

ABSTRACT

THE SHORT TERM EFFECTS OF LOW DYE TAPING VS. CALCANEAL TAPING IN PATIENTS AGED 18-70 YEARS OLD WITH PLANTAR FASCIITIS SYMPTOMS: A META ANALYSIS

Background: Plantar fasciitis (PF) is a common cause of heel pain in adults, for which more than 2 million Americans receive treatment each year.¹

Objective: The purpose of this meta-analysis and systematic review is to compare the short term effects of low-dye taping in conjunction with conventional therapy versus calcaneal taping in conjunction with conventional therapy in pain reduction and functional ability in patients aged 18-70 years old with either acute, sub-acute, or chronic plantar fasciitis symptoms.

Methods: The literature reviewed was conducted under the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Guidelines (PRISMA).³²

Results: The results from this meta-analysis do not support the original hypothesis that LDT in addition to conventional therapy interventions is superior to CT (with similar conventional therapy interventions) in reducing pain. The VAS forest plot resulted in a combined effect size of 0.033, a P value of 0.00062, a Q value of 14.76, a CI upper value of 0.989, a CI lower value of -0.923, and with a 95% confidence interval. A VAS/NPRS analysis produced a large Q statistic of 14.76 which demonstrates heterogeneity among LDT and CT when comparing studies using the VAS and NPRS as outcome measures.

Conclusion: A definitive result supporting one technique over the other in regards to pain reduction or improved functional ability cannot be found.

Key Words: Plantar Fasciitis, Taping, Anti-Pronation Tape, Low-dye, calcaneal, randomized controlled trial

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CALCANEAL TAPING IN PATIENTS AGED
18-70 YEARS OLD WITH PLANTAR
FASCIITIS SYMPTOMS:
A META ANALYSIS

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BACKGROUND

Prevalence, Risk Factors, and Clinical Presentation of Plantar Fasciitis

Plantar fasciitis (PF) is a common cause of heel pain in adults. It is estimated that more than 2 million Americans receive treatment each year for plantar fasciitis.¹ Plantar Fasciitis has been reported to affect a wide sample of patients, including both the non-athletic and athletic population.² In the non-athletic population, it is most frequently seen in weight bearing occupations, with 70% of cases involving unilateral symptoms. In the athletic population, 10% of all running athletes involved in basketball, tennis, football, long distance running, and dancing have noted high prevalence of PF.¹⁻³ Plantar Fasciitis can be equally present in both male and female patients within a wide age range.

Men and women with poor gait mechanics that include excessive pronation with resultant loss of plantar fascia extensibility are common risk factors for PF symptoms. Individuals with these poor gait mechanics, especially during loading and pre-swing phases, can affect both the athletic and sedentary populations.⁴⁻⁷ Other risk factors include limited ankle dorsiflexion range of motion, high body mass index in non-athletic individuals, consistent running, and work-related weight-bearing activities particularly under conditions with poor shock absorption such as worn shoe wear and unforgiving surfaces.² Plantar fasciitis symptoms, such as pain location, can vary in individuals.

Typically, plantar fasciitis symptoms are characterized by pain and palpable tenderness in the area of the medial tubercle of the calcaneus (medial heel), pain that is increased when taking the first few steps in the morning, and pain that is worse when weightbearing.⁸⁻¹⁰ Medial heel pain is considered a common clinical

finding as well. In order to better understand PF and its associated pathologies however, knowledge of the anatomy of plantar fascia is crucial.

Anatomy

The plantar fascia, or plantar aponeurosis, is the investing fascia of the sole of the foot and forms a strong mechanical linkage between the calcaneus and the toes. Synonymous with the deep fascia, the plantar aponeurosis arises predominantly from the medial process of the calcaneal tuberosity and attaches distally, through several slips, to the plantar aspect of the forefoot as well as the medial and lateral intermuscular septa.¹¹ Anatomically the fascia can be divided into 3 components or bands: the lateral, medial, and central bands.^{12,13}

When present, the lateral band arises from the lateral margin of the medial tubercle and provides a partial origin for the abductor digiti minimi muscle. At the level of the cuboid, the lateral band bifurcates into medial and lateral crura. The stronger lateral crux inserts into the base of the fifth metatarsal to form the plantar ligament of the sole. The medial crux, in contrast, courses distally and receives a contribution of the central band of the plantar fascia before coursing deep and inserting deep into the plantar plate of either the third, fourth, or fifth metatarsophalangeal joint. The central aponeurotic band is often cited as the major component of the plantar fascia both structurally and functionally. The apex originates from the plantar aspect of the medial process of the calcaneal tuberosity where it serves as a partial origin for flexor digitorum brevis as it conforms to the convex plantar surface of the calcaneus.¹¹

Overall, the role of the plantar fascia is twofold, to provide support of the longitudinal arch while also serving as a dynamic shock absorber for the foot and entire leg.¹⁴ Due to its vital function (supporting body weight and providing shock

absorption) and anatomical location, plantar fasciitis tissue can be exposed to various mechanisms of injury (see Appendix A).

Mechanism of Injury

Typically plantar heel pain comprises of inflamed fasciitis as well as tissue surrounding this fasciitis structure, hence termed plantar fasciitis. Plantar fasciitis is due to collagen disarray in the absence of inflammatory cells. This pathology can resemble that of tendinosis and the condition can also be referred to as plantar fasciosis or fasciopathy.¹⁵ The 2 most common underlying causes of plantar heel pain are mechanical and degenerative in nature and are believed to result from either trauma or overuse and can result in acute, sub-acute, and chronic conditions.

A common mechanically-related injury includes a predisposing factor such as excessive pronation. This contributes to the biomechanics of an adducted talus and everted calcaneus and can result in increased tension in the structures on the plantar surface of the foot, causing arch collapse and creating excessive tensile strain within the plantar fascia which can produce microscopic tears causing acute/sub-acute inflammation.¹⁴ Another form of injury can occur from prolonged degeneration.

Degeneration caused by repetitive stress to the origin of this fascia on the calcaneus may cause tissue breakdown and calcium deposits, forming spurs known as calcaneal spurs. This is indicative of chronic PF symptoms.¹⁶ Calcaneal spurs can be an irritating component of plantar fascia, present as heel pain, and are often developed through similar mechanisms. Due to this, both heel pain and PF pathologies are treated similar and are often times considered together.¹⁶ Heel pain can be caused by mechanical causes as well. Various interventions can be used in order to manage these mechanisms of injury (see Appendices B-D).

Interventions

The commonly prescribed treatment options for PF are conservative and surgical interventions.^{1,5,17,21} Some conservative interventions used to treat PF typically include ultrasound, stretching, and taping and are more conventional type interventions. Other conservative interventions include manual therapy, foot orthoses, night splints, etc. (see Table 1 for full list).¹⁷ This meta-analysis and systematic review will focus on conventional therapy interventions: ultrasound, stretching, and taping.

Ultrasound therapy is a common choice of treatment for reducing pain and inflammation in plantar fasciitis.¹⁸ Therapeutic ultrasound is a method of applying deep heat to connective tissue.¹⁹ This treatment strategy relieves plantar heel pain by both thermal and mechanical effect.^{20,21} Therapeutic ultrasound (US), described as a high-frequency mechanical wave, transmits energy through vibration, and is extensively used in clinics.⁷ Ultrasonic generators are able to deliver energy in 2 modalities: continuous or pulsed. In the continuous form, the wave power (measured as w/cm^2) remains steady, and its expected effects involve the production of deep heat, increased local blood flow, and pain relief. If used in high powers (1.3 to 3.0 w/cm^2), it also acts on fibrosis termination.⁷ Monophasic pulsed current can be used to promote fascia, wound, and pressure ulcer healing processes. Delivering of electrical current using electrodes has been shown to induce cellular actions and histological responses (such as collagen and deoxyribonucleic acid synthesis). Polarity from pulsed ultrasonic current can cause a negatively charged cathode to attract the positively charged fibroblast cells to promote and accelerate proliferation phases of plantar fascia.⁵¹

Ultrasound is used commonly in PT treatment settings.⁷ However, the evidence for the use of US for PF is controversial. Shanks et al. in 2010 conducted

a literature review of the effectiveness of ultrasound in lower extremity musculoskeletal conditions and deemed only 1 study out of 10 as high quality evidence (16+) and found no statistical significance between sham ultrasound and ultrasound treatments for both pain relief according to VAS and a pain questionnaire and functional outcome according to objective assessment of function.²² Additionally, research done by Martin et al. in 2014, used to revise the clinical practice guidelines, provides weak evidence for the recommendation that US alone cannot be recommended for individuals with PF.¹⁷

Another intervention used to treat PF is stretching, a technique that has been shown to be useful in individuals presenting with PF symptoms.^{7,23,25} Stretching techniques have also been used to alleviate symptoms associated with plantar heel pain as well. Stretching of the Achilles tendon and plantar fascia, performed 3 to 5 times daily, has been shown to be effective in decreasing the pain at the plantar fascia.⁵ Stretching of both the plantar fascia and Achilles tendon is also considered a conventional type of therapy in patients with PF symptoms. Sweeting et al. in 2011 conducted a systematic review of 6 studies concerning stretching techniques in patients with PF.²³ They reported that most participants improved over the course of the studies in both visual analog scale (VAS) scores and functional scores according to patient specific functional scale (PSFS), foot function index (FFI), and the foot health status questionnaire (FHSQ) but when stretching was compared to alternative or control interventions, the changes only reached statistical significance in one study that used a combination of calf muscle stretches and plantar fascia stretches in their stretching program. However, these authors revealed there is some evidence that plantar fascia stretching may be more effective than Achilles tendon stretching alone in the short-term. Martin et al. also reported that stretching of the plantar fascia and/or calf musculature received an A

score (indicating strong evidence) and can be used to provide short term relief for patients experiencing heel pain or PF.¹⁷ Even though stretching is shown to alleviate symptoms, it does not address the underlying pathology of poor foot biomechanics and therefore may only provide temporary relief.⁵ An intervention that can provide relief of pain symptoms while also providing stability for those with poor foot biomechanics is taping (see Appendices E-G).

Martin et al. gave taping an A score indicating strong evidence that supports the use of taping for patients with PF symptoms.¹⁷ There are various types of taping techniques available to treat plantar fasciitis. Two techniques are low dye taping²⁴ and calcaneal taping.^{24,25} These taping strategies can be valuable since tape typically remains in place for 24 hours a day for 7 to 10 days.²¹ These taping techniques are thought to improve the biomechanics of the faulty foot and can correct either rearfoot, midfoot or forefoot region alignment.²¹

Low-dye taping in particular involves an adhesive taping material meant to combat excessive pronation.²⁶ A detailed picture of this process with steps can be seen in Figure 1. This taping strategy includes placing an anchor strip with 1 to 1.5 inch tape first around the metatarsal heads followed by taping another anchor strip covering the medial and lateral borders of the foot. Then, another strip of taping begins at the fifth metatarsal head followed by the taping of the lateral border upwards towards the heel, coming around the calcaneus and across to finish where the taping originally began. After this, these steps are completed 3-4 more times starting and finishing at the 1st metatarsal head. A circling of the arch (3 times) followed by covering the original anchor strips with 2 more anchor strips is then applied.²⁷ This ensures supportive taping of the rearfoot and midfoot thus preventing excessive pes planus and pronation. Another form of taping is calcaneal taping.

Calcaneal taping involves taping of the posterior heel. Calcaneal taping is done using similar tape which is cut into 4 parts. A detailed picture of this process with steps can be seen in Figure 2. The first strip is applied distally to the lateral malleolus, pulls the calcaneus medially, and attaches to the medial aspect of the foot (distal to the medial malleolus). A second and third strip is then applied following the same pattern with overlap of approximately one third of the tape width moving in the distal direction. A fourth strip circles around the back of the heel starting distally to the lateral malleolus, wrapping around the posterior aspect of the calcaneus, and finally anchoring distal to the medial malleolus.¹⁴ Literature concerning conventional therapy such as ultrasound, stretching, low-dye taping, and calcaneal taping was gathered and assessed for this meta-analysis and systematic review.

Review of Current Taping Literature

Taping and Pain Relief

The low-dye taping technique and calcaneal taping technique have been shown to be effective treatment options for pain relief.⁵ Vicenzino et al. investigated the effect of 2 taping techniques applied vertically to support navicular height. Low-dye taping and LDT with calcaneal slings were compared. Low-dye tape with calcaneal slings was found to be more effective immediately after application and after exercising according to patient VAS reports.²⁷

Aishwarya et al. conducted a study that compared the effects of CT versus a modified LDT technique (less arch coverage, tape oriented in an X pattern on the surface of the underfoot) on the calcaneal angle in subjects with PF symptoms.⁴⁴ These authors found a pre-post comparison that showed reduced calcaneal eversion angle and reduced pain intensity in both treatment groups. They deemed

this reduction in calcaneal eversion and pain insignificant. However, a between-group analysis showed a significant reduction of calcaneal eversion angle in the CT group of 3.4° with a 95% CI range of -4.52° to 2.4° than the modified LDT group. The reduction in pain intensity in the CT group was 20.7 points with a 95% CI range of -30.61 to -10.72 and considered greater than the modified LDT group. They concluded that CT provided better relief of pain with improved biomechanical correction in the short term when compared to a modified LDT technique.

Park et al. compared the effects of LDT on pain and stability. The subjects were divided into 2 groups: a LDT group and a conservative treatment group. The low-dye taping group received LDT and TENS and the conservative group received TENS alone.²⁷ They found a within-group comparison of the VAS demonstrated that the LDT group and conservative group values significantly decreased after taping, but the LDT group value decreased more significantly than the conservative treatment group value and shown through a post-test between-group comparison ($p < 0.05$). The authors conducted a within-group comparison of the transfer area of the center of gravity value and found that this significantly increased after the taping intervention, but increased more significantly in the LDT group compared to the CT group as shown by another post-test between-group comparison ($p < 0.05$).

Ranjan et al. conducted a study that compared LDT (however they did not specify a control group) and found a decrease in VAS and an increase in FFI scores among subjects. The average VAS score pre-treatment was 65.41 and following treatment, 28.83. The average FHSQ score pre-treatment was 51.45 and following treatment, 71.54 (demonstrating an increase in functional ability). The

authors concluded LDT was effective in both reducing pain and increasing function in patients with PF symptoms.

Ernst et al. examined a modified LDT technique (same modifications as Aishwarya et al.) supporting the longitudinal arch to relieve pain.⁵ Nineteen of 20 subjects reported a decrease in pain post-taping. However there is differing evidence regarding pain reduction for taping as well.

In 2010, Van Der Water et al. conducted a systematic review of controlled trials to determine the efficacy of taping in patients with PF symptoms and found limited evidence that taping (both LDT and CT techniques) can reduce pain in the short term in patients with plantar fasciitis but the effects on disability were inconclusive.²⁹ Studies assessing arch height, foot pressure, and pronation before and after taping techniques also exist.

Taping and Arch Height, Foot Pressure, Ankle Dorsiflexion, and Pronation

Holmes et al. conducted an experiment to determine the effects of LDT in regards to subtalar neutral joint (STJN) position.²⁶ They found that a modified LDT procedure could be an effective tool for the placement of the subtalar joint into the neutral position. Low-dye taping may also be effective for maintaining the STJN position through light exercise up to 10 minutes. However, the study did not investigate whether or not the tape will continue to maintain the neutral position of the subtalar joint through more vigorous or longer periods of exercise.

Vincenzino et al. conducted a study concerning the initial effects of LDT on the medial and longitudinal arch during walking and running.⁴² They found that compared with the no tape control condition, LDT produced a significant mean

increase in the medial longitudinal arch height index during standing, walking, and jogging ($p < 0.05$).

Vincenzino et al. also conducted a study concerning plantar foot pressures following an augmented LDT (tape covering the first metatarsal head, around the posterior heel, and finished on the fifth metatarsal head followed by transverse strips anchored on the medial side covering the plantar surface) LDT predominantly increased plantar pressures in the lateral midfoot during walking and jogging.⁴³ Additionally, LDT reduced mean maximum pressure at the medial forefoot and at the medial rearfoot during walking.

Kang et al. conducted a study to investigate the effects of walking with CT in subjects with limited ankle dorsiflexion passive range of motion (DF PROM).⁵¹ Fifteen ankles in this study presented with limited DF PROM and were examined. After CT was applied, the subjects ambulated on a walkway for 10 minutes. A goniometer was used to measure the ankle DF PROM while the knee was in an extended position before and after walking with CT. The difference in ankle DF PROM between before and after walking with CT was analyzed using a paired t-test. The authors found that the ankle DF PROM was significantly increased after walking with CT. The authors concluded that walking with CT is effective for increasing the ankle DF PROM in individuals with limited ankle DF PROM.

Kang et al. conducted another study to determine the effects of walking with CT on ankle dorsiflexion (DF) and heel-off time during the stance phase of gait and ankle DF passive range of motion (PROM).⁵² Ten subjects participated in this study and were analyzed. Sixteen ankles with limited ankle DF PROM were tested. The subject's ankle DF PROM was measured using a goniometer and the ankle DF before heel-off and time to heel-off in the stance phase of gait was also measured using a 3D motion analysis system before and after walking with CT.

Data was analyzed using a paired t-test. The authors found that ankle DF before heel-off ($p = 0.001$), time to heel-off during the stance phase of gait ($p = 0.005$), and ankle DF PROM ($p < 0.001$) was significantly increased post-CT compared with pre-CT. They concluded that ambulating with CT is an effective self-exercise for improving ankle kinematics during gait and increasing ankle DF PROM in individuals with limited ankle DF PROM.

Yoon et al. also conducted a study to investigate the changes in passive ankle dorsiflexion range of motion (ROM), maximum plantar force, force-time, and time to heel off during walking between pre and post application of modified CT (calcaneal taping strategy meant to mobilize with movement).⁵³ Eighteen feet with limited ankle dorsiflexion in 13 people were examined. Subjects were first asked to walk before and immediately after applying the modified CT followed by walking for 5 minutes with the modified CT. A floor mat pressure measurement system (HR-mat) was used to measure maximum plantar force, force-time, and time to heel off. Passive ankle dorsiflexion ROM was measured using a standard goniometer. They found that passive ankle dorsiflexion ROM and time to heel off were significantly increased after 5-minute walking with the modified CT compared with walking before and immediately after applying the tape. Significantly increased plantar force and force-time on the hindfoot and significantly decreased force-time on the forefoot during walking after 5 minutes was observed in the modified CT group. They found no significant difference between before and immediately after applying the tape was observed in any variable. The authors concluded that walking an additional 5 minutes with modified CT increased passive ankle dorsiflexion ROM and time to heel off and improved dynamic plantar loading during walking.

Weon et al. conducted a study to determine the effects of CT on peak plantar pressure of the rearfoot and forefoot while ambulating.⁵⁴ Fifteen subjects with plantar heel pain participated in this study. A Pedoscan was used for the recording of plantar pressure data during ambulation. The participants walked along a 12 meter walkway before and after application of CT. The plantar pressure gait was measured 3 times under barefoot and CT conditions randomly at a normal walking speed. The peak plantar pressure data was calculated for the medial and lateral areas of the rearfoot and the forefoot. A paired t-test was used to determine significant differences in peak plantar pressures of the rearfoot and the forefoot before and after the application of CT. The authors found that CT resulted in statistically significant decreases in peak plantar pressure of the rearfoot (medial side: $p=0.03$; lateral side: $p=0.01$). However, there was no significant change in peak plantar pressure of the forefoot (medial side: $p=0.45$; lateral side: $p=0.40$). The authors concluded that CT is recommended to reduce plantar pressure of the rearfoot in weight-bearing activities in subjects with plantar heel pain.

Sanzo et al. conducted an experiment on vertical foot pressure in patients with PF symptoms and found that LDT significantly decreased the pressure transmitted through the foot during contact phases of gait.³⁵ They did not find a significant effect on the path of the center of pressure (COP). However, they did find that the COP line was moved laterally thus decreasing medial plantar surface pressure. They concluded that LDT may assist with the healing process to prevent chronicity and degeneration due to excessive vertical foot pressure during contact phases of gait and may be a possible consideration for treatment in the acute stages of PF by unloading the foot as well.

Harradine et al. conducted a study concerning LDT and rearfoot motion/position before and after exercise and found that taping immediately

reduced resting calcaneal stance position significantly ($P < 0.05$) but this control was lost after exercise.³⁷ They concluded that LDT made no significant difference in total pronation or maximum pronation velocity during walking.

O'Sullivan et al. conducted a study concerning LDT on rearfoot motion and plantar pressure during the stance phase of gait and found LDT is associated with reduced peak plantar pressure in the midfoot and forefoot that indicate reduced pronation with LDT.³⁸ LDT appears to reduce both pronation and supination in the rearfoot, rather than simply reducing pronation, when assessed using 3D motion analysis. The authors concluded that there is a potential that LDT can reduce pronation by restricting rearfoot motion rather than pronation specifically. However, the degree of change observed with LDT was very small, and further research is needed to clarify the clinical significance of these initial findings.

Radford et al. conducted a systematic review of the effect of LDT on kinematic, kinetic, and electromyographic variables and found LDT provides a small change in navicular height post application, although it is unclear whether this change is clinically important.³⁹ There was high heterogeneity between some trials examining other variables, indicating that more research is needed to confirm the results of previous trials.

Russo et al. conducted a study concerning the effect of LDT on peak plantar pressures of normal feet during gait and found overall, LDT significantly reduced the peak plantar pressures of normal feet during gait.⁴⁰ Of particular interest was that a significant reduction in mean peak plantar pressure was observed in the medial midfoot (1.4 N/cm^2) and an increase occurred in the lateral midfoot (2.6 N/cm^2).

Keenan and Tanner examined the effects of high-dye and low-dye taping of the rear foot.⁶ Eighteen subjects were tested under 3 conditions: barefoot, low-dye

taping, and high-dye taping (taping of low-dye style with additional taping that crosses the talocrural joint). Two-dimensional motion of the rearfoot was assessed for each condition. The results indicated that inversion was increased with both high-dye and low-dye taping as compared with no taping at all. However, only high-dye taping, significantly reduced the eversion of the rearfoot and was considered more effective for control of pronation. Various outcome measures can be used to gauge the effects of taping on patients with PF symptoms.

Outcome Measures

Typical and clinically accepted outcome measurements gauging progress of individuals with plantar fasciitis symptoms include the visual analog scale (VAS), foot function index (FFI), plantar fasciitis disability scale (PFDS), foot and ankle outcome score (FAOS), foot health status questionnaire (FHSQ), patient specific functional scale (PSFS), numerical pain rating scale (NPRS), foot pain and disability scale (FPDS), McGill pain questionnaire, and the American orthopedic foot and ankle score (AOFAS). Of these outcome measures, the VAS and NPRS have been shown to have a high correlation between each other.³¹ The VAS is of particular interest in this meta-analysis due to its reliability and clinical use in measuring pain. The VAS includes a subjective report from a patient that ranges from 0 (no pain) to 10 (worst pain) or 0-100, depending on the VAS template.

Importance, Hypothesis, and Purpose of this Meta-Analysis and Systematic Review

Taping as an intervention, or as part of an intervention, for the treatment of plantar fasciitis has been used for at least 70 years.⁵ During this literature review, only one systematic review by Podolsky et al. was found assessing the efficacy of low-dye and calcaneal taping treatment strategies.⁵⁷ There is limited evidence and

studies done comparing the efficacy of low-dye taping and calcaneal taping in treatment of plantar fasciitis.¹⁸ Therefore, it was considered relevant to review the literature concerning this topic.⁵ Studies have shown low-dye taping techniques to improve PF symptoms in regards to pain reduction.^{5,18,27,29} It is hypothesized that low-dye taping combined with conventional therapy (ultrasound and stretching) will be more effective in reducing pain than calcaneal taping combined with conventional therapy (ultrasound and stretching) in patients with PF symptoms. A meta-analysis comparing VAS and NPRS scores was conducted in order to assess both taping techniques and their effects on reported pain in patients with PF symptoms. Due to this meta-analysis only comparing pain as an outcome measure among subjects, a systematic review was also considered appropriate to further investigate LDT and CT effects on function. The systematic review conducted included articles concerning patients with PF symptoms, taping interventions, and functional outcome measures such as the FFI, PSFS, FHSQ, and FPDS in order to assess the functional effects of both taping techniques. This ensures a comparison of articles that include a subjective pain assessment (VAS, NPRS) and a functional questionnaire assessment (see Appendix H).

The purpose of this meta-analysis and systematic review is to compare the short term effects of low-dye taping in conjunction with conventional therapy versus calcaneal taping in conjunction with conventional therapy in pain reduction and functional ability in patients aged 18-70 years old with either acute, sub-acute, or chronic plantar fasciitis symptoms.

METHODS

Literature Search Strategy

The literature reviewed was conducted under the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Guidelines (PRISMA).³² The databases searched consisted of: CINAHL plus with full text (EBSCO), Proquest Physical Education Index, Pubmed, Academic Search Complete (EBSCO), Cochrane Central Register of Controlled Trials, and Cochrane Database of Systematic Reviews. All databases were accessed through Henry Madden Library under the physical therapy subject heading. Search terms included: “plantar fasciitis AND randomized control trial, randomized controlled trial, randomized clinical trial, systematic review, antipronation, taping, and tape.” All articles screened were published from 2005-2016, written in the English language, concerning the human species, and peer reviewed. Inclusion and exclusion criteria were established for this meta-analysis and systematic review as well.

Inclusion Criteria

Articles screened for this meta-analysis underwent an inclusion/exclusion criteria based on relevancy. The inclusion criteria consisted of studies needing to contain the VAS or NPRS as an outcome measure, involving patients between the ages of 18-70 years old with either acute (4 weeks or less), sub-acute (within 4 to 16 weeks), or chronic (16 weeks or more) plantar fasciitis symptoms, studies involving male *and* female individuals, and study designs with appropriate scientific evidence. Systematic reviews, randomized clinical trials, cohort studies, and case control studies were considered studies with appropriate scientific evidence.

Exclusion Criteria

Studies were excluded if they were deemed outside of the inclusion criteria. Additionally, studies including subjects having a clinical disorder where therapeutic ultrasound is contraindicated, spasticity throughout the lower extremity, previous surgery or treatment for plantar fasciitis, history of ankle or foot fractures, congenital deformities of the foot or ankle, impaired circulation to the lower extremities, referred pain due to sciatica and/or other neurological disorders, history of any skin condition where myofascial release is contraindicated, subjects with arthritis, subjects with traumatic heel pain (including use of pain or anti-inflammatory medication), those with corticosteroids injections preceding 3 months, and subjects with known tape allergies were excluded from this meta-analysis.

Study Selection

Studies were gathered and assessed using a standardized method by a single reviewer. Studies that did not meet the inclusion criteria were excluded. Those studies that were appropriate after inclusion and exclusion criteria screening were then assessed for this meta-analysis. An in-depth outline of this process, including a list of the inclusion and exclusion criteria, can be seen in Figure 3. Individual study quality was assessed using the PEDro scale.

Study Quality

Studies used for this meta-analysis were assessed via the 11-point PEDro scale in order to gauge quality.³³ A higher score indicates a higher validity and a lower score indicates a risk of study bias. Individual points are given to studies based on whether or not certain validity criterion are met. The first criterion of the PEDro scale is not used for the total score of the study assessed, making the total

point value 10 points. Studies included in this meta-analysis ranged from 1 to 4 on the PEDro scale and can be seen in Table 2. Remaining studies were then entered into a MetaAnalyst© software.

Data Collection

Selected studies were then entered and interpreted by MetaAnalyst© software program in order to produce statistical results. Treatment statistics including outcome measure effect sizes, statistical homogeneity, statistical heterogeneity, and a forest plot was produced by this software. Data from the results sections of each study were extracted and used for the statistical portion. Individual control and experimental group results were extracted from studies and combined during this meta-analysis based on similar sample sizes and outcome measures used in the studies. Combining of data was necessary due to limited amounts of studies involving the same parameters (similar sample size, outcome measures used, duration of study, and conventional therapy parameters).

Extracted data from the studies used in this meta-analysis included means, standard deviations, and sample sizes and are outlined in a forest plot. This forest plot can be seen in Figure 4. An in-depth discussion of results can be found in the section titled *Results* below. Only post-test data was used during the statistical analysis portion of this meta-analysis.

Analysis of Data

Lower extremity pain was determined by the VAS and NPRS outcome measure. For the purpose of the meta-analysis, potential homogeneity and effect size was assessed using a Q value based on Cohen's standards. These standards indicate a Q value of $>.8$ as being a large effect, a value between $.3-.8$ as a moderate effect, and a value of $<.3$ as a small effect. A p-value of $<.05$ is

considered to be statistically significant with a 95% confidence interval. Forest plots were used to assess the grand effect size between studies. A random effect size model was considered appropriate due to the small amount of studies included in this meta-analysis.

RESULTS

Meta-Analysis and Systematic Review Study Selection

A total of 687 potential articles were obtained and screened from databases consisting of CINAHL plus with full text (EBSCO), Proquest Physical Education Index, Pubmed, Academic Search Complete (EBSCO), Cochrane Central Register of Controlled Trials, and Cochrane Database of Systematic Reviews. Further screening of these articles was done in order to eliminate duplicates, leaving 586 articles. These remaining articles were then assessed based on appropriateness of their abstracts and whether or not they were written in the English language. Those not written in the English language or showing no relevancy in abstracts were discarded from the study, leaving 28 articles. The remaining 28 articles were screened based on free full text availability, peer reviewed, and non-experimental study criteria. All 28 articles were deemed appropriate after this screening. These articles were then eliminated or kept based on experiment design, those that did not have an experimental design were eliminated. After this elimination, 9 remaining articles were used for qualitative synthesis. Of these 9 articles, only 4 used similar outcome measures (VAS, NPRS and FFI) and presented with similar treatment time parameters (1 week), this deemed them appropriate to compare and use. For a detailed flow diagram outlining this process, see Figure 3. For a list of characteristics of studies extracted from databases, hand searches, reference list/citations see Figure 3. Included study characteristics were also assessed during this meta-analysis and systematic review.

Included Study Characteristics of Meta-Analysis

A characteristic list of all 4 studies used for this meta-analysis can be seen in Table 2. The 4 studies included in this meta-analysis were randomized

controlled trials and were within the publication dates of 2010-2016. PEDro scores of these articles ranged from 1-4 out of a 10 point scale. A detailed description of individual PEDro scores can be seen in Table 3. Sankhe et al., Vishal et al., Dhillon et al., and Agrawal et al. were the authors of the remaining 4 studies used for this meta-analysis. All 4 studies had similar age ranges and length of treatment times (7 days). Dhillon et al. and Agrawal et al. used a similar subject amount (30 subjects) with the exception of Vishal et al. who conducted their study using 60 subjects and Sankhe et al. who used 52 subjects.

Sankhe et al. compared low-dye taping to calcaneal taping using 2 groups (Group A and Group B).¹⁸ Group A received US on a continuous mode, with an intensity of 1 W/cm² and a frequency of 1 MHz for 5 minutes in a prone position for 7 sittings, 1 sitting per day. This was followed by CT. Group B received US with the same parameters as Group A followed by LDT. Both groups received these 2 interventions daily for 7 days but did not receive stretching interventions. This study gave moderate description of their methods but did not include pictures of the 2 taping techniques and did not give reproducible specifics regarding both taping techniques. Sankhe et al. used both the VAS and FFI as outcome measures to gauge patient pain and functional levels before and after 7 daily treatment sessions. The authors revealed that during the comparison of group A and group B there was significant reduction in pain in group B ($p < 0.001$). However, the authors failed to report their FFI results and used a 0-100 VAS scale that was scaled down to a 0-10 scale in order to input the statistics for this meta-analysis. The authors still concluded that LDT was significantly more effective than CT in reducing pain and increasing foot function in patients with plantar fasciitis without quality functional results.

Vishal et al. also compared low-dye taping to calcaneal taping using 2 groups.²¹ Group A received US at a continuous mode with an intensity of $1\text{W}/\text{cm}^2$ and a frequency of 1 MHz for 5 minutes in prone lying for 7 sittings with 1 sitting per day. Stretching was also given in the form of passive stretching of the ankle flexors and plantar fascia performed in supine lying with the soleus muscle stretched during knee flexion and a gastrocnemius stretch with the knee extended. Overpressure was placed upon the bottom of the foot while the ankle was in dorsiflexion, a passive stretch was then applied to the big toe flexors to incorporate stretch to the plantar fascia. These stretches were given for 3 repetitions each and held for a count of 30 seconds per stretch in addition to CT with reproducible detail and pictures. Group B received the same US and stretching interventions in addition to LDT with reproducible detail and pictures. Vishal et al. also used both the VAS and FFI as outcome measures to gauge patient pain and functional levels before and after 7 daily treatment sessions. They found that there was significant change in pain relief as per VAS score ($p < 0.001$) and improvement in functional ability as per FFI ($p < 0.0001$). They concluded that both groups revealed a decrease in pain and an increase in function but that group A demonstrated better results than group B.

Dhillon et al. conducted a study comparing low-dye taping versus myofascial release in patients with PF symptoms.⁵⁵ They placed subjects into 3 groups, Group A, B, and C. All groups received US (US with an output of $1\text{w}/\text{cm}^2$, pulsed mode 1:4 ratio, for 5 minutes with frequency of 1 MHz) and stretching (patient was asked to complete active calf stretch in standing by leaning against the wall, holding each stretch for 1 minute, and repeating 5 times each session). Group A received just US and stretching. Group B received the same US and stretching interventions combined with a myofascial technique to the underside of

the foot. Group C received the same US and stretching interventions combined with low-dye taping given in reproducible detail (similar to Vishal et al.). Interventions were given daily for 7 days. Data was collected on the 1st and 7th day using the NPRS as a pain outcome measure. The authors concluded that all 3 groups showed significant reduction of pain. However, a between groups analysis was done that demonstrated group B as showing more significant reduction of pain.

Agrawal et al. compared calcaneal taping to sham taping using 2 groups.⁵⁶ Group A received US set at 3 Mhz with 1.0 w/cm² and continuous for 7 minutes with stretching (a passive stretch applied to the big toe flexors in order to stretch the plantar fascia for 3 repetitions. Each stretch was held for a count of 30 seconds) and CT was given described in reproducible detail with a picture. However, a modified calcaneal taping technique was used (tape passes medially and superiorly to the tendon of the tibialis anterior to avoid problems while ambulating first strip is placed obliquely around the back of the heel while the calcaneus is externally rotated and extended around the lower leg, then a second strip of tape is used to reinforce the first). The patient is asked to keep the tape in place for 24 hours. Group B received the same US and stretching parameters as group A in addition to sham taping. The VAS and patient specific functional scale (PSFS) were outcome measures used in this study to gauge patient pain and functionality. A significant difference was found post treatment among the groups for VAS ($p=0.0265$). A highly significant difference was found post treatment among the groups for PSFS ($p= 0.0062$). There were significant differences found between pre and post VAS and PSFS scores in both the experimental and control group. The authors concluded that a modified CT was shown to be a more

effective tool for the relief of plantar heel pain than sham taping when combined with conventional physical therapy.

These 4 studies used slightly differing US parameters (with the exception of Vishal et al. and Sankhe et al.) and also had differing stretching techniques used, with the exception of Sankhe et al. (which did not include a stretching intervention). This, amongst other components, adds to the potential risk of bias amongst the 4 studies used for this meta-analysis and is discussed further in the *Discussion* section. Data analysis of all 4 studies was assessed during this meta-analysis.

Data Analysis of Individual Studies Used in Meta-Analysis

The effect sizes were assessed using a Q-value, with a Q value of more than 0.8 as having a large effect, between 0.3-0.8 as having a moderate effect, and less than 0.3 as having a small effect. Potential homogeneity was assessed by using a P value, with a P value of more than 0.05 considered homogenous and a P value of less than .05 considered heterogeneous. A random effect size model was considered appropriate due to the differing I^2 values amongst the articles. This random effects model compared individual article group means and correlating standard deviations for this meta-analysis. In this meta-analysis, individual study statistics were also assessed.

The VAS forest plot resulted in a combined effect size of 0.033, a P value of 0.00062, a Q value of 14.76, a CI upper value of 0.989, a CI lower value of -0.923, and with a 95% confidence interval. It should be noted that a meta-analysis Q value lower than the degrees of freedom and a P value more than .05, labels a group of studies as homogeneous. When comparing the VAS statistics Q value for this meta-analysis, the Q value (14.76) is significantly higher than the degrees of

freedom (2) and the P value (0.00062) is significantly lower than .05 which also shows that the VAS results are heterogeneous, similar to the forest plot results. This makes the results for the VAS forest plot heterogeneous with a moderate effect size. A total of 4 studies were used to produce these results to make 3 comparisons, or plots, in the VAS forest plot results. A detailed forest plot can be seen in Figure 4. For this systematic review, studies were screened via the same parameters as the articles used for the meta-analysis. However, studies were included if they contained any type of functional outcome measure correlated with either LDT or CT and any duration of treatment. A total of 5 studies were deemed appropriate for this systematic review and are assessed below.

Included Study Characteristics of Systematic Review

The purpose of this systematic review is to compare the short term effects of low-dye taping in conjunction with conventional therapy versus calcaneal taping in conjunction with conventional therapy on functional ability in patients aged 18-70 years old with either acute, sub-acute, or chronic plantar fasciitis symptoms. A characteristic list of all 5 studies used for this systematic review can be seen in Table 4. The studies included were 5 randomized controlled trials and were within the publication dates of 2006-2016. These studies reviewed failed to meet the criteria for this meta-analysis for a variety of reasons including differing time parameters, differing outcome measures used, and differing interventions compared to taping. Studies reviewed are meant to add to the understanding of both LDT and CT and their effects on function in patients with acute, sub-acute, and chronic PF symptoms.

Abd El Salam et al. conducted a RCT aimed to compare 2 methods of arch support, LDT and medial arch support (MAS) in patients with PF symptoms.⁴⁵

Thirty patients, 23 men and 7 women, with unilateral plantar fasciitis were randomly assigned to either the LDT or MAS group. Both groups were assessed before and after experiment conduction for foot function and pain. Both groups received 9 sessions over 3 weeks consisting of ultrasound and calf muscles stretching in addition to either LDT or MAS. They were instructed to maintain supportive intervention (LDT or MAS) throughout this period as well. Pre-post comparison showed reduced pain and improved function in both groups. Between-groups analysis showed non-significant difference in pre-VAS and pre-FPDS. Post-VAS and post-FPDS showed significant improvement in patients in the MAS group. Results indicate that MAS is more efficacious for short-term management of pain and disability in patients with plantar fasciitis than LDT.

Goyal et al. conducted a RCT meant to compare LDT and iontophoresis.⁴⁶ The purpose of the study was to observe the effect of a combination of LDT and iontophoresis or LDT alone in the treatment of PF symptoms. A total of 30 patients (16 males; 14 females) were selected as subjects and were further divided into 2 groups. Each group comprised of 15 subjects (8 males; 7 females). The results of the study show an improvement in the mean values of both VAS and FFI scores after treatment in both groups. A statistical significance was found between LDT combined with iontophoresis than LDT alone. It was concluded that the patients with PF that were treated with a combination therapy (LDT and iontophoresis) experienced significantly more recovery from pain and an increase in functional ability.

Hyland et al. conducted a RCT comparing CT, sham taping, and plantar fascia stretching.⁴⁷ A total of 41 subjects were randomly assigned into 4 groups, (1) stretching of the plantar fascia, (2) CT, (3) control (no treatment), and (4) sham taping. A visual analog scale (VAS) for pain and a patient-specific functional scale

(PSFS) for functional activities were measured pretreatment and after 1 week of treatment (posttreatment). A significant difference was found post-treatment among the groups for the VAS ($P < .001$). Specifically, significant differences were found between stretching and CT (mean \pm SD, 4.6 ± 0.7 versus 2.7 ± 1.8 ; $P = .006$), stretching and control (mean \pm SD, 4.6 ± 0.7 versus 6.2 ± 1.0 ; $P = .026$), CT and control (mean \pm SD, 2.7 ± 1.8 versus 6.2 ± 1.0 ; $P < .001$), and CT and sham taping (mean \pm SD, 2.7 ± 1.8 versus 6.0 ± 0.9 ; $P < .001$). However, no significant difference among groups was found for posttreatment PSFS ($P = .078$). Calcaneal taping was shown to be a more effective tool for the relief of plantar heel pain than stretching, sham taping, or no treatment.

Patil et al. conducted a RCT comparing LDT and myofascial release in patients with PF symptoms.⁴⁸ A total of 30 patients suffering from chronic PF were randomized and divided into 2 groups. 15 patients underwent a myofascial release technique and 15 patients underwent a LDT administered for 1 week (7 treatment sessions total). Outcome measures used included the VAS and FFI and were collected at baseline and 1 week after initiation of therapy. The data was analyzed using statistical testing which was performed using a SPSS 17 software package. Results revealed significant improvement for all outcome measures in each group ($p < 0.05$). Additionally significantly greater improvements were detected in favor of the myofascial release group ($p < 0.05$). They concluded findings that indicate a potential benefit after giving a myofascial release technique in patients with chronic planter fasciitis over LDT.

Radford et al. conducted a RCT to determine the effectiveness of LDT on pain and function.⁴⁹ Ninety-two participants with plantar heel pain (mean age 50 ± 14 years; mean body mass index 30 ± 6 ; and a median self-reported duration of symptoms 10 months, range of 2 to 240 months) were recruited from the general

public. Participants were randomly allocated to (i) low-Dye taping and sham ultrasound or (ii) sham ultrasound alone. The duration of follow-up for each participant was 1 week. No participants were lost to follow-up. Outcome measures included 'first-step' pain (measured on a 100 mm Visual Analogue Scale) and the Foot Health Status Questionnaire domains of foot pain, foot function and general foot health. Participants treated with LDT reported a small improvement in 'first-step' pain after 1 week of treatment compared to those who did not receive taping. The estimate of effect on 'first-step' pain favored the LDT (ANCOVA adjusted mean difference -12.3 mm; 95% CI -22.4 to -2.2; $P = 0.017$). There were no other statistically significant difference between groups. Thirteen participants in the taping group experienced an adverse event however most were mild to moderate and short-lived. When used for the short-term treatment of plantar heel pain, LDT provides a small improvement in 'first-step' pain compared with a sham intervention after a 1-week period.

DISCUSSION

Meta-Analysis Review

Four studies were deemed appropriate for this meta-analysis. All studies were assessed with the same internal and exclusion criteria. Of these 4 studies, all were deemed randomized controlled trials by the authors. The purpose of this meta-analysis was to determine the effectiveness of low-dye taping versus calcaneal taping on pain reduction in patients with plantar fasciitis symptoms. This meta-analysis compares both low-dye taping and calcaneal taping interventions and can add to the existing body of literature in order to determine which of these taping methods is more beneficial or requires further available literature.

It should be noted that a traditional meta-analysis typically uses studies that include both interventions of interest in order to produce results and compare interventions directly. However, this meta-analysis was unique in that 2 studies, Dhillon et al. and Agrawal et al., did not compare either taping techniques directly (within the same study) yet had intervention combinations that met the inclusion criteria.^{55,56} In order to add to this meta-analysis comparison, it was necessary to combine LDT and conventional therapy intervention statistics with CT and conventional therapy intervention statistics from 2 separate studies which generated 3 comparisons and a subsequent forest plot. These generations produced results that are not significant however.

The results from this meta-analysis do not support the original hypothesis that LDT in addition to conventional therapy interventions is superior to CT (with similar conventional therapy interventions) in reducing pain. The VAS forest plot resulted in a combined effect size of 0.033, a P value of 0.00062, a Q value of 14.76, a CI upper value of 0.989, a CI lower value of -0.923, and with a 95%

confidence interval. A VAS/NPRS analysis produced a large Q statistic of 14.76 which demonstrates heterogeneity among LDT and CT when comparing studies using the VAS and NPRS as outcome measures. Two studies (Dhillon et al./Agrawal et al. and Sankhe et al.) favored LDT over CT and one study (Vishal et al.) favored CT over LDT when comparing VAS and NPRS results.^{18,21,55,56} Therefore, it cannot definitively be said that one taping technique is superior to the other in reducing pain through VAS and NPRS in patients with PF symptoms.

In a traditional meta-analysis, effect sizes are typically assessed after several studies have been compared in order to more definitively review interventions being assessed. For this meta-analysis, only 4 studies comprising 3 comparisons were produced. Review of these comparisons demonstrated a moderate effect size between the 2 taping interventions. This effect size indicates a moderate difference between taping techniques but again, this should be interpreted with caution due to the limited amount of studies assessed.

After review of the results of this meta-analysis, there cannot be definitive support of the original hypothesis of LDT as being more effective than CT in reducing pain in patients with PF symptoms. Results of this meta-analysis demonstrate heterogeneity, meaning these results should be interpreted with caution and implications of this analysis will be discussed to help interpret the results produced. Some of the limitations causing heterogeneity across these studies include lowered PEDro scores, differing US intervention parameters, differing stretching intervention parameters, differing baseline patient characteristics, and lack of detail in taping techniques.

Limitations of Meta-Analysis Studies Causing Heterogeneity

A significant component causing heterogeneity in this meta-analysis involves the poor methodological quality of all 4 studies used. PEDro scores of the 4 studies used for this meta-analysis ranged from 1-4 out of a 10 point scale and can be considered to have high to moderate risk of bias. Of significant concern includes all 4 studies lacking similarities in baseline subject characteristics, lacking blinding of patients, lacking blinding of treating therapists, and lacking concealed allocation thus presenting an increased chance for risk of bias due to differing subject presentations, patient performance/perception bias, and treating therapist care. Those studies with the lowest PEDro score included Dhillon et al. and Sankhe et al.^{18,55} Specifically, Dhillon et al. report vague findings and make it difficult to assess true patient baseline characteristics and interpretation of statistics.⁵⁵ Sankhe et al. demonstrate similarity in vague reporting as Dhillon et al. and also fail to report functional outcomes, even though a functional outcome measure was intended to have been utilized.^{18,55} Additionally, writing of both studies present with grammatical errors that warrant concern in regards to authenticity of being peer reviewed. In addition to poor methodological quality, differing US parameters were also present among studies.

Vishal et al. and Sankhe et al. had identical US parameters used but Agrawal et al. and Dhillon et al. had differing parameters.^{18,21,55,56} These differences among parameters contribute to the heterogeneity between studies. Vishal et al. and Sankhe et al. outlined US parameters with a frequency of 1 MHz.^{18,21} A lower frequency US, such as a 1 MHz setting, is typically intended to induce healing effects on deeper tissue.²² Plantar fascia is considered superficial tissue and therefore may not experience the intended effects of a lower frequency US setting. Agrawal et al. and Dhillon et al. utilized a high frequency setting of 3

MHz which is more appropriate for inducing healing effects on superficial tissue such as plantar fascia.^{55,56} However as stated earlier, Shanks et al. concluded that there is no current high-quality evidence available that supports therapeutic US in the treatment of lower limb musculoskeletal conditions.²² Additionally, Martin et al. in 2014 revised the clinical practice guidelines concerning plantar fasciitis and deemed evidence supporting US and its effects as weak.¹⁷ Stretching parameters varied among the articles used in this meta-analysis as well.

All 4 studies outlined differing stretching techniques (with the exception of Sankhe et al. which did not include a stretching intervention) thus furthering the heterogeneity in this meta-analysis.¹⁸ Vishal et al. conducted stretching in subjects that involved passive stretching of the ankle flexors and plantar fascia, Agrawal et al. conducted plantar fascia specific stretching where a passive stretch was applied to the toe flexors, and Dhillon et al. conducted stretching interventions that involved subjects completing active calf stretching in standing by leaning against a wall.^{21,55,56}

Stretching of the plantar fascia and plantar flexors have been shown to have positive effects in patients with plantar fasciitis symptoms.^{5,11,15} However, Sweeting et al. in 2011 conducted a systematic review of 6 studies concerning stretching techniques in patients with PF and concluded there were too few studies to assess whether stretching is effective compared to control or other interventions, for either pain or function. However, they did find some evidence that plantar fascia stretching may be more effective than Achilles tendon stretching alone in the short-term in regards to pain reduction.²³

Martin et al. also reported that stretching of the plantar fascia and/or calf musculature received an A score (indicating strong evidence) and can be used to provide short term relief for patients experiencing heel pain or PF as well.¹⁷ Those

subjects receiving just plantar fascia stretching versus plantar fascia stretching combined with plantar flexor stretching could have reported an increase in pain reduction regardless of whether they underwent LDT or CT. Baseline characteristics of the studies used in this meta-analysis varied.

Baseline characteristics of subjects in all 4 studies varied from acute, sub-acute, and chronic conditions. These factors can further add to the cause for heterogeneity. Patients with acute PF symptoms can respond differently than patients with chronic PF symptoms. Vishal et al. and Sankhe et al. reported patients who presented with symptoms more than 4 weeks, both sub-acute and acute conditions of PF, while Agrawal et al. included patients with symptoms more than 1 week but less than 6 weeks, which included acute and sub-acute symptoms.^{18,21,56} Dhillon et al. included subjects with symptoms more than 6 weeks, ranging from sub-acute to chronic presentations of PF symptoms.⁵⁵ These differing timelines of symptoms among patients are a cause of heterogeneity, considering acute and chronic presentations of PF symptoms can respond differently to treatment even though both taping techniques were done under short term (1 week) conditions. As mentioned earlier, taping can be considered a short term intervention and may have a different effect on patients with an acute presentation of PF versus chronic PF. Patients with acute PF symptoms could present with more immediate pain relief than patients with chronic conditions because acute symptoms may be more inflammation based than the chronic presentation in which inflammation has been replaced by a change in the pliability of soft tissue, ie. scar tissue. In the case of acute PF symptoms, studies suggest that taping can provide immediate biomechanical changes in pronation and ankle position that can place less damaging forces and plantar pressure on already inflamed tissue.^{47,48,49} Biomechanical alignment changes in patients with acute PF

symptoms can lead to a biased improvement in patient reported pain. Conversely, those with chronic PF symptoms may have tissue scarring, calcaneal spurs, and tissue restrictions resulting in a limit in response to pain relief following taping. Furthermore, calcaneal spurs can also impinge on tissue after newly aligned ankle and foot positioning thus causing continued or increased patient reported pain. Authors of all 4 studies also included a wide age range of subjects.

Agrawal et al. reported patients with ages from 18 to 35, Vishal et al. reported ages 18 to 52, Dhillon et al. reported ages 18-40, and Sankhe et al. reported ages from 18 to 65.^{18,21,55,56} Authors of the studies did not stratify subjects by BMI, activity level, or high arch versus low arch as well. For example, an 18 year old athletic subject may have varying responses compared to a 65 year old sedentary subject. Taping of a sedentary person with an increased BMI may not have as much biomechanical change (decreased plantar pressure difference) compared to the same taping of a person who is active and within a normal BMI. Additionally, authors did not mention arch height in subjects prior to interventions. Both LDT and CT are considered biomechanical adjustments and a person who already has an increased arch may not report decreased pain from either taping technique. Studies presented with limited reproducible taping detail which is important for interventions such as taping.

Taping detail ensures that taping techniques are done correctly and can be compared effectively. Vishal et al. and Dhillon et al. included detailed taping strategies with accompanying pictures.^{21,55} Agrawal et.al. also outlined reproducible taping detail through steps of taping but did not show a picture of their final taping.⁵⁶ Conversely, Sankhe et al. provided moderate detail to their taping technique but did not include a picture of the finished taping.¹⁸ Agrawal et al. utilized a modified CT technique that included tape passing medially and

superiorly to the tendon of the tibialis anterior with the first strip being placed obliquely around the back of the heel while the calcaneus is externally.⁵⁶ A second strip of tape was used to reinforce the first. This taping method varies from the CT mentioned in other studies assessed. Agrawal et al. demonstrated a CT technique that could cause decreased biomechanical adjustment due to less calcaneal anti-pronation support compared to the more prevalent method of CT seen in other studies.⁵⁶ This vague reporting of taping by Sankhe et al. and modified CT method conducted by Agrawal et al. could further increase the reason for heterogeneity in this meta-analysis.^{18,56}

Analysis of Systematic Review

The purpose of this systematic review was to compare the short term effects of low-dye taping and calcaneal taping on functional ability in patients aged 18-70 years old with either acute, sub-acute, or chronic plantar fasciitis symptoms. This review was conducted in order to add to the understanding of both LDT and CT and their effects on function. The studies included were 5 randomized controlled trials and were within the publication dates of 2006-2016. Again, these studies reviewed failed to meet the criteria for this meta-analysis for a variety of reasons including differing time parameters, differing outcome measures used, and differing interventions compared to taping.

All 5 studies assessed in this systematic review demonstrated a decrease in pain through VAS scores of both LDT study groups and CT study groups. Of these, 4 studies conducted by Abd El Salam et al., Goyal et al., Patil et al., and Radford et al. compared LDT with conventional therapy interventions which included US, Achilles tendon stretching, foot intrinsic muscle strengthening, and iontophoresis (with the exception of Radford who paired LDT with sham US as

interventions).^{45,46,48,49} And the remaining study, Hyland et al. compared CT independently.⁴⁷ However, this analysis of the systematic review will focus on the functional outcome measure results found among these studies.

Of the 5 studies reviewed, 3 studies reported an increase in functional ability scores after LDT via functional outcome measures (the MFPDS, FFI, and FHSQ) that have been validated and cited as reliable throughout literature.^{45,46,48} These 3 studies reported subject populations that ranged from 24-70 subjects. This amount range of subjects can be considered clinically relevant and can add to the current understanding of available research concerning LDT and function. There was one study that demonstrated LDT as having no significant effect on functional outcomes (Radford et al.).⁴⁷ This study compared LDT and sham US versus sham US alone found no significant difference between groups using the FHSQ.⁴⁷ One study concerning CT was assessed during this systematic review (Hyland et al.).⁴⁹

This final study compared CT versus stretching of the plantar fascia, sham taping, and a no treatment control group in patients with PF symptoms.⁴⁹ Authors found no significant difference between groups using the PSFS. After review of the literature, a total of 3 studies were found (2 of which were included in this meta-analysis) concerning CT and its effects on function. Vishal et al. and Agrawal et al. conducted studies that were reviewed in this meta-analysis but also reported functional outcomes via the FFI and PSFS.^{21,56} Vishal et al. reported a significant improvement in PSFS scores in both LDT and CT groups.²¹ Agrawal et al. reported a significant improvement in FFI scores in subjects receiving CT.⁵⁶ Therefore, CT also presents with limited evidence regarding its effect on improving functional ability in patients with PF symptoms. There is a significant gap in the literature concerning CT that warrants review however. This lack of literature concerning CT could be due to Middleton et al. describing a LDT

technique in 1992 that has been well cited and prevalent in the literature since, thus standardizing the LDT technique.¹⁶ A standardization of CT does not seem to exist and therefore may not be utilized as much as the LDT method.

The results of this systematic review yield limited evidence that both LDT and CT can improve functional ability in patients with PF symptoms. It is difficult to compare both techniques directly due to the lack of literature and available literature quality concerning these 2 techniques. Therefore a definitive result supporting one technique as being more functionally beneficial over the other cannot be found. This lack of literature warrants further review.

Limitations of Literature

Podolsky et al. conducted a systematic review of taping in 2015 and analyzed 5 randomized control trials, one cross-over study and 2 single group repeated measures studies.⁵⁷ They concluded taping in the short term is beneficial during the treatment of plantar fasciitis. They also found that best evidence exists for low dye taping and calcaneal taping. They recommended more research being needed to investigate the long-term effect and effectiveness of specific taping techniques. However, gaps in the literature concerning low-dye taping compared to calcaneal taping exist. Currently, it seems only 2 studies, Sankhe et al. and Vishal et al., compare both low dye and calcaneal taping directly.^{18,21} In addition to this, taping as an independent intervention was uncommon in majority of articles screened for this meta-analysis. Majority of studies screened included other interventions coupled with taping techniques. These additional interventions included stretching, ultrasound, foot intrinsic strengthening, modifying foot wear, orthopedic inserts, and iontophoresis medications. Of these interventions, stretching coupled with ultrasound were most prevalent. Another component to a

quality meta-analysis involves the comparison of articles that compare low-dye taping versus calcaneal taping with similar intervention parameters. For example, a study comparing low-dye taping and stretching versus calcaneal taping and stretching would benefit by including similar stretching interventions (since plantar fascia stretching can produce differing results than plantar flexor stretching). This component adds to the existing limitations due to the possibility of different stretching techniques confounding results. Reporting of reproducible interventions varies among the literature as well.

Interventions described in some of the articles assessed were not specific enough to reproduce. For taping, reproducible detail is important in order to accurately assess articles when comparing intervention effectiveness. As discussed previously there is a standardized technique for LDT that has been alluded to in the literature however CT does not have the same standardization. Three of the 4 articles gathered for this meta-analysis used reproducible and detailed taping techniques with the exception of Sankhe et al. (which was assumed to have used the same LDT and CT technique as Vishal et al.).^{18,21} Literature gaps such as these should be addressed in order to raise our understanding of the types of taping techniques and improve clinical implications. The clinical implications that can be gathered from this meta-analysis are still useful and can be used for currently treating therapists however.

Clinical Implications of Meta-Analysis Combined with Systematic Review

Results of this meta-analysis do not support the original hypothesis of LDT as being superior to CT in reducing pain for patients with plantar fasciitis symptoms. Again, these results should be interpreted with caution due to the heterogeneity found in this meta-analysis. However, LDT (in addition to

conventional therapy) may demonstrate a positive effect in VAS and NPRS as seen in the literature.^{3,16,45,46,47} Several studies support that LDT can provide relief of pain according to VAS scoring.^{5,27,29} A moderate amount of studies exist that support LDT (in addition to conventional therapy) as improving functional ability as well.^{6,7,45,46,48} For example, Landorf et al. and Patil et al. demonstrated a positive effect in both VAS and functional scores when LDT was compared against sham taping.^{18,34} Clinicians can use a LDT technique to improve short term subjective pain perception and functional ability in patients with PF symptoms. Especially individuals who present with plantar fasciitis due to a high BMI, having limited dorsiflexion range of motion, or being a consistent runner. In this situation the application of LDT can support the medial longitudinal arch thereby decreasing the ground reaction forces on plantar fascia tissue.

A review of the literature conducted by Martin et al. show that medial arch inserts can demonstrate pain reduction in patients with PF symptoms as well, however, it can be argued that taping can be a quick and relatively inexpensive first attempt at biomechanical adjustments of the foot.¹⁴ Low-dye taping can further inform the therapist and patient suffering from PF symptoms whether or not the patient could benefit (presenting with reduced pain and improved function) from biomechanical adjustments that more rigid taping and arch support provide. However, it should be noted that majority of studies available concerning LDT involve LDT in combination with other interventions and therefore makes it difficult to compare the effects of LDT as an independent intervention. Calcaneal taping should be considered too.

The lack of literature concerning CT further weakens the evidence of this technique in reducing pain and improving function in patients with PF symptoms. However, a few studies have demonstrated calcaneal taping as improving VAS

scores and functional ability in patients with PF symptoms.^{45,47} Due to this benefit, this technique should not be excluded from potential treatment plans. Calcaneal taping could be an appropriate alternative technique utilized in patients that report no difference in pain level or functional ability after a LDT method is applied.

Low-dye tape is considered a short term treatment with a short term effect and could be used in patients with forms of acute, sub-acute, and chronic PF symptoms. Low-dye taping can be an appropriate intervention to decrease current patient reported pain levels during treatment for example. Although research does not support that LDT can have lasting effects after removal of tape, the short term effects on pain relief can benefit patients during physical therapy treatments in order to proceed with other planned interventions. Studies demonstrate LDT as an adjunct to therapy.^{5,18,21,27,29} Low-dye taping is an appropriate adjunct tool that a physical therapist can utilize in combination with other conventional therapy techniques including foot intrinsic strengthening, plantar flexor stretching, plantar fascia stretching, and other modalities in order to better treat patients with PF symptoms. Literature concerning both plantar fascia and plantar flexor stretching has been proven to reduce pain in patients with PF symptoms and can therefore be used in combination with LDT.¹¹ However, modalities such as ultrasound have weak supporting evidence concerning pain reduction in patients with PF symptoms and should be considered as an alternative method of treatment for plantar fasciitis. Risk of bias within this meta-analysis exists and is discussed below.

Risk of Bias in This Meta-Analysis and Systematic Review

Risk of bias in this meta-analysis include selective reporting in studies and combining data amongst studies. Studies used for this meta-analysis had

individual interventions selected and combined in order to produce a forest plot and present the results in an organized fashion. For example, intervention statistics were retrieved from Agrawal et al. and Dhillon et al. and combined in order to generate 3 comparisons for this meta-analysis.^{55,56} Combining data of studies that have similar parameters with differing authors reporting results can increase the risk of bias. However, all 4 studies used for this meta-analysis presented results in a table that included experimental and control pre/post means and standard deviations helping to decrease the chance for bias. Combining studies with differing methodological quality (especially differing PEDro scores) can further increase the risk of bias and must be acknowledged. It should also be noted that authors can be responsible for withholding or misinterpreting results in order to support a hypothesis as well. Future studies can benefit from this information and add to the current literature concerning LDT and CT in patients with PF symptoms.

Future Studies

Future studies should include a more similar baseline of patient characteristics. Differing acuity of PF symptoms could be a starting point and help to limit heterogeneous findings. Furthermore, more studies could be designed with higher quality and higher PEDro scores. For example, blinding of treating therapists and patients could be conducted to further decrease risk of bias within studies and produce more credible results. An increase of studies with randomized controlled trials and systematic review designs could add to the current literature and help diminish existing gaps as well. Less confounding interventions like ultrasound could be omitted in future research. Ultrasound can be a component that adds to heterogeneity found in other meta-analyses and systematic reviews.

Suggestions like these would contribute to improved homogeneous pools of data possibly providing a more accurate analysis between taping techniques.

Conclusion

The results from this meta-analysis do not support the original hypothesis that LDT in addition to conventional therapy is superior to CT (with similar conventional therapy) in reducing pain. A systematic review comparing LDT to CT for improvement of functional abilities in patients with PF symptoms was also conducted. The results of this systematic review yield limited evidence that both LDT and CT can improve functional ability in patients with PF symptoms. Therefore a definitive result supporting one technique over the other in regards to pain reduction or improved functional ability cannot be found.

However, several studies have been found demonstrating LDT (in addition to conventional therapy) as reducing pain in patients with PF symptoms.^{5,27,29} Additionally, a moderate amount of studies have been found that demonstrates LDT (in addition to conventional therapy) improving functional abilities in patients.^{45,46,48} Therefore, one technique is not more efficacious than the other for pain reduction or functional ability. However, low-dye taping can continue to be used in clinical settings when treating patients with PF symptoms.

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TABLES

Table 1. List of Conventional Therapy Interventions

Manual therapy

Therapeutic exercises

Foot orthoses

Night splints

Neuromuscular re-education

Dry needling

Other physical agents (electrotherapy, low-level laser therapy, and phonophoresis)

Modifying shoe-wear

Weight loss education

Table 2. Studies Included in Meta-Analysis

Article	# of subjects	Age range of subjects	interventions	Outcome measures	Length of study	Type of study
Agrawal et al. 2015 (symptoms more than 1 week, less than 6 weeks)	30	18-35	Ultrasound + Plantar Fascia Stretching + Sham Taping vs. Calcaneal Taping + Ultrasound + Plantar Fascia Stretching	VAS, PSFS	7 days	RCT
Vishal et al. 2010 (symptoms more than 1 month)	60	38.4 ± 14 (mean age: 38.5 ± 15.35 for calcaneal taping, 38.3 ± 14.1 low dye taping)	Low-Dye Taping + Ultrasound + stretching vs. Calcaneal Taping + Ultrasound + Plantar Fascia Stretching	VAS, FFI	7 days	RCT
Dhillon et al. 2013 (symptoms more than 6 weeks)	30	18-40	Ultrasound + calf stretching (group A) vs. Ultrasound + calf stretching + myofascial release (group B) vs. Low-Dye Taping + Ultrasound + Stretching (group C)	Numerical Pain Rating Scale (NPRS), similar to VAS	10 days (data taken on 7 th day)	RCT
Sankhe et al. 2016 (pain for more than 4 weeks)	52	18-65	Calcaneal Taping + Ultrasound vs. Low-Dye Taping + Ultrasound	VAS, FFI	7 days	RCT

Table 3. PEDro Scores of Articles Used in Meta-Analysis

PEDro Criteria	Dhillon et al. 2013	Agrawal et al. 2015	Sankhe et al. 2016	Vishal et al. 2010
Eligibility criteria were specified	✓	✓	✓	✓
Subjects were randomly allocated to groups			✓	✓
Allocation was concealed				✓
Groups were similar at baseline			✓	
There was blinding of all subjects				
There was blinding of all therapists		✓		
There was blinding of assessors measuring outcomes		✓		
Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups				
All subjects received the treatment or control as allocated		✓		✓
The results of between group comparisons are reported for at least one outcome	✓	✓	✓	✓
The study provides both key measures and measures of variability				
Total	1	4	3	4

Table 4. Studies Used in Systematic Review

Study	Study Design	Population Size (N) and Characteristics	Interventions	Outcome Measures	Treatment Parameters/ Study Length
Abd El Salam et al. 2011	RCT	<u>N</u> = 30 <u>Age Range</u> = 40-60 years <u>Duration of Symptoms</u> = 4 weeks or more	LDT + US vs. Medial Arch Support + US	VAS, MFPDS	3 sessions weekly, x3 weeks
Goyal et al. 2013	RCT	<u>N</u> = 30 <u>Age Range</u> = 24-58 years <u>Duration of symptoms</u> = Unknown	LDT + Iontophoresis vs. Iontophoresis	VAS, FFI	Daily sessions, x7 days
Hyland et al. 2010	RCT	<u>N</u> = 41 <u>Age Range</u> = 18-65 years <u>Duration of Symptoms</u> = Unknown	Stretching of PF vs. CT vs. Control (no treatment) vs. Sham Taping	VAS, PSFS	Daily sessions, x7 days
Patil et al. 2016	RCT	<u>N</u> = 30 <u>Age Range</u> = 30-70 years <u>Duration of Symptoms</u> = Unknown	LDT + US + Foot Intrinsic Muscle Strengthening + AT stretching vs. Myofascial Release + US + Foot Intrinsic Muscle Strengthening + TA stretching	VAS, FFI	Daily sessions, x7 days
Radford et al. 2006	RCT	<u>N</u> = 92 <u>Age Range</u> = 18 years or older <u>Duration of Symptoms</u> = 2-240 Months	LDT + Sham US vs. Sham US	VAS, FHSQ	Daily sessions, x7 days

FIGURES



Figure 1. Low-Dye Taping Technique

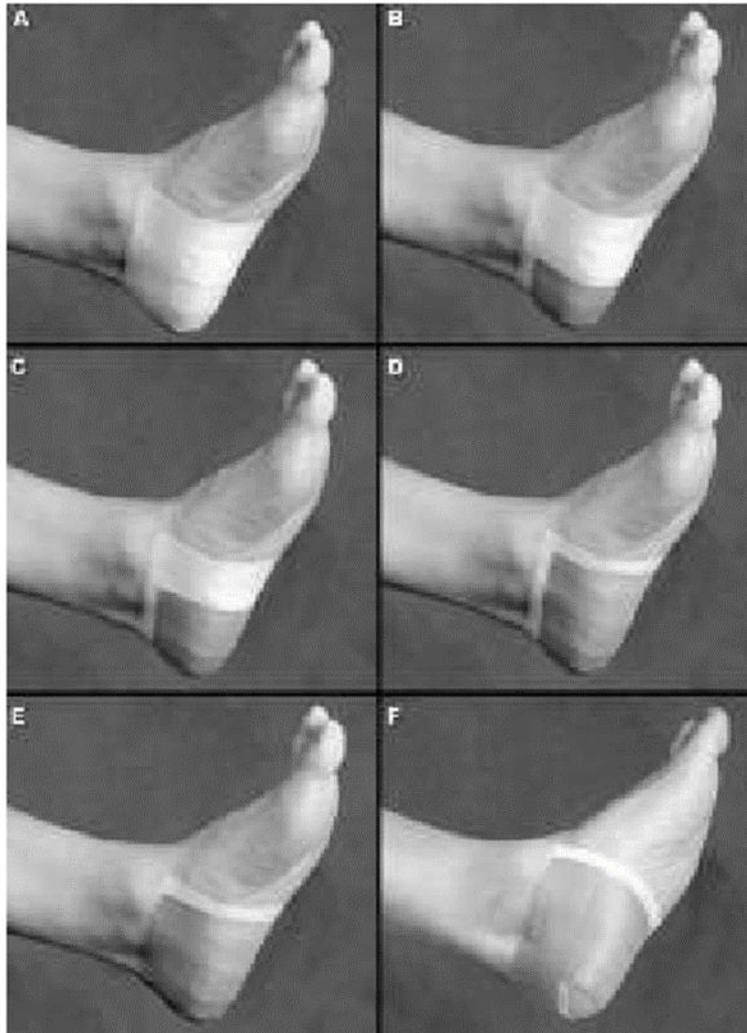


Figure 2. Calcaneal Taping Technique

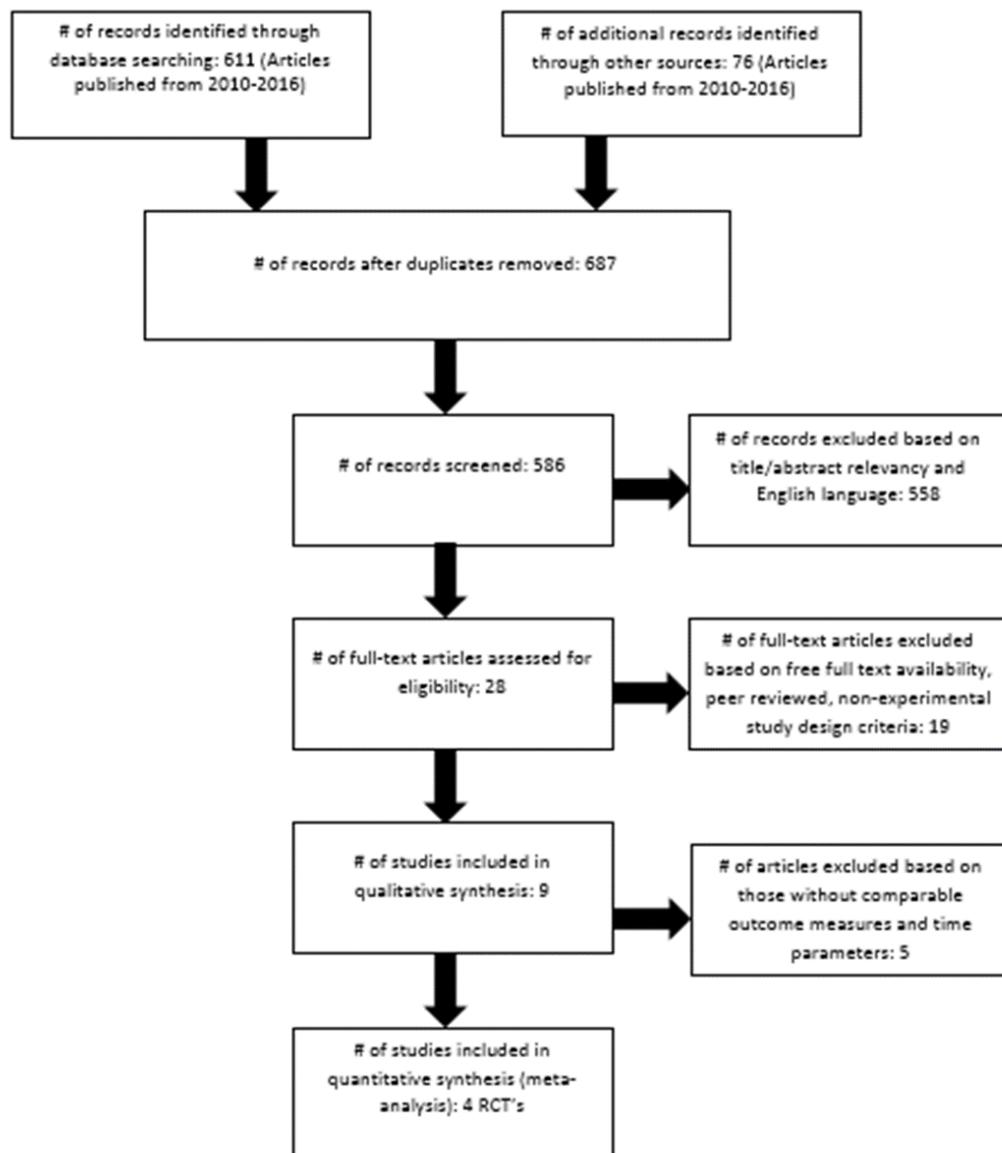


Figure 3. Consort Diagram

(Effect Size: 0.033, P Value: 0.00062, Q Value: 14.76, Heterogeneous, Moderate Effect, Upper CI: 0.989, Lower CI: -0.923, 95% CI)

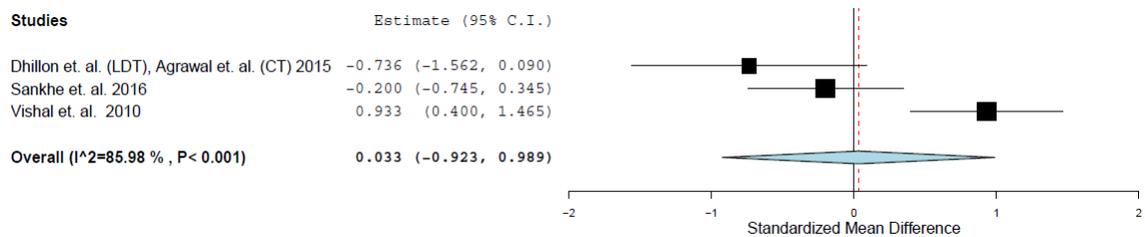
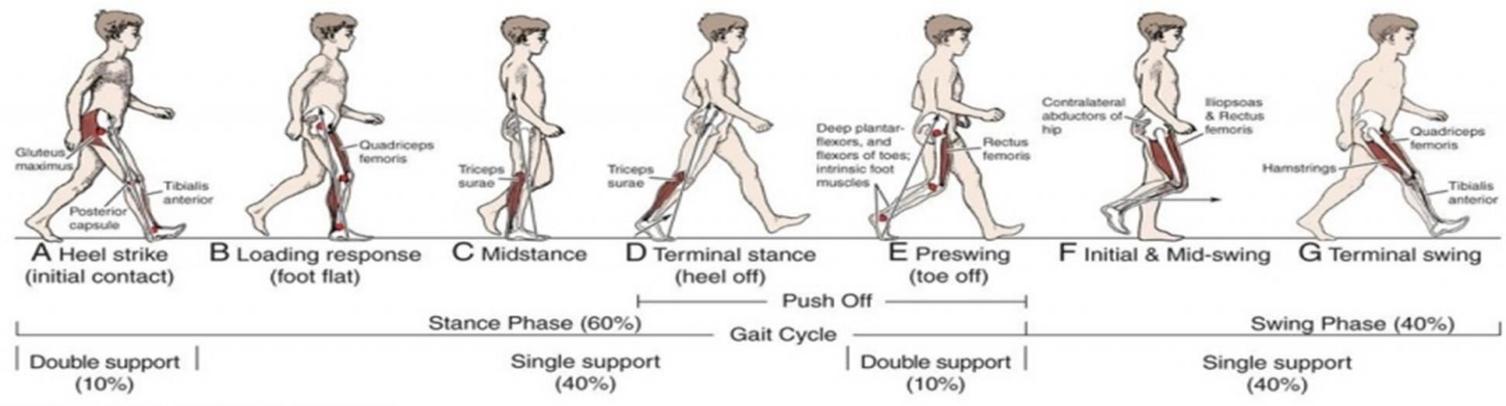


Figure 4. VAS Forest Plot

APPENDICES

APPENDIX A: GAIT CYCLE



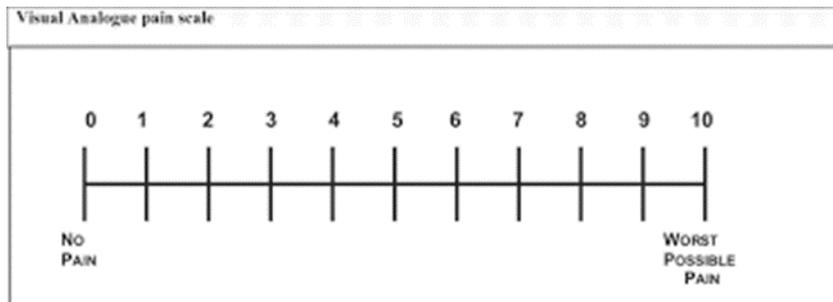
Copyright © 2011 Wolters Kluwer Health | Lippincott Williams & Wilkins

APPENDIX B: VAS, NPRS OUTCOME MEASURES

The Numeric Pain Rating Scale Instructions

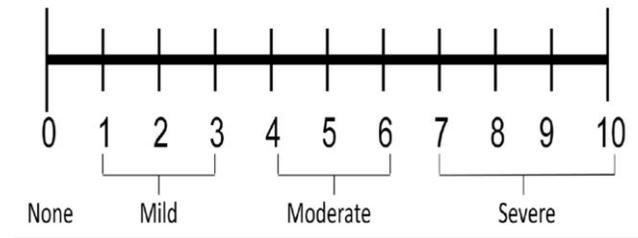
General Information:

- The patient is asked to make three pain ratings, corresponding to current, best and worst pain experienced over the past 24 hours.
- The average of the 3 ratings was used to represent the patient's level of pain over the previous 24 hours.



Patient Instructions (adopted from (McCaffery, Beebe et al. 1989):

"Please indicate the intensity of current, best, and worst pain levels over the past 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)"



APPENDIX C: PATIENT SPECIFIC FUNCTIONAL SCALE

The Patient-Specific Functional Scale

This useful questionnaire can be used to quantify activity limitation and measure functional outcome for patients with any orthopaedic condition.

Clinician to read and fill in below: Complete at the end of the history and prior to physical examination.

Initial Assessment:

I am going to ask you to identify up to three important activities that you are unable to do or are having difficulty with as a result of your _____ problem. Today, are there any activities that you are unable to do or having difficulty with because of your _____ problem? (Clinician: show scale to patient and have the patient rate each activity).

Follow-up Assessments:

When I assessed you on (state previous assessment date), you told me that you had difficulty with (read all activities from list at a time). Today, do you still have difficulty with: (read and have patient score each item in the list)?

Patient-specific activity scoring scheme (Point to one number):

0 1 2 3 4 5 6 7 8 9 10

Unable to
perform
activity

Able to perform
activity at the same
level as before
injury or problem

(Date and Score)

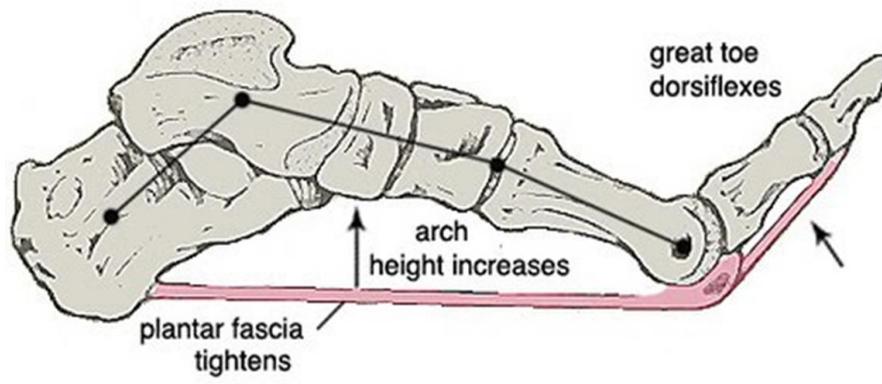
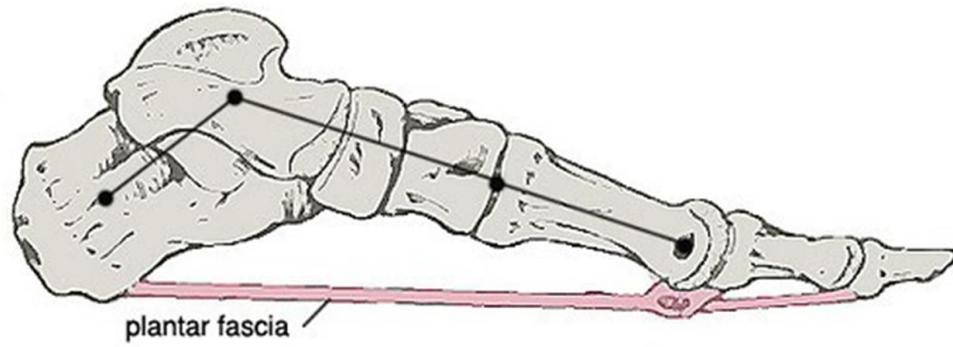
Activity	Initial					
1.						
2.						
3.						
4.						
5.						
Additional						
Additional						

Total score = sum of the activity scores/number of activities

Minimum detectable change (90%CI) for average score = 2 points

Minimum detectable change (90%CI) for single activity score = 3 points

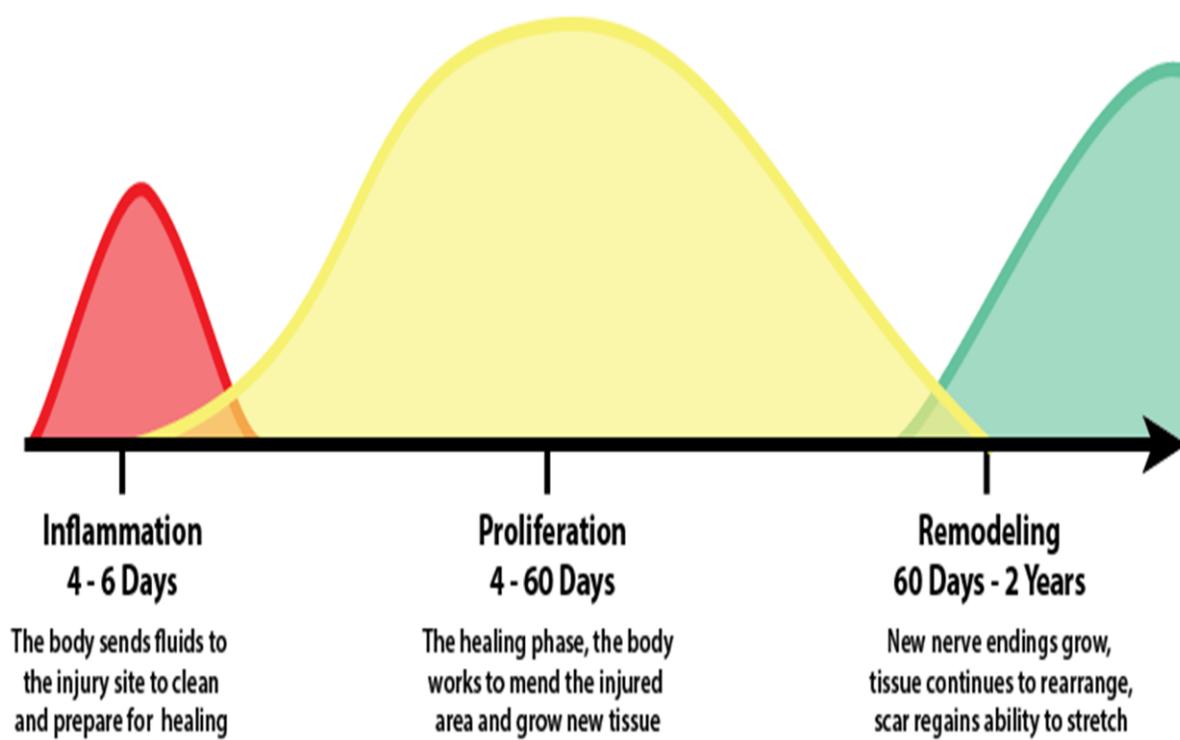
APPENDIX D: WINDLASS MECHANISM



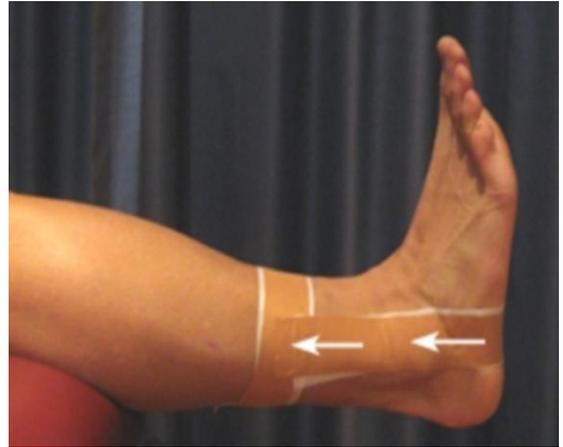
APPENDIX E: MARTIN ET AL. CLINICAL PRACTICE
GUIDELINES SCORING

GRADES OF RECOMMENDATION BASED ON		STRENGTH OF EVIDENCE
A	Strong evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study
B	Moderate evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation
C	Weak evidence	A single level II study or a preponderance of level III and IV studies, including statements of consensus by content experts, support the recommendation
D	Conflicting evidence	Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting studies
E	Theoretical/ foundational evidence	A preponderance of evidence from animal or cadaver studies, from conceptual models/principles, or from basic science/bench research supports this conclusion
F	Expert opinion	Best practice based on the clinical experience of the guidelines-development team

APPENDIX F: STAGES OF INJURY



APPENDIX G: MODIFIED FORMS OF TAPING



APPENDIX H: EVIDENCE HEIRARCHY TRIANGLE

