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The integration of acetic acid iontophoresis, orthotic therapy and physical rehabilitation for chronic plantar fasciitis: a case study

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A 15-year-old female soccer player presented with chronic plantar fasciitis. She was treated with acetic acid iontophoresis and a combination of rehabilitation protocols, ultrasound, athletic taping, custom orthotics and soft tissue therapies with symptom resolution and return to full activities within a period of 6 weeks. She reported no significant return of symptoms post follow-up at 2 months. Acetic acid iontophoresis has shown promising results and further studies should be considered to determine clinical effectiveness. The combination of acetic acid iontophoresis with conservative treatments may promote recovery within a shorter duration compared to the use of one-method treatment approaches.
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KEY WORDS: acetic acid iontophoresis, plantar fasciitis, heel pain, custom orthotics and foot physical rehabilitation.

Cas d'une joueuse de soccer de 15 ans présentant une fasciite plantaire chronique. Elle a été traitée avec une iontophorèse d'acide acétique et une combinaison de protocoles rééducatifs, d'ultrasons, de bandages, d'orthèse adaptée et de traitements des tissus mous avec résolution des symptômes et retour aux activités dans une période de six semaines. Elle n'a signalé aucun retour significatif des symptômes après un suivi de deux mois. L'iontophorèse d'acide acétique a présenté des résultats prometteurs et des études supplémentaires doivent être envisagées en vue de déterminer l'efficacité clinique. La combinaison d'iontophorèse d'acide acétique avec des traitements conservateurs est susceptible d'entraîner un rétablissement plus rapide comparé aux approches thérapeutiques à méthode unique.
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MOTS CLÉS : iontophorèse d'acide acétique, fasciite plantaire, talalgie, orthèse adaptée et rééducation podologique

Introduction

Plantar fasciitis or plantar heel pain is a commonly seen condition and can occur among all age groups, sex, ethnicity, or activity levels.[1] It is most frequently seen in overweight male runners (BMI > 25 kg/m^2) older than 30 years of age.[3] Plantar fasciitis is considered to be an overuse syndrome as it develops over time and is a result of repeated stress that exceeds the body's inherent capacity to repair and adapt which eventually leads to the failure of the ligaments, bones and muscles.[3] The plantar fascia acts as a stabilizer of the longitudinal arch, which is very important in the propulsive phase of gait as it serves to make the foot a rigid lever via the "windlass effect" mechanism.[4,5] Plantar fasciitis is an inflammation of the plantar fascia during the acute stages and most commonly results in heel pain at the medial tubercle of the calcaneus.[6] Tendonitis has 3 stages to its inflammation: acute – onset to 2 weeks, subacute 2–6 weeks and chron-

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ic greater than 6 weeks.[7] Given that it can also be associated with an overuse syndrome, the term – osis would be more applicable than – it is since the former refers to an insidious chronic tendon degeneration due to a partial rupture of the fibres and a mechanical overload while the latter refers to an acute traumatic inflammatory response.[8,9,10,11] Tendonitis is generally the old term that is now differentiated into tendonitis – inflammatory and considered a relatively more acute condition and tendonosis – a non-inflammatory and chronic condition.[12] Lateral radiographs are usually unremarkable; however a small percentage of patients will have a bony spur located at the medial calcaneal tubercle.[13] Hiss sites that the physiological reaction to constant excessive stress loads will cause the formation of new connective tissues progressing from fibrocartilagenous fibers to cartilaginous to bone.[14] This adaptive process would normally not produce pain, however if during any stage of the process the stress levels were to overcome the connective tissue formation then micro tearing and inflammation would develop causing the characteristic heel pain syndrome.

Typically, the pain with plantar fasciitis is worse in the morning and improves with walking and stretching or it remains as a constant ache that worsens after a period of rest. The development of plantar fasciitis has been suspected to be caused by overuse and an accumulation of microtrauma and can be related to repetition of athletic activity, improper biomechanics, improper training programs, abnormal anatomy, inappropriate footwear, nerve entrapment, tight triceps surae, fat-pad atrophy, repetitive micro trauma, muscle strength imbalances and range of motion deficits.[15,16] Hypomobile joints do not absorb weight-bearing stress and hence manipulation and mobilization of both the bony and soft tissues are often recommended for the treatment of plantar fasciitis.[17] Risk factors for plantar fasciitis include obesity or sudden weight gain, reduced ankle dorsiflexion, pes planus and occupations that require prolonged periods of weight bearing.[1] Usually the patient profile will exhibit the following characteristics: excessive pronation, pes planus, tight gastrocnemius/soleus complex, participation in running activities with a recent history of maladaptive excessive training demands or plantar foot injury.[2] Plantar fasciitis is usually unilateral and self-limiting however the typical resolution time is anywhere between 6–18 months. Early recognition and treatment of plantar fasciitis with conservative therapies is usually successful in approximately 80% of cases.[2,18,19] Unsuccessful cases that have undergone conservative treatments for periods no less than 6 months are typically referred for cortisone injection or surgery with a limited degree of success and the potential for adverse negative results over the long term.[19,20,21]

Treatments prescribed for acute cases of plantar fasciitis usually include general stretch/strength exercises, orthotics, NSAIDs, ice, physical therapy modalities, night splints, activity modification, athletic taping and heel pads.[1,19] In a narrative review of randomized controlled trials, Stuber concluded that the use of joint mobilizations and manipulation, stretching of the plantar fascia and Achilles tendon, orthotics and night splints were recommended over other forms of conservative treatment.[19] In cases of chronic heel pain these treatment regimes are typically less successful and require longer periods of recovery. The use of acetic acid iontophoresis prescribed treatments for chronic heel pain has shown promising results within 3–4 weeks and over an extended follow up period of greater than 2 years.[22] Iontophoresis is a non-invasive drug delivery system that uses a low electrical current to deliver aqueous ionic solutions transdermally to superficial areas. The aqueous acetic acid is ionized to form the negatively charged acetate ion which is then transmitted through the skin. It has been speculated that the physiological responses to chronically inflamed tissue results in higher concentrations of insoluble calcium carbonate to an injured area which contributes to the ongoing pain cycle and abnormal restructuring of myofascial tissue.[22] The acetate ion in acetic acid combines with the calcium ion in calcium carbonate to form more soluble calcium acetate which is then able to dissolve within local blood circulation and be removed from the site of injury.[23]

$$CaCO_3 + 2H(C_2H_3O_2) = Ca(C_2H_3O_2)^2 + H_2O + CO_2$$

The following case study illustrates the use of various prescribed treatments and acetic acid iontophoresis in an adolescent female competitive soccer player with a history of chronic heel pain.

History and presenting complaints

A 15-year-old female competitive soccer player presented with chronic, constant bilateral heel pain and a diffuse, dull ache and stiffness in the anterior thighs bilaterally.

Her symptoms initially began insidiously one year ago and were gradually worsening. She reported that she had previous episodes of heel pain in the past but it would spontaneously resolve after 1–2 days of rest. Her symptoms were aggravated by activities involving running and prolonged standing. The intensity of pain was 7/10 in the morning and 4/10 throughout the day. Relieving factors included rest and ice. At that point, she was evaluated by her family doctor and referred for x-rays. X-rays were unremarkable for heel spurs or fractures. She was diagnosed with plantar fasciitis and referred to a podiatrist. The podiatrist prescribed a 3 mm rigid, full length orthotic with a neutral heel post and given stretches for the gastrocnemius/soleus muscles. She was instructed to wear the orthotics for all activities and that her symptoms would resolve within 2–6 weeks.

The patient's heel pain mildly improved. After a period of 1 year, she reported that her pain was characterized as a constant, dull ache localized over the medial calcaneal tubercle with an intensity of 5/10. In addition, she developed increasing stiffness and a constant ache in her anterior thighs bilaterally. She reported that she still had severe pain with her first few steps in the morning and especially after intense running the previous day. Her anterior thigh pain was aggravated while playing soccer and limited her playing time to less than 20 minutes. The severe heel pain would last 2–4 hours after onset. The application of ice would reduce the pain intensity but she reported that a constant dull ache was localized to the heel. She was not taking any medications or natural supplements. She had a history of exercised-induced asthma and allergies to pollen. Systems review, previous accidents / hospitalizations and past illnesses were unremarkable and other than the heel pain she was in good health.

Exam Findings

Vitals
This 5'5" soccer player weighed 145 lbs. She is a non-smoker and reported being in good health.

Posture
Standing posture evaluation revealed generally good alignment in the lumbopelvic region. She had bilateral pes planus with mild calcaneal eversion and bilateral functional genu valgus (Figure 1).

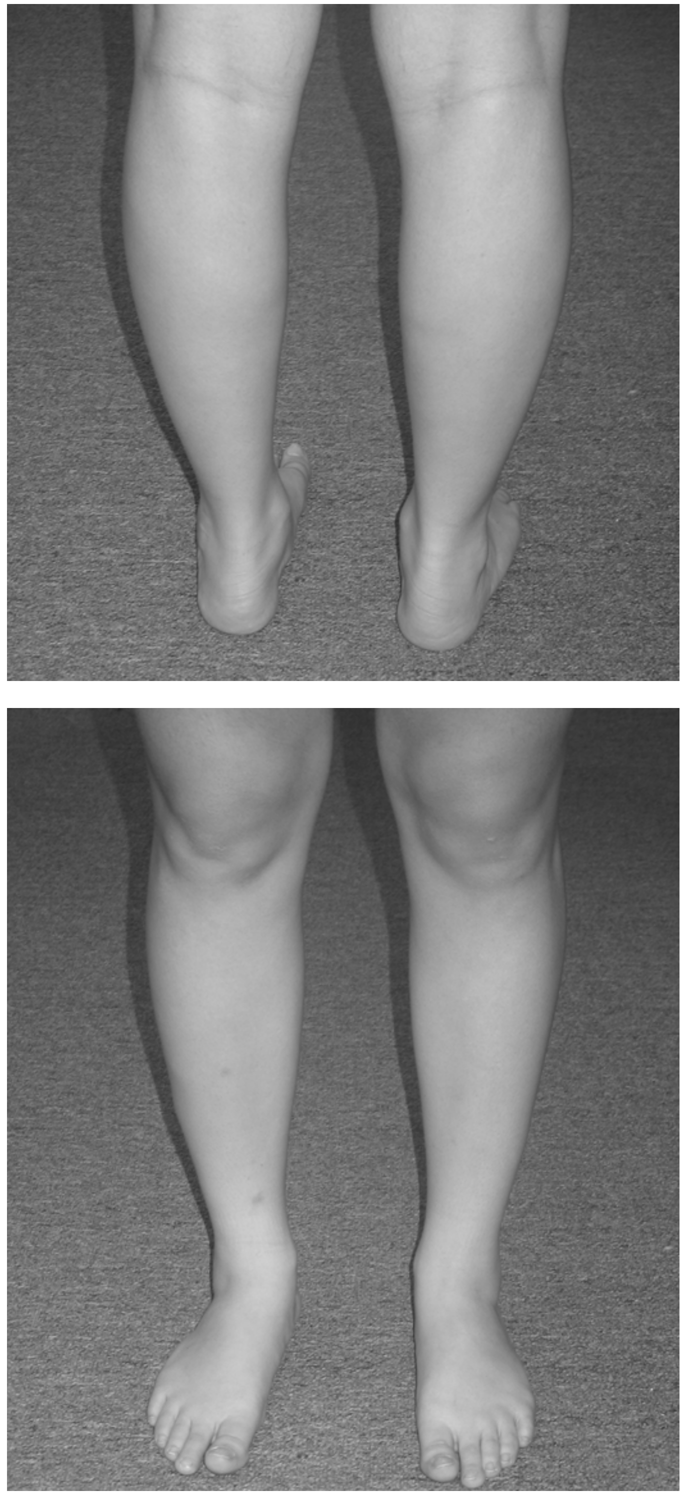

Figure 1 *Standing postural evaluation demonstrating bilateral pes planus with mild calcaneal eversion.*

Physical Evaluation and Gait

Ankle range of motion was limited in passive dorsiflexion bilaterally. Extension of the 1st metatarsal phalangeal joint was within a normal range of movement but produced pain along the plantar aponeurosis. Severe tenderness was provoked on palpation over the medial calcaneal tubercles bilaterally (more severe on the right side). Muscle hypertonicity was noted bilaterally in the gastrocnemius/soleus complex. Taut bands were found in the plantar aponeurosis and fascia. Calluses were apparent in the medial aspect of the 1st rays. Joint play revealed restrictions in the subtalar and ankle mortise joints bilaterally.

Active knee range of movement was within normal limits. Resisted knee movements were unremarkable. Mild atrophy was noted in the right vastus medialis oblique (VMO) muscle. Contraction of the quadriceps in extension produced a mild lateral deviation of the patella. Thomas and Ely's tests for hypertonicity of the hip flexors and quadriceps muscles were positive bilaterally.

Active hip range of movement was within normal limits. Resisted right hip abduction was mildly weak. A trigger point was found in the right tensor fascia lata (TFL) muscle. Ober's test was positive for TFL / iliotibial band hypertonicity.

Gait assessment revealed prominent forefoot overpronation with mild foot flaring laterally. One-leg standing functional genu valgus testing was positive bilaterally. Heel and toe walking was normal.

Leg length comparisons were within normal limits. The following orthopedic tests were negative: anterior and posterior drawer, talar tilt, Kleiger's, Thompson's, Homan's, Noble's compression and Hibb's.

Clinical impression

Chronic bilateral plantar fasciitis secondary to longstanding poor biomechanical foot function with associated muscle hypertonicity of the gastrocnemius/soleus complex, tensor fascia lata and mild atrophy of the right vastus medialis oblique.

Treatment Plan

Phase 1: Reduce pain intensity/inflammation and patient education

Due to the chronic nature of her heel pain, acetic acid iontophoresis was used at a frequency of 3 times per week for 2 weeks and then 2 times per week for 2 weeks. The treatments were delivered using the Empi Dupel Iontophoresis System with an 80–90 mA·min dosage with 4 ml of 5% acetic acid solution. Acetic acid has a negative ionic polarity so it was added to the delivering pad which was connected with the negative (cathode-black) electrode to repel the acetic acid ions through the skin into the underlying tissue. The buffering pad was placed just above the treatment area over the Achilles tendon and was connected to the positive (anode-red) electrode.

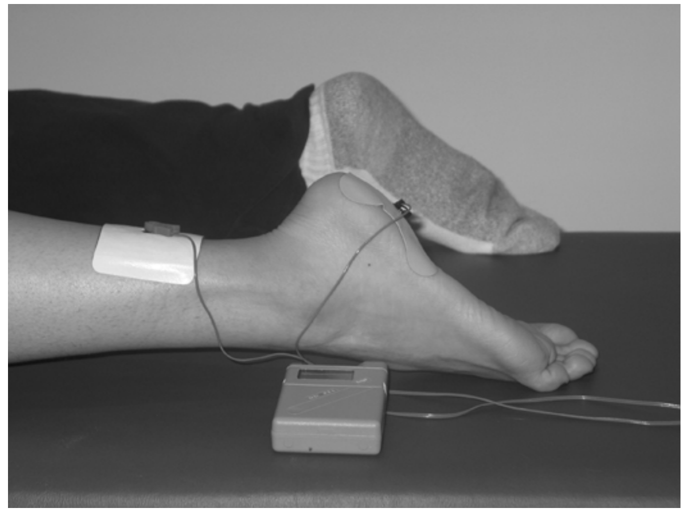

Figure 2 *Acetic acid iontophoresis applied to the heel with buffered Dupel pads.*

The acetic acid iontophoresis was then immediately followed by a 50% pulsed ultrasound at 1.5 W/cm^2 intensity for 8 minutes (Figure 2).

The patient was instructed to limit playing soccer and running activities for the following 2 weeks. She was unable to comply with restricted activity due to a number of injured teammates and she continued to play to her own ability during the course of treatment with restricted playing times and limited practices to facilitate recovery. Bilateral plantar fascial taping using the arch taping technique[24] was utilized before games and practices to reduce tension on the plantar fascia (Figure 3). Ice massage or the use of cold packs for 15–20 minutes was recommended daily and after activity to reduce pain and recurrent inflammation.

Figure 3 *Athletic taping of the plantar arch.*

Phase 2: Reduce fascial tension, muscle hypertonicity, joint hypomobility and biomechanical dysfunctions

Once the pain intensity reduced, manual manipulation of soft tissues was used in an attempt to restore normal muscle lengths and joint movements. Treatments began utilizing light myofascial therapy on the plantar fascia and gastrocnemius/soleus complex. Mobilizations/manipulations to hypomobile articulations were performed on the ankle mortise and subtalar joints. As the patient improved, deeper myofascial treatments were applied to the plantar fascia, tibialis anterior, fibularis longus/brevis, tensor fascia lata (TFL) and iliotibial (IT) band. Transverse frictions to the plantar fascia insertion were applied followed by ice massage. At that time, the patient began using a new pair of full-length custom orthotics with a 2 mm thickness, 2-degree medial extrinsic heel post and full heel cushion.

Phase 3: Muscle stretch/strengthening, ankle proprioception and return to full activity

The patient was given daily stretches utilizing 2 sets of 20–30 seconds hold for the following: plantar fascia, gastrocnemius, soleus, tibialis anterior, quadriceps, hamstrings, iliopsoas, TFL and IT band. Foot towel scrunches and scoops were performed to facilitate the small muscles of the foot and stabilize the plantar fascia. Theraband exercises for ankle inversion/eversion and dorsiflexion/plantarflexion were performed and progressed from red to green to blue bands at a frequency of 3 times per week with 2–3 sets of 15–20 repetitions. Open chain exercises beginning with leg extensions emphasizing terminal knee extension to enhance VMO muscle activity and hamstring curls were prescribed using the Zinovieff weightlifting protocol to enhance leg strength. This protocol recommends incorporating 3 sets of 10 repetitions with the first set using the 10 repetitions maximum (RM) weight, ¾ RM weight for the second set and ½ RM weight for the third set. Proprioceptive exercises progressed from 1-leg standing with eyes open to eyes closed, standing wobble board exercises to 1 leg stance with leg bends. Functional lower limb strengthening exercises utilizing half lunges and wall squats were used to facilitate closed chain movement patterns. Progressive jogging from 5 km to 10 km with increasing 1 km intervals were prescribed and monitored for symptom aggravation. Once the patient was able to jog 10 km and participate in full practices without aggravating any symptoms, she then returned to regular soccer activity without any limitations.

Discussion

Acute plantar fasciitis is an overuse syndrome that usually responds quite well with conservative treatment.[2,4,13,25,26,27,28,29,30] It is an overuse syndrome whereby the repair process cannot keep up with the stress that the body endures. The three major sources of stress are poor training technique, repetitive overuse and inherent biomechanical imbalances.[3] Large increments in training demands without enough time for recovery can initiate an inflammatory process especially in areas with biomechanical abnormalities. The repetitive sprints and jogging activity sustained during soccer can cause additional aggravation to the inflamed condition. The patient's pes planus with mild heel eversion and overpronation contributed to added tensile stresses on the plantar fascia. Chronic cases of plantar fasciitis present additional variables that can be addressed with the integration of various therapeutic interventions. This case study demonstrated that the combined use of acetic acid iontophoresis, physical therapy modalities, athletic taping, soft tissue therapy, joint mobilization / manipulation, stretch / strengthening exercises and proprioceptive facilitation and orthotics helped this patient return to her regular activities within a period of six weeks.

Treatment using acetic acid iontophoresis had been previously indicated in treating conditions such as myositis ossificans, calcific bursitis and calcific tendonitis. The rationale for treatment would primarily aim at increasing the solubility of calcium deposits in tendons and soft tissues[22,31] to encourage the removal of excess calcium ions from the injury site into the blood stream. With respect to pain generation, current literature focuses beyond radiographic evidence of pathological calcified or ossified structures and places a greater emphasis on the physiological events that precedes this process. Histopathologic changes of patients who have chronic heel pain include an initial low-grade periosteal inflammation, edema, fibroblastic and inflammatory cell proliferation.[22] Calcium deposits infiltrate inflamed, dead, or dying tissue despite normal blood calcium levels and normal calcium metabolism.[32] One theory proposes that denatured proteins from damaged cells unmask reactive groups that bind with phosphate radicals that attract and bond with calcium ions, which in turn, open collagen bundles causing tissue swelling, fat saponification and further tissue disruption.[22] Consequently, these calcium ions break protein cross-linkages with polyaminoglycans like chondroitin sulfate disrupting other protein linkages.[33] The continual progression of chronic tissue inflammation due to abnormal stress progresses from a physiological reaction to fibrocartilagenous tissue formation leading to cartilage deposition and eventual bone spur development.[22] Shama and Kominsky noted that of 1,000 patients who had been radiographed, only 132 had evident heel spurs of which, only 39% complained of a history of heel pain.[22] Thus, it could be reasoned that bone spurs are the long-term pathological response to maladaptive tissue dysfunction and that the deposition of dystrophic calcium that occurs prior to osseous formation is the primary focus of chronic pain generation. Japour et al. describes in detail the theoretical biochemical process where the use of acetic acid iontophoresis converts insoluble calcium carbonate in chronically inflamed tissue to calcium acetate, which is blood-soluble.[22] Pulsed ultrasound was used to reduce inflammation, perfuse local blood flow and facilitate the removal of the newly formed calcium acetate into the blood and thereby remove it from the localized area of heel pain.

The use of athletic taping provided temporary mechanical stability and support for the strained plantar fascia.[31,34] The amount of actual mechanical support has been questionable and current literature places a greater emphasis on proprioceptive mechanisms via sensory afferent cues through traction of the tape on the skin to reduce pain intensity and increase muscular and joint support.[35] Nonetheless, athletic taping and or bracing are effective means to limit range of motion, increase proprioception and reduce pain intensity to injured structures.[36,37] Studies have shown that athletic taping was superior to anti-inflammatories and heel cup treatments[1] or NSAIDs in combination with injections.[15] Athletic taping using non-elastic zinc oxide tape to the plantar fascial arch as described in Arhheim was initially used to reduce strain and pain intensity on the plantar fascia.[24] In addition, prophylactic bilateral plantar arch fascial taping was utilized before practices and games to encourage a progressive return to soccer activity and limit the aggravation of symptoms. Once the patient had adapted to the new orthotics, the athletic taping was omitted from treatment to evaluate her progressive response.

Ample evidence exists, based on subjective pain relief, symptom resolution and patient satisfaction, to support the continued use of orthotics in treating biomechanical injures in the lower limb, particularly in runners.[25,27,28] Orthotic intervention is appropriate for those injuries resulting from identifiable abnormal biomechanics such as hyperpronation, excessive rearfoot eversion, high eversion velocity, increase internal rotation, increased impact and loading rate of vertical ground reaction force, excessive supination with increased ankle inversion movements and external rotation moments.[28,38] In addition, orthotics may also derive their benefit by altering muscle activation and proprioceptive mechanisms involved in regulating muscle function and dampening soft-tissue vibrations.[28]

For plantar fasciitis with associated pes planus, Nawoczenski et al. prescribes a firmer, more rigid orthotic with a medial heel post to help minimize excessive pronation.[28] Gross et al. suggests that the custom semi-rigid foot orthotics may maintain medial longitudinal arch height sufficiently to reduce tensile stress within the plantar fascia and provide clinically significant reductions in pain and disability.[27] The custom orthotics may incorporate a viscoelastic polymer-filled heel cushion at the medial calcaneal tubercle for additional pressure relief.[28] In addition, straight-last footwear with motion control features such as reinforced heel counter and medial midsole reinforcement should be recommended for this foot type.[28]

In prescribing orthotics, the age, weight, foot type, biomechanical characteristics and activity level should be considered to determine the degree of rigidity and accessory modifications necessary to limit excessive movements of the lower limb complex. This 145 pound patient with forefoot overpronation was initially given a very rigid 3mm thick orthotic with a neutral heel post. Over the course of one year, this orthotic was not successful in significantly reducing her symptoms and led to the development of additional problems in the knee, quadriceps and lateral pelvic musculature. Through clinical experience, it was determined that a 2 mm thick orthotic with a 2-degree extrinsic medial heel post and additional heel cushion was appropriate for her weight level and biomechanical foot dysfunction. This orthotic would be able to provide enough support for the longitudinal arch and limit overpronation and rearfoot eversion. Accommodation to the new orthotic took two weeks with a progressive reduction in lower limb pain and an increased ability to sustain longer running and playing times.

Several manual therapeutic techniques were used to manipulate soft tissue and joint structures to restore normal muscle lengths and joint movements. Initial treatments focused on the plantar fascia and gastrocnemius/soleus complex to reduce tension and muscle hypertonicity. Manipulation and mobilization of the ankle mortise, subtalar and tarsal-metatarsal joints as well as axial traction were performed in the presence of restricted motion. Deeper myofascial treatments focused on the anterior and lateral leg compartment and the TFL/IT band complex. Brantingham et al. describes the benefits of soft tissue therapy on the plantar muscles and fascia in addition to joint manipulation to restore normal myofascial movement.[17] Cross-frictional massage was used to soften and reduce fibrotic scar tissue[17] in the plantar muscles and fascia followed by ice massage during the late phases of recovery.

The prescribed stretches were advised to be done twice per day for 20 seconds and included stretches for the gastrocnemius, soleus, fibularis, TFL and IT band, quadriceps, hamstring and iliopsoas muscles. Once the pain intensity reduced, non-weight-bearing stretching of the plantar fascia as described in DiGiovanni et al. was included in the daily routine.[39] Towel scrunches and foot scoop exercises were used to facilitate the intrinsic muscles of the foot and reduce plantar fascial tension. Foot inversion/eversion and ankle dorsi/plantar flexion strengthening exercises targeting the extrinsic muscles of the lower leg progressed using increasingly resistive Theraband tubing to reduce muscular imbalance and increase mechanical stability. These exercises were performed every other day and progressed from 2 sets of 15–20 repetitions to 3 sets over a 4 week period. During the 3rd–6th week, a wall pulley machine was used to perform the same exercises within the clinic. VMO facilitation, weighted knee extension and flexion exercises using a weight ratio of 1.3 to 1 ratio was used to target the quadriceps and hamstring muscle groups. Strength progression was monitored utilizing the Zinovieff weightlifting protocol. Closed chain modified lunges and wall squats were used to facilitate compound muscle groups and functional movement patterns. Modified jogging was initiated during this phase of recovery and progressed from running 5km to 10 km with 1 km intervals over a period of 2 weeks.

Proprioceptive exercises were used to facilitate intrinsic and extrinsic muscles to enhance motor coordination, strength and stability thereby reducing tensile stress on the plantar fascia. Balance exercise improves proprioception during both the rehabilitation phase and the competition phase of recovery.[40,41] The proprioceptive exercises progressed from 1-leg standing with eyes open to eyes closed; standing wobble board exercises to 1 leg stance wobble board exercises with leg bends.

Conclusion

Plantar fascitis is a common condition that can be effectively treated by conservative interventions; however, chronic conditions present additional concerns for therapeutic intervention. The results of this study demonstrate that the integrative use of acetic acid iontophoresis in combination with active rehabilitation (stretch/strength programs, theraband and balance board exercises), ultrasound, mechanical control of the foot with taping and orthotics, joint mobilization/manipulation and soft tissue therapies is more effective than the limited approach of just one method. The use of multiple therapies is required to resolve the effects of tissue adaptation due to chronic inflammation while improving musculoskeletal abnormalities and biomechanical imbalances. This integrative approach in the conservative management of chronic plantar fascitis resulted in the resolution of symptoms and a high degree of patient satisfaction within 6 weeks of treatment.

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