantar surface of the cuboid. Together the long and short ligaments give rise to the 'spring ligament' which is responsible for the longitudinal arch formation of the foot.¹⁵ Because of its origin on the medial calcaneous and insertion into the navicular, the spring ligament provides the proper stability between the rearfoot and midfoot, creating the longitudinal arch. The tibial nerve has superficial branches, termed the medial calcaneal nerves, that bifurcate distal to the medial malleolus. The tibial nerve then divides into its medial and lateral plantar branches, which pass deep to the abductor hallucis muscle belly. There is a third controversial deep branch that innervates the abductor digiti minimi muscle which is thought to be a division of the lateral plantar nerve. Baxter and Thigpen¹⁶ proposed that plantar heel pain often represents a compression neuropathy of this third branch to the abductor digiti minimi. The remaining perifascial structure, the subcutaneous plantar calcaneal bursa, is present around the above mentioned structures. This bursa acts as a lubricating material to promote normal plantar function. However, when inflamed, the bursa's lubricating mechanism is restrained, resulting in an irritated and a painful plantar heel.

It appears that the plantar fascia, the musculature, the ligaments, the nerve supply, and the subcutaneous plantar calcaneal bursa of the inferior foot are all located in the anatomical vicinity where plantar fasciitis develops. Abnormal stresses to these structures secondary to deficiencies in foot and

ankle biomechanics and in plantar fascia function can become significant factors leading to the etiology of plantar fasciitis.

GAIT BIOMECHANICS/FUNCTION OF THE PLANTAR FASCIA

The knowledge of functional biomechanics of the foot and ankle are momentous in the understanding of pathological overuse syndromes, such as plantar fasciitis. Normally, the support phase of gait can be divided into three distinct phases: heelstrike, pronation, and supination.¹⁷ At heelstrike, the foot is in supination, which is a combination of subtalar joint inversion and forefoot adduction.^{9,18} In this position, the bones of the foot are locked and stable. However, immediately after heelstrike, the foot begins to pronate, a combination of subtalar joint eversion and forefoot abduction, to allow for shock absorption, ground terrain changes, and walking equilibrium.^{18,19} As a result, the forefoot and rearfoot unlock, creating a less stable joint position. Normal pronation is important because the midfoot becomes flexible and absorbs the shock of heelstrike and dissipates the forces throughout the foot. The foot briefly returns to a neutral position and then supinates towards the end of the stance phase. From midstance to terminal stance the foot resupinates, creating a locking mechanism that acts as a rigid lever for a stable and effective pushoff.¹⁸

Throughout the normal progression of gait (heelstrike, pronation, supination), the plantar aponeurosis experiences alternating states of tautness. Although the plantar fascia is important in absorbing stress throughout the

stance phase, it is the resupination phase from midstance to heelstrike where the plantar fascia plays a vital role.²⁰ The tension in the fascia increases from midstance and reaches a maximum at pushoff.⁹ As the body weight rolls forward, the toes extend and the metatarsal heads push down into the plantar fascia. This action pulls maximally on the deep attachments of the plantar fascia and, in turn, tightens the fascia and elevates the arch, thereby aiding in resupination of the foot¹⁶ (See Figure 2). Tension within the plantar aponeurosis, described as the 'Spanish Windlass Effect,'²⁰ causes the fascia to act as a strap on the longitudinal arch, allowing for the locking mechanism and for increased stability to push off the ground.¹¹

In summary, the plantar fascia functions to help maintain the integrity of the longitudinal arch of the foot during the final phase of gait (Spanish Windlass Effect). However, with abnormal biomechanics and anatomical deficits, the true function of the plantar fascia may be impeded.

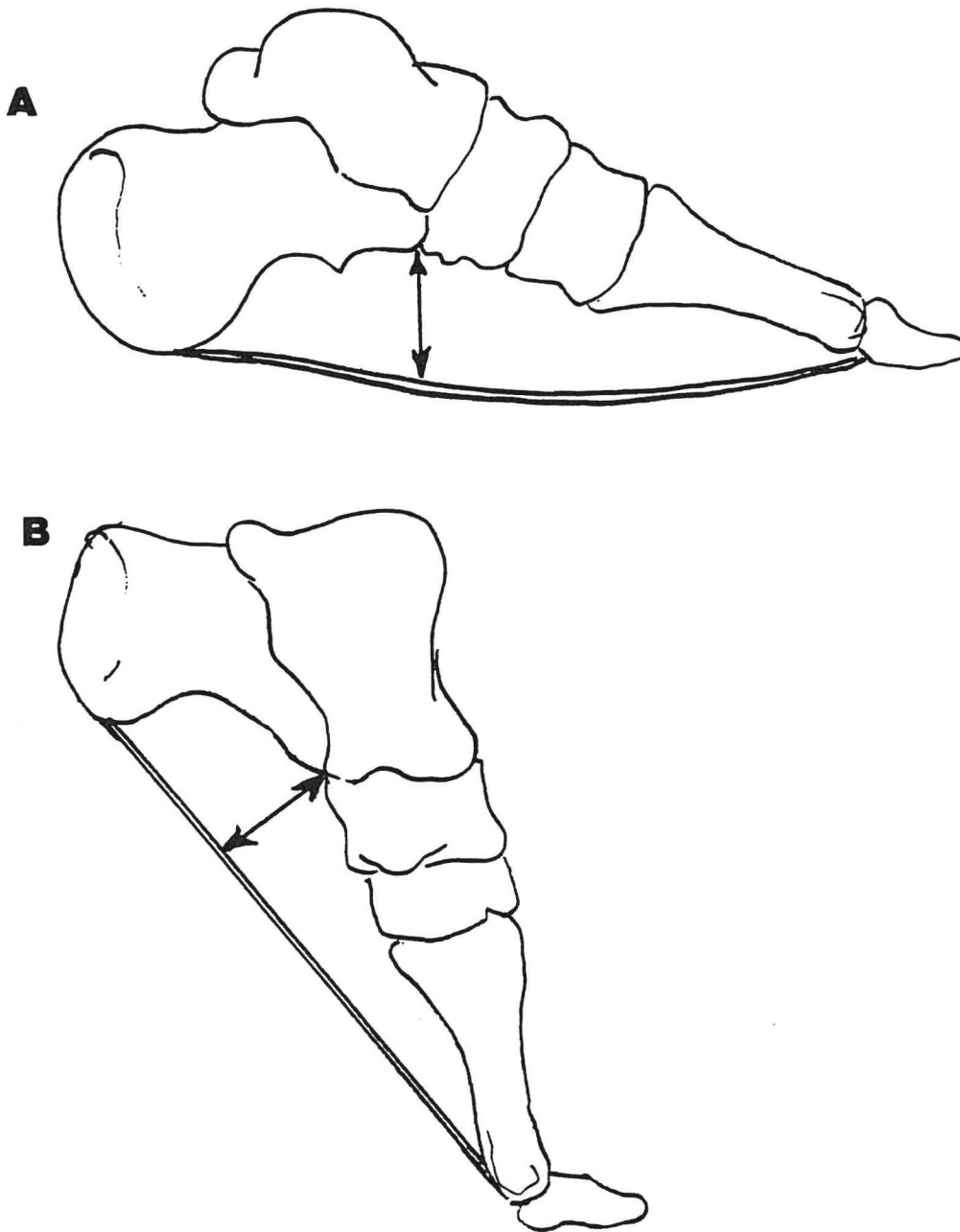


Figure 2. Windlass effect of toe extension. A. Plantar aponeurosis in a slack position with the foot in neutral. B. Increased tension of the plantar aponeurosis as the toes extend, raising the medial arch facilitating supination.

MECHANICAL ETIOLOGIC FACTORS

Biomechanical/anatomical variables cited as predisposers of plantar fasciitis include excessive pronation, rigid cavus foot, and hallux rigidus.^{4,6,7,9,21,22} Excessive pronation can be caused by an osseous mechanical deformity, a congenital deformity, or a tight Achilles tendon complex.^{4,7,9} Each of these biomechanical/anatomical elements can result in an increased tensional stress on the medial calcaneal origin of the plantar fascia.⁹

Abnormal pronation is a compensatory action for a soft tissue or osseous deformity that can ultimately result in plantar fasciitis.^{19,21} As previously mentioned, pronation normally occurs from heelstrike to midstance, to absorb and dissipate body and ground reaction forces. However, excessive pronation refers that the foot is pronating beyond the midstance phase.¹⁹ This excessive pronation creates an inordinate stretch of the plantar fascia and causes resultant microtearing at the medial calcaneal tubercle. In addition, the foot does not become resupinated by toeeff, so continued stress is placed on the fascia and the arch remains depressed. When pronation is allowed to continue, the 'Windlass' function is inhibited and the plantar fascia is overstretched which results in an inflammatory response at the medial calcaneal tubercle, secondary to the repetitive overload.^{7,9}

A second proposed mechanism of plantar fasciitis is flat (pronating) feet, which involves ligament laxity and can be caused by congenital deformities.²¹ With the short and long plantar ligaments becoming ineffective, the plantar fascia provides the only support for the longitudinal arch of the foot. Thus, the force on the arch is directly transferred to the plantar fascia, again overloading at the calcaneal origin.^{2,9}

Throughout the normal progression of gait, the posterior calf musculature typically absorb and dissipate the applied forces.² However, a tight Achilles tendon creates a valgus heel position at heelstrike and during pushoff, thereby restricting ankle dorsiflexion at midstance and limiting midfoot supination during the last part of weightbearing and toeoff. Consequently, when the Achilles tendon stretch is inhibited, excessive pronation occurs and the plantar fascia is abnormally stretched.^{2,6,9} In this way, a tight Achilles tendon/posterior calf muscle is an indirect anatomical mechanism of plantar fasciitis.

Another commonly cited biomechanical predisposer of plantar fasciitis is rigid cavus foot.^{4,9,21} This foot demonstrates a valgus forefoot and a varus rearfoot and is characterized by a dropped forefoot, clawed toes, and callus formation under the first and second metatarsal heads.⁴ Because of the position and rigidity of the foot, the normal tension of the plantar fascia is tight. A cavus foot develops plantar fasciitis secondary to the inability to absorb and dissipate forces from heelstrike to midstance when pronation should occur.

Therefore, the already tight plantar fascia is loaded much like the stretch of a bowstring.^{6,9}

A final possible predisposer of plantar fasciitis is hallux rigidus, which is restricted motion of the first MTP joint.^{21,22} As the 'Spanish Windlass Effect' demonstrates, the primary function of the plantar fascia is elevating the longitudinal arch via toe extension during pushoff.²⁰ However, when the first MTP motion is limited, the mechanical ability of the plantar aponeurosis to tighten, elevate, and stabilize the longitudinal arch of the foot is altered. Creighton and Olson²² conducted a study to determine whether there is any difference in the amount of flexion and/or extension at the first metatarsophalangeal joint in runners with plantar fasciitis. They noted a significant decrease in active and passive extension as well as passive flexion of the first MTP joint in runners who suffered from plantar fasciitis. In addition, Creighton and Olson²² believed that due to the loss of stability in the medial longitudinal arch which accompanies decreased extension range of motion at the first metatarsophalangeal joint, a separate evaluation of this joint is necessary when dealing with plantar fasciitis sufferers.

In short, abnormal biomechanics and anatomical deficits contribute to the etiology and clinical symptoms of plantar fasciitis. Still, several non-mechanical components, such as improper footwear, repetition of athletic activity, and inappropriate training programs, are additional risk factors pertaining to the etiology of plantar fasciitis.

NON-MECHANICAL ETIOLOGIC FACTORS

The onset of plantar fasciitis can be the result of problems of a nature other than anatomical or biomechanical (mechanical etiology factors). Warren and Jones¹⁷ conducted a study to establish mechanical and non-mechanical predictive variables of plantar fasciitis. Although they were unable to correctly predict the presently injured patients with plantar fasciitis, they discovered interesting non-mechanical factors common with patients suffering from plantar fasciitis. The non-mechanical variables from the patients' histories indicated that the runners who had plantar fasciitis were older, had run more years, averaged the most miles per week, and weighed the most.¹⁰ Furthermore, the authors concluded while anatomical and biomechanical factors may be predisposers of plantar fasciitis, other non-mechanical variables, such as training routines, footwear, running surfaces, etc., can be the reason that previous mechanical maladaptions may become evident in chronic injury conditions.¹⁰

The footwear that athletes and sedentary individuals wear is extremely important in preventing the occurrence and progression of plantar fasciitis^{9,23}. An improper-fitting shoe can cause or aggravate plantar fasciitis symptoms. For example, a shoe with a soft, flexible heel counter and an inadequate heel

cushion can lead to irritation around the medial calcaneous. Likewise, proper-fitting, comfortable, and supportive shoes may prevent plantar fascial injuries from occurring in the first place.²³ Shoes of individuals with plantar fasciitis have been found to have the following deficiencies: 1) a loose and flexible heel counter allowing excessive pronation of the subtalar joint, 2) insufficient arch support causing flattening of the medial longitudinal arch of the foot, 3) an extra flexible sole leading to metatarsophalangeal hyperextension and increased fascia tautness, 4) narrow toe box restricting forefoot movement, 5) inadequate insole and heel cushioning, preventing shock absorption of the body and ground reaction forces, and 6) worn-out shoes allowing formation of functional biomechanical deficits.^{2,9,10,23,24}

Inappropriate training programs and prolonged daily activities are additional non-mechanical etiologic predisposers to plantar fasciitis.^{9,25} Because plantar fasciitis is a repetitive overuse injury, individuals involved in repetitive activities are prone to added stress, irritation, and pain to the medial calcaneous.²⁶ Common training errors cited as predisposers to plantar fasciitis include an increase in mileage over a short period of time, training on hills, and running on various surface terrain's--grass, cement, asphalt, sand, etc. In addition, a recent increase in training frequency and training intensity, along with inadequate recovery time between workout activities can initiate and progress plantar fascial symptoms. Finally, training inexperience and unconditioned individuals should be considered as possible factors.^{2,9,26,27}

Athletes and sedentary individuals with plantar fasciitis need to be aware of their activity schedules and give their bodies time to adapt to the non-mechanical external stresses by gradually increasing the intensity and frequency of a particular activity or job.

The identification of the non-mechanical etiologic factors, as well as the mechanical risk factors, are extremely important for the implementation of a comprehensive rehabilitation treatment plan. However, understanding the pathophysiological mechanisms and the inflammatory tissue response of plantar fasciitis will enhance the overall awareness of this repetitive overuse injury and needs to be considered before the conservative rehabilitation plan is developed.

PATHOPHYSIOLOGICAL MECHANISMS/INFLAMMATORY RESPONSE

The pathophysiology of plantar fasciitis usually consists of a repetitive plantar fascial strain, but may also occur secondary to a sudden direct trauma to the plantar fascial origin.⁹ The gradual degenerative nature of this chronic overload injury forms a spectrum of different pathological tissue conditions. When the pull on the periosteum of the medial calcaneus is strong enough, proximal microtearing occurs, the periosteum is slightly avulsed, and hemorrhaging results. The inflammatory tissue response of the plantar fascial strain allows the regeneration of new fibrotic connective tissue. However, as the repetitive overload continues, this new connective tissue becomes fibrocartilagenous and, in time, ossifies. This ossification process develops into a bone spur which projects down into the perifascial structures and presents as heel pain.²⁸

Because of the different possible pathophysiological mechanisms, the plantar fascia itself may present in different fibrotic states. LeMerlle et al²⁹ conducted a study to compare the histopathologic makeup of two plantar fascial tissue specimens. Microscopic examination of the first specimen revealed portions with very dense fibroconnective tissue (fibrovascular hyperplasia, fibroblastic proliferation) demonstrating areas of dense fibrosis and chronic

inflammation; whereas, the second tissue sample showed fraying of the fascial surface with no fibrosis. The authors concluded that the specimens revealed substantial pathological differences, suggesting plantar fascial pain may have different sources.²⁹ The two common sources are a constant state of breakdown/repair of the proximal plantar fascial attachment and a fascia hypertrophy causing nerve entrapment.^{11,29} Meaning the plantar pain can be either caused by "plantar fasciitis" or nerve impingement of the lateral plantar nerve.²⁹

Despite the pathophysiologic mechanism or the histopathologic make-up of plantar fasciitis, the plantar fascial origin usually becomes painful and stiff after a rest from weightbearing activities.²⁶ It is perceived that when weightbearing activities are resumed, the inflammatory/healing process which has started by the formation of new connective tissue is interrupted and the site is aggravated.³⁰ Consequently, the repetitive overload process which causes the onset of plantar fasciitis also prevents the healing process from occurring. Therefore, the conservative and comprehensive rehabilitation treatment program of plantar fasciitis must reduce the acute symptoms and decrease the repetitive overload cycle by correcting the mechanical and non-mechanical etiologic factors.

REHABILITATION

Rehabilitation should begin with a complete and accurate diagnosis.²

This can be accomplished by assessing the different possibilities and outcomes of this overload injury. A thorough evaluation includes a history, physical examination, and musculoskeletal evaluation.^{2,3} By performing an extensive evaluation that finds physical symptoms and functional deficits, a comprehensive rehabilitation treatment plan can be developed to resolve the various complications.^{2,6,9}

The comprehensive, conservative treatment plan for plantar fasciitis includes two separate phases.^{2,9,31} During the acute stage of injury, the emphasis is on reducing symptoms, such as inflammation and pain.^{14,32} The subacute phase includes the determination and correction of mechanical and non-mechanical etiologic factors.^{2,7,33} The comprehensive, conservative treatment plan should be designed to control the inflammatory tissue response and to reduce tension on the plantar fascia and associated structures.⁷ By addressing these two distinct phases, many individuals with plantar fasciitis will find relief and will return to normal activities of daily living.

The majority of plantar fasciitis sufferers will respond to acute treatments, such as rest, ice, elevation, compression, anti-inflammatory medications, heel

cups, and therapeutic modalities.^{2,9,31} These initial treatments reduce the inflammatory tissue response and decrease painful symptoms. According to Brody,⁵ rest is often an effective early treatment for overuse injuries, such as plantar fasciitis. Individuals with plantar fasciitis should modify and/or limit their strenuous activity to allow time for the plantar fascia to heal. In addition, an ice massage or slush bath for 20 minutes, several times a day, can help alleviate plantar discomfort temporarily during the acute phase.³⁴ Other initial treatments to reduce the inflammatory response include elevation and compression.^{2,9,23} Anti-inflammatory medications are also recommended for the treatment of plantar fasciitis.^{2,9,24} Common oral medications used include Butazolidin, Tundearil, Naprosyn, Indocin, and Motrin.²⁴ Although non-steroidal anti-inflammatory medications can be used, the patient with plantar fasciitis must be made aware of possible side effects and must be supervised during their use.³⁴

Heel cups are also helpful in alleviating acute symptoms.⁴ The plastic heel cup supports the soft tissues, absorbs some of the impact during stance phase, and distributes pressure away from the inflamed plantar fascia.^{4,31} Heel cups can be placed in regular shoes and worn throughout normal activities. A heel cup or shoe lift should be used during the acute stage to see if the patient experiences temporary relief and benefits from these rubber inserts.^{9,31} Arnie Keck, a faculty member in the physical therapy program at the University of

North Dakota, suggested that treatment of plantar fasciitis and other heel problems is often successful with the use of a simple heel cup.³⁵

Additional therapeutic modalities used during the acute stage include pulsed ultrasound, phonophoresis, galvanic stimulation, and iontophoresis.^{9,31} These modalities are used when the more conservative treatments of rest, ice, compression, and elevation are ineffective. Although these therapeutic modalities assist in reducing the inflammatory response and enhance tissue healing, some believe they are not of great benefit in certain cases. According to Schepisis et al,⁴ unless the biomechanical abnormalities are appropriately corrected, the role of physical therapy modalities provide only temporary relief and appear limited. On the other hand, Kleinkort³⁶ demonstrated that phonophoresis (10% hydrocortisone preparation) appears to reduce the signs and the symptoms of an inflammatory response commonly associated with plantar fasciitis.

Following control of the acute inflammatory process, the mechanical and non-mechanical etiologic factors must be addressed. Conservative treatments and techniques used during this second stage include therapeutic exercise, low-dye taping procedure, and orthotic fabrication.^{2,6,7,9,23}

Kibler et al³⁷ conducted a study to examine the strength and flexibility findings in the muscles that are used in running. Three groups of athletes took part in the study: 1) a control group of 45 athletes with no symptoms, 2) 43 athletes with unilateral symptomatic plantar fasciitis, and 3) the same 43

athletes' asymptomatic contralateral feet. Analysis of the data indicated approximately 80% of the symptomatic feet had significant restricted range of motion and significant lower peak torque scores.³⁷ Forty-one of the 43 feet in group two were found to have peak torque deficits in the plantarflexors on the affected side. In addition, 37 feet showed a tightness in the gastroc-soleus musculature, defined as less than 5 degrees of dorsiflexion above neutral on the affected side or lacking 10 degrees or more of dorsiflexion compared to the unaffected side.³⁶ Therefore, the authors concluded that strength and flexibility deficits in the supporting musculature in the posterior calf and foot are affected by plantar fasciitis. In addition, they felt that these anatomical and physiological alterations create a functional deficit in the normal foot mechanics, thereby causing or contributing to the overt clinical symptoms of plantar fasciitis.³⁷

Several authors recommend stretching and strengthening exercises for the treatment of plantar fasciitis.^{15,38} Krissoff and Ferris³⁸ advised stretching the gastroc-soleus complex as well as the intrinsic and extrinsic musculature of the foot. Middleton and Kolodin²³ believed stretching exercises decrease the probability of musculotendinous injuries to the foot and help reduce soreness of the plantar fascia.

Specific stretches utilized in the treatment of plantar fasciitis include the classic wall lean stretch for the gastrocnemius muscle with the knees extended and the modified wall lean stretch for the soleus muscle with the knees slightly bent (See appendix A).^{14,31,38} The golf ball stretch, dorsiflexion of the great toe,

(See Appendix A) and a deep friction massage along the longitudinal arch are additional stretching exercises used to help loosen fascial tissues of the intrinsic foot.²³ Many authors believe it is essential to perform stretching exercises several times a day, but especially in the morning, before and after strenuous activity, and before bedtime.^{23,31} An individual with plantar fasciitis should hold each stretch for 10-15 seconds and repeat each exercise 15 times.

In addition to stretching exercises, Middleton and Kolodin²³ reported strengthening exercises for the intrinsic muscles of the foot help to prevent recurrence of plantar fasciitis. The strengthening exercises are divided into two categories: 1) weightbearing and 2) non-weightbearing. The non-weightbearing exercises are used specifically during the acute phase and include the ankle alphabet, toe squeeze, marble pick, and ankle circle.²³ The weightbearing exercises include the step squeeze, towel grab, and towel scoop (See appendix A).²³

Stretching and strengthening exercises for supporting musculature of the posterior calf and foot are essential for individuals with plantar fasciitis.^{2,9,23,31,38} By increasing foot and ankle range of motion and strengthening of the foot musculature through exercise, functional etiologic factors can be corrected. Therefore, a return to normal foot biomechanics with no extra tension of the plantar fascia may prevent recurrence.²³

Another conservative treatment technique used during the second phase is biomechanical strapping or taping of the foot.^{7,23,31} Biomechanical

maladaptions, specifically excessive pronation of the foot, have been identified as possible causal factors for plantar fasciitis.³⁴ Several authors recommend low-dye taping as a means for correcting such problems.^{7,23,34,39} Whitesell and Newell³⁹ noted that low-dye taping stabilizes the head of the first metatarsal through plantar flexion and decreases foot pronation. Newell and Miller³⁴ reported that a positive response to this taping is indicative of mechanical problems and can be used as a guide for orthotics. This taping technique can temporarily support the arch, control heel inversion, and change heel strike position.⁴

Low-Dye Strapping Procedure

Although many authors describe different low-dye taping modifications,^{7,23,31} the following procedure appears to be the most effective from a therapeutic standpoint.⁷ Materials include taping adherent, one-inch adhesive tape, and an optional moleskin. Begin by applying the skin adhesive to the entire foot. At this time, place a moleskin on the plantar aspect of the foot (metatarsals to the calcaneus). This moleskin pad is used as a cushioning effect;^{23,31} however, it is not required for proper foot alignment. An anchor strap is placed across the plantar metatarsal heads extending to the dorsum of the foot without encircling it. (See figure 3A) With the foot and ankle in a neutral position, the first longitudinal strap begins at the first metatarsal head, extends down the medioplantar border of the foot, rounds the calcaneus, and courses up the lateroplantar border, ending at the fifth metatarsal head (See figure 3B).

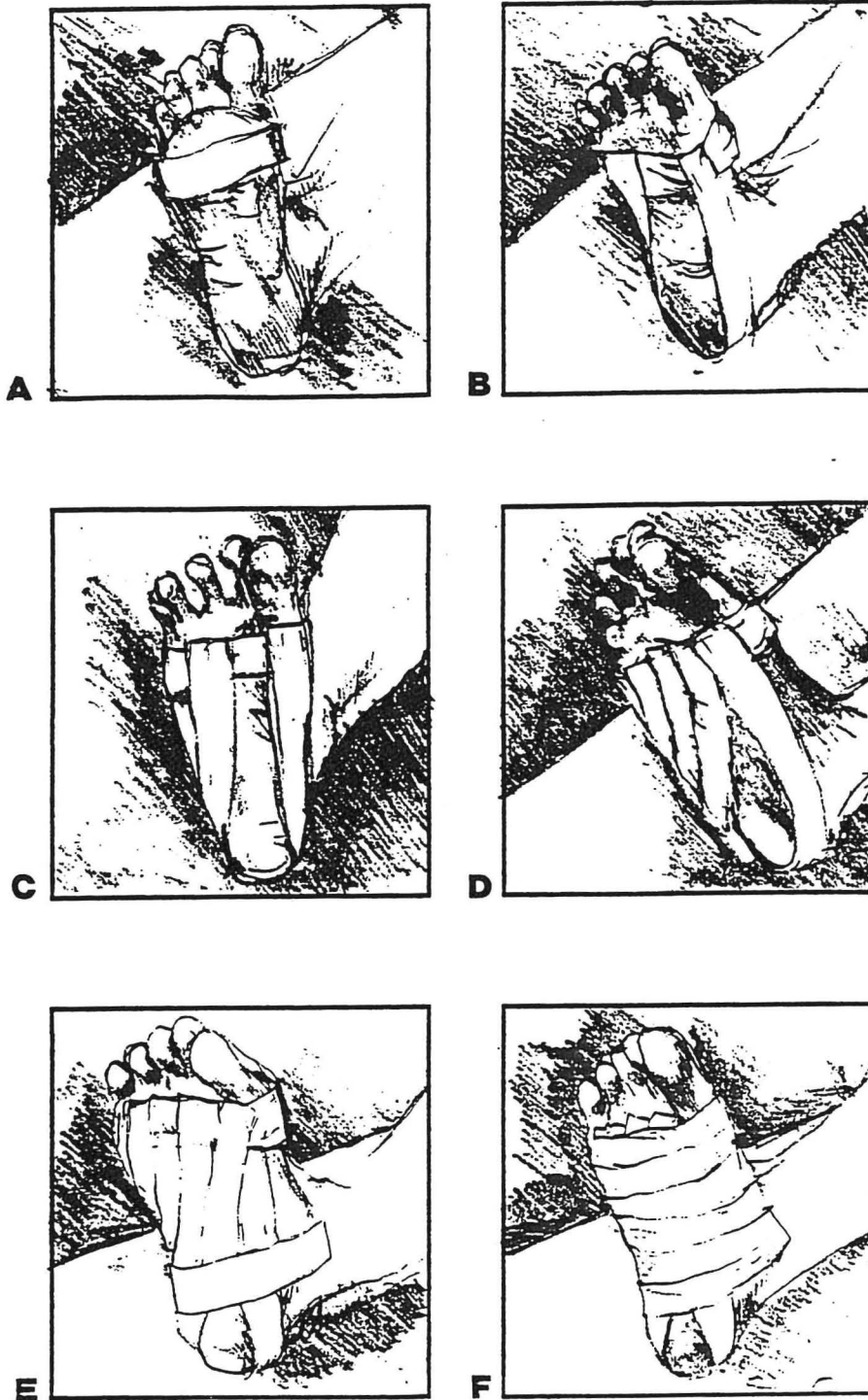


Figure 3. Low-dye strapping procedure. A. First anchor strap. B. First longitudinal strap. C. Second longitudinal strap. D. Last longitudinal strap. E. First closing strap. F. Completed low-dye taping.

Subsequent longitudinal straps should be started in the same manner at the first metatarsal head and end at the next medial metatarsal head until the final longitudinal strap starts and terminates on the first metatarsal⁷ (See figures 3C and 3D). Following the longitudinal straps, the first ray should be mildly plantar flexed.⁷ Place the first closing strap below the lateral malleolus, extend it medially and anchor it in the navicular area⁷ (See figure 3E). Subsequent closing straps are continued down the foot to the level of the metatarsals by overlapping the previous closing straps about one third of the tape width (See figure 3F). The closing straps should eliminate the longitudinal bow stringing and help with foot alignment.⁷

When the low-dye tapping procedure is correctly applied, the first ray will be plantar flexed at the metatarsophalangeal joint and the medial longitudinal arch will be elevated and well maintained.³¹ Overall, this low-dye strapping technique modifies forces on the medial longitudinal arch during weightbearing activities and may indicate that the control of foot mechanics with orthotic therapy will be beneficial.^{7,23,31,34,36}

Orthotic fabrication is another effective way in treating plantar fasciitis conservatively. Orthotics can correct foot biomechanical maladaptions that, when combined with non-mechanical factors, create excessive stress to the origin of the plantar fascia.³¹ The purpose of orthotic devices is to place the subtalar joint in its neutral position during the midstance of ambulation,³¹ preventing excessive forces on the plantar structures. Torq et al³⁴ reported that

orthotics alleviate the continuous and constant pulling of the fascia at the calcaneal origin by reducing the fascia tautness that causes fascial strain and by supporting the longitudinal arch.

Gross et al⁴⁰ conducted a study on the effectiveness of orthotic shoe inserts for long distance runners with a variety of lower extremity orthopedic problems. Of the 347 runners treated with orthotic shoe inserts, over 75% reported complete resolution or great improvement of symptoms; whereas, only 20% reported slight improvement or experienced no change in their symptoms. In this study, the orthotic insert provided a high level of pain relief in all of the diagnostic categories.⁴⁰ In fact, approximately 72% of the runners with plantar fasciitis had complete relief or great improvement of their symptoms. The authors concluded that orthotic shoe inserts appear to modify minor biomechanical deficits, thereby allowing the runner to achieve a higher level of participation.⁴⁰ In addition, the authors felt the use of orthotic shoe inserts in conjunction with conservative modalities of therapy is an appropriate treatment method for runners with lower extremity complications.⁴⁰

The type of orthotic recommended to a plantar fasciitis sufferer is according to specific needs. A variety of ready-made arch supports are available in local shoe stores; however, custom-made orthotic devices may also be prescribed and fabricated.³¹ Orthotic material for these custom-made devices vary from felt to polypropylene, while texture of the materials include a soft, flexible, semi-rigid, or rigid composition.^{31,41,42}

Goulet⁴¹ reported success with a soft orthotic support made of felt and foam. He utilized this easily constructed soft orthosis under the medial longitudinal arch with weightbearing activities and decreased the thickness of the orthosis as the plantar fasciitis symptoms subsided. On the other hand, McPoil et al⁴² conducted a study to compare custom-made rigid versus soft foot orthotics. The authors purpose was to determine if differences existed in the forefoot and rearfoot force-time integral values measured while walking and running on a treadmill.⁴² The results showed both orthotic conditions reduced the force-time integral when compared to the shoe condition; however, only the soft orthotic condition significantly reduced the rearfoot force-time integral values with walking and running. The authors concluded that custom-made soft orthotics should be considered over rigid orthotics for individuals who require a reduction of the forces acting throughout the foot and lower extremity during walking and running.⁴²

McPoil and Corwell⁴³ also investigated the effect of insole material on force and plantar pressures during walking. Specific indications for the use of insole material include lower extremity and/or foot problems, which reduce normal shock attenuations and cause hypersensitivity of the plantar foot surface.⁴³ The study included 12 subjects who walked barefoot over a pressure platform with one of the following insole materials placed on the platform: 1) PPT, 2) Spenco, and 3) Viscolas. PPT is an open cell urethane foam, Spenco is a neoprene rubber foam with nylon covering, and Viscolas is a

viscoelastic polymer material.⁴³ The authors concluded that a reduction in maximum plantar pressure was seen only with PPT and Spenco in the rearfoot region.⁴³ Furthermore, PPT and Spenco appear to have the ability to distribute pressures over a wider area of the foot, therefore are the best suited for pathologies like plantar fasciitis where plantar pressures must be reduced.⁴³

In summary, orthotic shoe inserts are utilized to allow the foot to operate in a mechanically efficient manner, thereby reducing the inflammatory response commonly associated with plantar fasciitis.^{6,9,44} Although simple soft, flexible orthotics may be beneficial, a semirigid, custom-made orthotic appears to reduce excessive plantar fascial strain by supporting the first metatarsal bone and maintaining the medial longitudinal arch.⁶ Overall, an orthotics success relies on its ability to reduce mechanical foot abnormalities and decrease plantar pressure forces on the medial aspect of the plantar calcaneus.^{2,6,44}

The majority of plantar fasciitis sufferers will respond quite well to a progressive conservative rehabilitation program.^{23,34} Successful management of plantar fasciitis by conservative means has been reported as high as 94%.⁴⁵ However, when the conservative treatments have been utilized with no success, some recommend a steroid injection at the origin of the plantar fascia on the medial calcaneus^{7,9,32} or surgical intervention.^{9,46}

The steroid injection is usually a temporary relief reducing the inflammatory response and decreasing the acute plantar pain.⁹ No more than three injections should be given in any one series secondary to an increased

risk of plantar fascia rupture.³³ Although steroid injections can dramatically improve plantar pain, it is suggested that injections should be used in conjunction with other conservative treatments, such as orthotics and lower extremity stretching/strengthening exercises, thereby allowing for the correction of both the mechanical and non-mechanical etiologic factors.^{6,9}

The most severe cases of plantar fasciitis may require surgical intervention. The criteria for surgery include having had plantar fasciitis for at least one year, experiencing little or no success with conservative methods, and/or being unable to resume normal activities of daily living.^{9,46} The surgical procedure consists of a small longitudinal incision on the medial/inferior surface of the calcaneus.^{4,9} Degenerative plantar fascia is resected and a heel spur, if present, is surgically excised.^{4,46} After the proximal plantar fascia is released, the surface of the medial calcaneus is smoothed out with an osteotome to create a fibrous healing response and to allow the plantar fascia to heal in a lengthened position.⁴ Postoperatively, the patient is non-weightbearing for three weeks to allow for connective tissue healing. A progressive rehabilitation follows as tolerated and appropriate.⁴

In short, plantar fascial release appears to be a popular method of surgical management.^{4,9,46} Surgical release of the fascia at the medial tubercle of the calcaneus may provide relief of the inflammatory response which ultimately results in localized fibrosis and degeneration of the plantar fascial origin, thereby allowing the fascia to assume a position of less tension.⁴

However, surgical intervention is only recommended after failure of conservative measures.^{4,9,46}

The prevention of plantar fasciitis requires understanding the mechanisms of the injury prior to experiencing the symptoms.^{9,23} Education focuses on the prevention of non-mechanical etiologic factors. Proper shoe selection is critical to avoid plantar fasciitis in athletes as well as sedentary individuals.²³ A comfortable shoe with adequate insole cushioning, sufficient longitudinal arch support, and stiff heel counter may prevent plantar strain injuries.²³ Also, regularly engaging in a lower extremity strengthening and stretching exercise program will facilitate appropriate flexibility and strength in the foot and ankle, and will allow adequate biomechanical alignment to tolerate weightbearing activities.⁹ Finally, recognizing and treating abnormal foot mechanics may prevent the repetitive cycle which initiates plantar fasciitis.^{9,23}

CONCLUSION

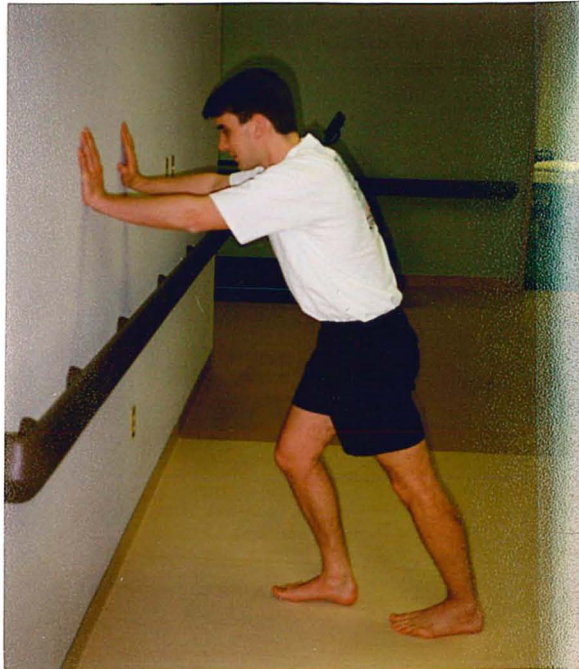
Plantar fasciitis is a repetitive overuse injury found in athletes as well as overweight sedentary individuals. The plantar fascia, which is responsible for maintaining the integrity of the longitudinal arch, becomes inflamed and/or torn at its origin on the medial aspect of the calcaneus by repetitive stresses placed upon it. The pain and stiffness noted with weightbearing activities usually occurs when first walking in the morning, after long periods of sitting, or at the beginning/end of a workout. Commonly cited mechanical predisposers, such as excessive pronation, rigid cavus foot, and hallux rigidus, are frequently responsible for development of an increased tensional stress on the plantar fascial origin. In addition, non-mechanical etiologic factors, such as training routines, footwear, and running schedules, can increase the likelihood of plantar fasciitis. Conservative management of plantar fasciitis includes the reduction of symptoms and the determination and correction of the etiology by utilizing modalities, exercise, and foot appliances. The treatment techniques reduce inflammatory response and allow for proper foot alignment, thereby preventing the repetitive overload cycle to continue. Although surgical intervention can be beneficial, prevention strategies and conservative methods usually alleviate plantar fascial complications and should be tried initially.

APPENDIX A

Classic Wall Lean Stretch

Stand with hands on the wall, _____
 foot in front of the _____ foot.
 Lean body forward with back leg
 straight. Keep heel on floor.
 Stretch is felt in calf.

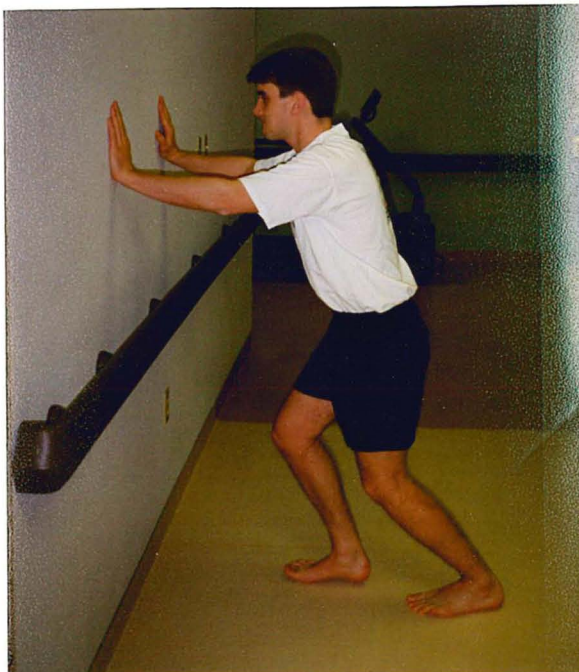
Hold _____ seconds
 _____ repetitions
 _____ times/day



Modified Wall Lean Stretch

Stand with hands on the wall, _____
 foot in front of the _____ foot.
 Lean the body forward with back knee
 slightly bent. Keep heel on floor.
 Stretch is felt in Achilles tendon.

Hold _____ seconds
 _____ repetitions
 _____ times/day



Golf Ball Stretch

While in a seated position, place a golf ball under the foot and slowly roll it up and down the medial arch. Do not use too much pressure.

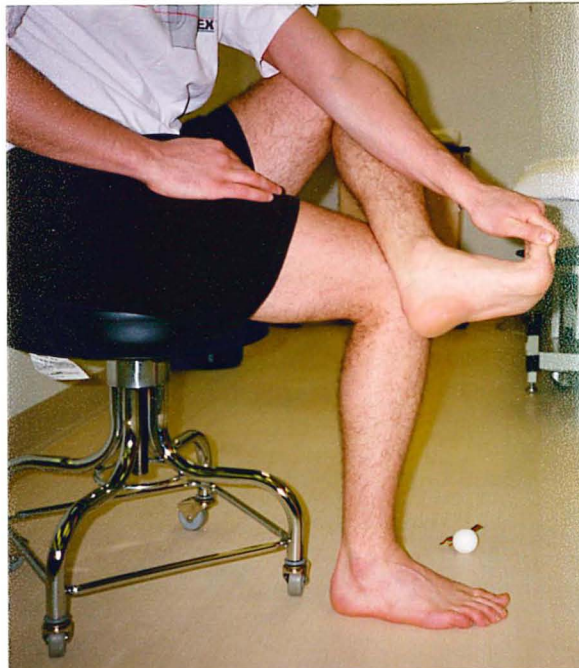
Perform _____ minutes
_____ times/day



Great Toe Dorsiflexion Stretch

Sit in chair and cross the _____ foot over the _____ leg. Gently grasp the great toe by the _____ hand, applying an upward force. Stretch is felt in the plantar fascia.

Hold _____ seconds
_____ repetitions
_____ times/day



Step Squeeze

Stand on a stairstep with toes overlapping the edge. Contract the toes against the step, squeezing the step's edge.

Hold _____ seconds
_____ repetitions
_____ times/day



Towel Grab

Sit in chair and lay a towel on the floor in front of you. Gather the towel into a roll with your toes.

_____ repetitions
_____ times/day



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