Windlass Taping Technique for Symptomatic Relief of Plantar Fasciitis

Beth Jamali, Martha Walker, Brian Hoke, and John Echternach

Context: Windlass taping is used to reduce pain in plantar fasciitis and thought to take stress off the plantar fascia. ***Objective:*** To investigate the effects of windlass taping. ***Design:*** Single group, repeated measures. ***Setting:*** Outpatient physical therapy clinics. ***Patients:*** 20 subjects with plantar fasciitis. ***Intervention:*** Windlass taping technique. ***Main Outcome Measures:*** Pretaping and posttaping measures included pain levels using a visual analog scale (VAS), resting-stance calcaneal position, tibial position, and navicular height. Fifteen also reported a VAS after wearing the tape for 24 h. ***Results:*** Median VAS score 37 mm pretape and 6 mm immediately posttape and 24 h later. Wilcoxon matched-pairs signed ranks test significant ($P = .001$) for reduction in pain scores. Paired t tests significant ($P = .01$) for a difference between means of pretaping and posttaping measurements for resting-stance positions. ***Conclusions:*** Windlass taping decreased pain in patients with plantar fasciitis and caused small changes in resting-stance positions. ***Key Words:*** arch support, first ray

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Plantar fasciitis is defined as inflammation of the plantar aponeurosis at its insertion on the medial calcaneal tubercle.[1-5] It is an overuse injury common in runners and aerobic dancers, but it also occurs in the general nonathletic population. Clinical presentation typically includes pain, often described as knifelike, pinpointed to the plantar aspect of the heel at the aponeurosis insertion. Pain is also reported in the medial longitudinal arch, with thickening and nodulation of the fascia in chronic cases. Both the insertion of the aponeurosis and the medial longitudinal arch are usually tender to palpation. Pain might be reproduced by passive toe extension. The pain is usually greatest during the first few steps in the morning or after prolonged sitting, and it is the most pronounced with weight bearing.[2,4,6-8]

Although some patients with plantar fasciitis have systemic conditions such as rheumatoid arthritis or systemic lupus erythematosus, most plantar fasciitis is thought to occur as a result of repeated stress applied to a foot that has abnormal alignment or mechanics.[3,9-12] The abnormality might not

Jamali, Walker, and Echternach are with the School of Physical Therapy, Old Dominion University, Norfolk, VA 23529. Hoke is with Atlantic Physical Therapy, 1016 First Colonial Rd, Virginia Beach, VA 23454.

cause a problem until weight-bearing activity is increased, as in running, walking, or exercising more than usual. The amount of activity that constitutes "overuse" is relative to the person's normal activities and varies greatly from one person to the next. With plantar fasciitis, it is thought that some combination of foot abnormality and repetitive activity results in more stress to the plantar aponeurosis than it can physiologically accommodate, and inflammation occurs.

Hicks, in 1954, described the arch-raising effect of metatarsophalangeal joint extension as being similar to that of a windlass.[13] A windlass is a mechanical device similar to a winch used to lift a weight that winds a rope or chain around a roller using a crank or lever. The plantar aponeurosis, or fascia, originates at the calcaneus and inserts at the base of the proximal phalanx of each of the toes. When the toes are extended, the dorsal sliding of the phalanx relative to the metatarsals pulls the plantar aponeurosis forward, around the heads of the metatarsals, creating tension on the plantar aponeurosis and causing a "windlass effect." This tension causes the arch to rise by shortening the distance between the metatarsal heads and the calcaneus. Hicks described this mechanism as purely passive, independent of muscle function occurring at the end-of-stance phase when the heel is raised and the body moves forward over the extended metatarsophalangeal joints.[13]

Excessive pronation in stance has been cited as a common cause of plantar fasciitis.[2,3,5] Subtalar pronation is a normal phenomenon of weight acceptance in the gait cycle. As weight is transferred onto the foot, the subtalar joint pronates and the medial longitudinal arch flattens (the navicula drops). Coupled with this, the calcaneus everts, moving into a position of relative valgus, and the tibia internally rotates. This normal chain of events encourages slight knee flexion for shock absorption at the beginning of the stance phase of gait. As the foot passes through midstance, the subtalar joint moves out of pronation, the medial longitudinal arch rises, the calcaneus moves toward inversion, and the tibia externally rotates.[14-17] A foot that overpronates or remains pronated into terminal stance puts excessive stress on the medial plantar fascia.[2,15,18]

One of the common treatments for plantar fasciitis has been to use an orthotic device that prevents overpronation, supports the medial longitudinal arch, or supports normal rear-foot-to-forefoot alignment. This type of treatment addresses the cause of the problem rather than just the symptoms of inflammation. Several studies have reported good results using either custom orthotic devices or over-the-counter arch supports to maintain the foot in more normal alignment during gait or sports activities.[3,19,20] The use of athletic tape to support the longitudinal arch is also a commonly employed treatment for plantar fasciitis.[2,10,12,19,20] The technique, called low-dye taping, involves athletic tape applied to the plantar surface of the foot while it is in a relaxed, non-weight-bearing position. The tape is thought to take stress off the plantar fascia in weight bearing, which should lead to decreased pain.[2,5]

As described previously, motions of lower extremity joints are closely linked with one another during weight-bearing activities. Motion and position at one joint affects distal and proximal segments. Based on this, taping to support the arch could affect more than just arch height. If taping prevents the arch from flattening in relaxed standing, it should also decrease subtalar pronation as reflected by a decrease in calcaneal eversion, and consequently there should be less tibial internal rotation. With increasing tibial vara angles, foot pronation increases to allow the medial aspect of the foot to contact the floor.[21] Therefore, decreasing pronation through taping might also decrease the amount of functional tibial varus in resting stance.

The purpose of this study was to examine the effects of a modified low-dye taping method, which we call "windlass taping," on biomechanical measures of foot position and pain in subjects with plantar fasciitis. The windlass technique differs from traditional low-dye taping in the position of the foot during taping. During windlass taping the forefoot is everted and the first metatarsophalangeal joint is extended so that the arch is raised. Based on our clinical experience, we expected that the windlass taping would result in an immediate decrease in pain during weight bearing because of decreased stress to the plantar fascia. We also expected that windlass taping would result in increased navicular height, decreased calcaneal valgus, and decreased tibial varus in our subjects when they were standing in normal resting posture. These positional changes should be associated with the increased arch support that the tape is purported to provide.[2,10,12,19,20]

Methods

A single-group, repeated-measures design was used for this study. Approval to perform the study was granted by the Old Dominion University Human Subjects' Review Committee before initiation of the study. The number of subjects included in the study was determined by the number of patients fitting the inclusion criteria who sought treatment in the participating clinics during a 6-month period of time. Twenty subjects, 14 female and 6 male, participated in the study. Criteria for admission included a diagnosis by a physician of unilateral plantar fasciitis and the ability to ambulate fully weight bearing without an assistive device. Foot alignment was not used as part of the inclusion criteria. Each subject completed and signed a consent form before participating. The subjects completed a visual analog scale (VAS) for pain. Mattacola et al[22] found that the VAS is easily administered and determined the scale to be an effective means for evaluating pain intensity when repeated measures are involved. The VAS used in this study consisted of a 10-cm line with *no pain* on the left end of the line and *worst pain imaginable* on the right end. The subjects were

instructed to make a vertical mark on the line that best represented their symptoms at the time they were completing the scale.

Subjects were then placed prone, and a marking pen was used to identify the most prominent aspect of the navicular tuberosity (see Figure 1). Two dots were also drawn posteriorly to bisect the calcaneus as described by Sell et al,[23] and 2 dots were drawn to bisect the distal third of the lower leg (see Figure 2).

Once the subjects were marked, they were positioned in bilateral stance and instructed to stand "normally." The researchers made no attempt to position the subjects, but tracings were made of the position of their feet in order to ensure the same position and base of support for the pretape and posttape measurements. The examiner then measured calcaneal position (see Figure 3) using a Craftsman® inclinometer parallel to the marks on the calcaneus and holding the inclinometer in the frontal plane. Leg position was similarly measured with an inclinometer held to the marks on the distal leg to determine the amount of tibial varus (see Figure 4). To measure navicular height, a standard index card was placed vertically on the medial aspect of the foot, just anterior to the navicula, with the edge of the card resting on the supporting surface (see Figure 5). The height of the mark on the navicular tuberosity was then marked on the index card. The distance from the edge of the card to the mark on the card was then measured using a standard tape measure, and the distance was recorded in millimeters. Three trials were recorded of each measurement.

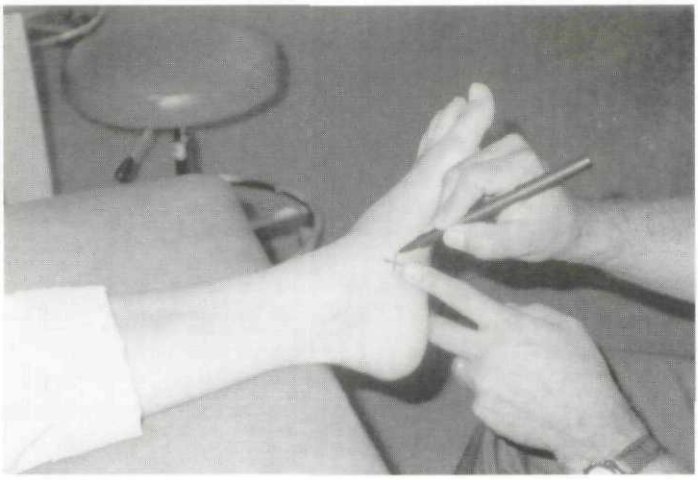


Figure 1 Pretape marking of the navicular tuberosity.

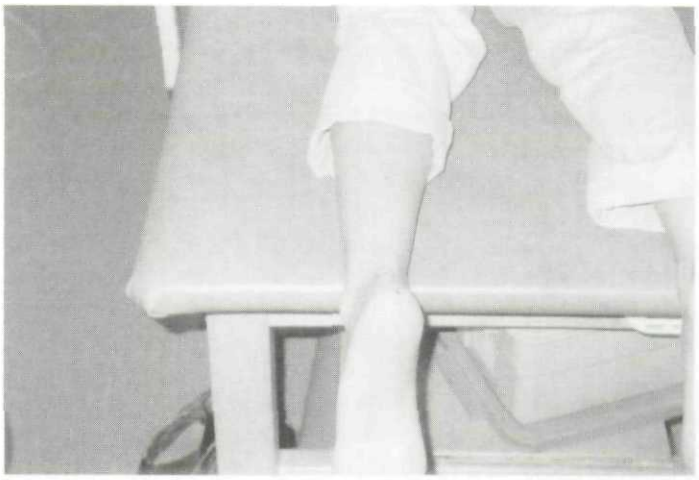


Figure 2 Pretape marking of lower leg landmarks, including bisection of the calcaneus and bisection of the distal third of the lower leg.

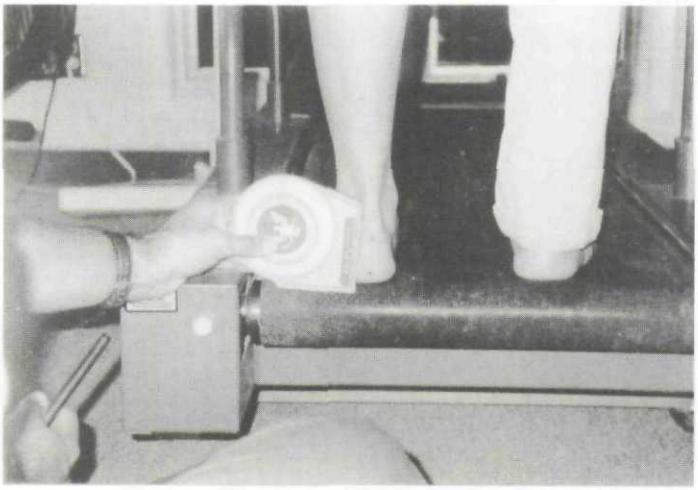


Figure 3 Pretape measurement of calcaneal position using an inclinometer.

After the pretape measurements, each subject was positioned in supine with the foot to be taped extending past the edge of the plinth, and the windlass taping technique was performed (Figures 6 and 7). A quick-drying spray adhesive was applied to the foot before tape application, and a standard athletic tape was used. All measurements and windlass taping were performed by 1 of 2 investigators who were experienced in these techniques.

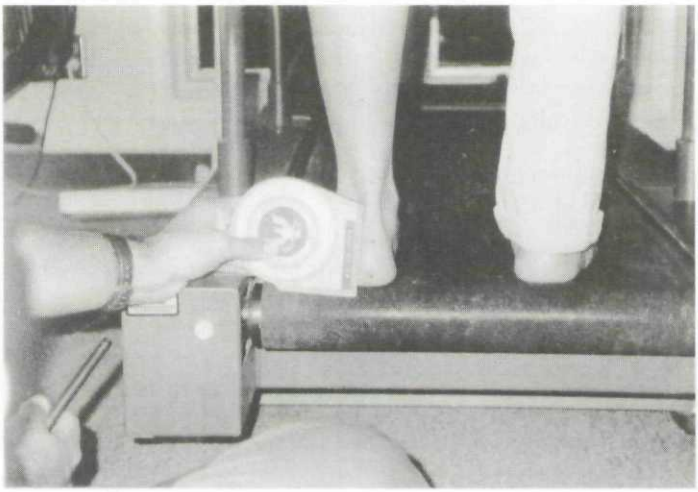


Figure 4 Pretape measurement of tibial position using an inclinometer.

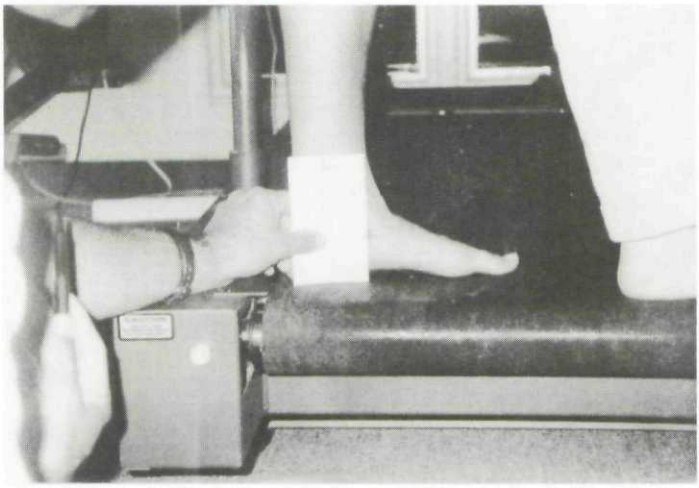


Figure 5 Pretape measurement of navicular height using an index card.

Investigators practiced the technique together to ensure that they were applying the tape consistently.

After taping, the subject was asked to walk a short distance and assess the feel of the tape. At this point, the subject filled out a second VAS for pain. The subject was not shown his or her marks from the previous VAS. Subjects were then repositioned in normal relaxed stance, and 3 measurements were made—of navicular height, calcaneal position, and tibial position—following the same procedure as before taping (see Figures 8, 9, and

The subject is positioned supine, with the foot to be taped hanging off the edge of the plinth. The taper will be facing the plantar aspect of the subject's foot.

1. Prepare the foot with an adhesive spray.
2. Using 1-in tape, apply 2 to 3 anchor strips directly under the plantar surface of the metatarsal heads, beginning at the 1st metatarsal head running laterally to the 5th.

   Note: Do not bowstring the tape when applying the anchor across the metatarsal heads. The thumb can be used to apply a gentle pressure in the dorsal direction at the 2nd and 3rd metatarsal heads to ensure that the tape is applied smoothly across the heads.
3. Apply a heel lock. Beginning at the 1st metatarsal head, apply a strip along the medial border of the foot, around the calcaneus, and attaching at the 5th metatarsal head. Apply a total of 1 to 2 strips.
4. Have the individual *actively* dorsiflex (extend) the hallux *without* recruitment of the tibialis anterior muscle (which will be noted via palpation and observation of the tibialis anterior muscle). Manual assistance/demonstration of the movement of the hallux into dorsiflexion can be performed. This will cause plantar flexion of the 1st ray via the windlass mechanism described by Hicks. Second, have the individual *actively* evert the forefoot to activate the peroneal musculature, which will promote further plantar flexion and eversion of the 1st ray.
5. Place a strip directly beneath the first metatarsal head, across the plantar surface of the forefoot, around the calcaneus, and along the medial border of the foot, returning to the 1st metatarsal head.

   Note: Care must be taken to *not* wrinkle the tape. If the tape will not pass around the calcaneus without wrinkling, it should be torn, and the sequence continued as described.
6. Place a strip directly beneath the 5th metatarsal head, across the plantar surface of the foot, along the lateral border, returning to the origin at the 5th metatarsal head.
7. Repeat steps 5 and 6 for a total of 2 strips each.
8. Using 1.5-in tape, close by starting at the dorsomedial aspect of the 1st metatarsal head and continue circumferentially to the dorsolateral aspect of the 5th metatarsal head. Continue heading posteriorly toward the calcaneus. As you get closer to the heel, switch to 1-in tape to better conform to its curvature. Circle the last strip around the calcaneus in the same location as the heel lock placed in the beginning.
9. Have the individual stand, approximately half normal weight bearing on the taped extremity. If there is any pulling of the skin on the dorsum of the foot, release the edges of the tape at the dorsomedial and dorsolateral aspects of the 1st and 5th metatarsal heads and replace the tape. Apply 2-in Conform® elastic tape for final closure/wrapping to the dorsum of the foot.

Figure 6 Detailed description of windlass taping technique.

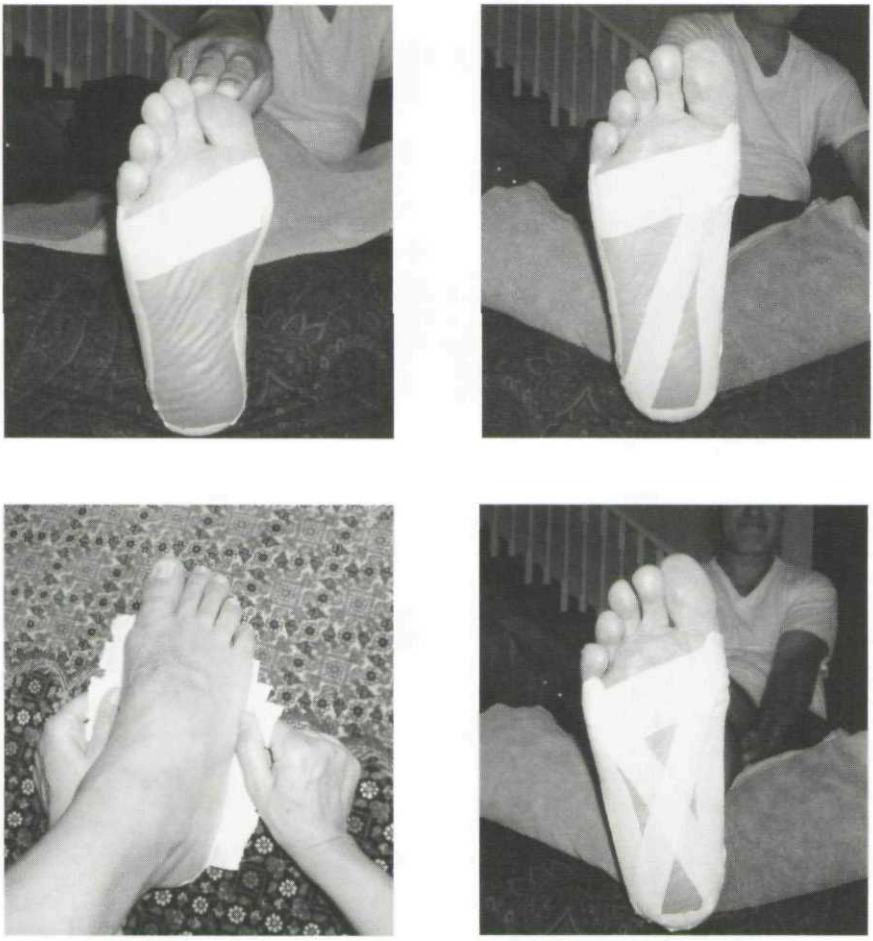


Figure 7 Windlass taping technique, clockwise from upper left: (a) Anchor strips and heel lock. Subject actively extends the great toe and everts the foot. (b) Apply strip from first metatarsal head around heel. (c) Apply strip from fifth metatarsal head around heel. (d) With patient in partial weight bearing, release the edges of tape for comfort.

10). Subjects were then instructed to wear the tape for 24 hours. They were given a third VAS to fill out when they removed the tape, and they were asked to make a note on the VAS of the time the tape was removed. They were asked to return the VAS to the researcher at the next scheduled visit. The researcher recorded the time of initial tape application so that total amount of time the tape was in place could be calculated. A research assistant recorded the data so that the investigator would be blinded to the results.

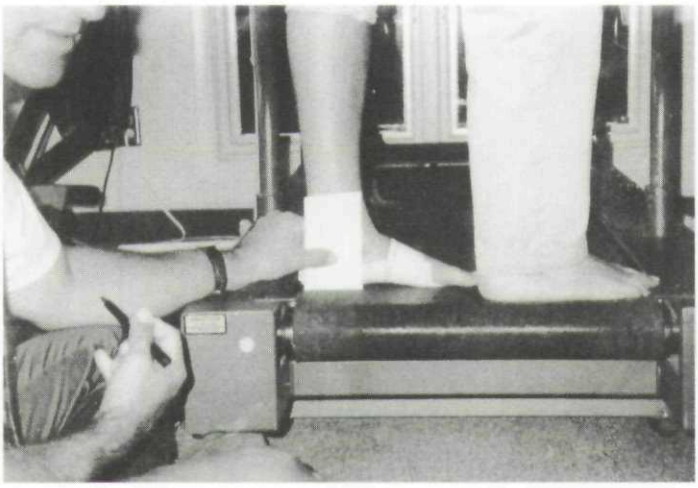


Figure 8 Posttape measurement of navicular height using an index card.

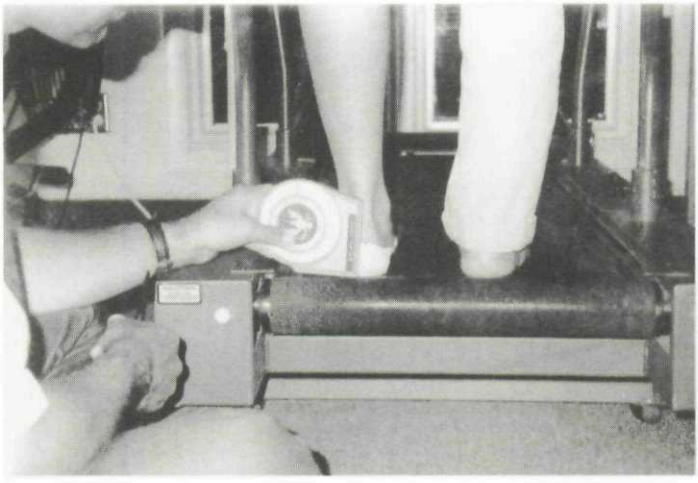


Figure 9 Posttape measurement of calcaneal position using an inclinometer.

Because the VAS is an ordinal scale, we used nonparametric statistics for the pain data. The median VAS was calculated for each condition: pretaping, immediately posttaping, and 24 hours posttaping. The median change in pain from one condition to the next was calculated. Friedman's test for related samples was used to test for significant difference among the 3 VAS trials. For a post hoc test, the Wilcoxon matched-pairs signed ranks test was used to identify where significant differences between trials existed.

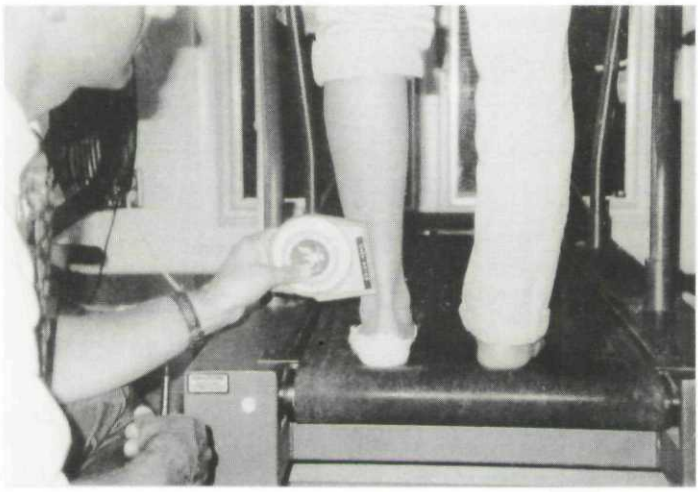


Figure 10 Posttape measurement of tibial position using an inclinometer.

Intraclass correlation coefficients ($ICC_{3,1}$) were calculated for repeated measures of both the pretaping and the posttaping data for navicular height and calcaneal and tibial position to determine reliability of the measures. Means, ranges, and standard deviations were calculated for each of these 3 measurements pretaping and posttaping. The average change in position pretaping to posttaping was then determined for each of these 3 variables. Paired *t* tests were used to compare pretaping and posttaping averages for navicular height and for calcaneal and tibial angle.

Results

The median score for the VAS was 37 mm before tape application, with an interquartile range of 19–58 mm, indicating that 50% of the values lay between these values. Immediately after taping, the VAS median score was 6 mm, with an interquartile range of 3–25 mm. Fifteen of the 20 subjects recorded and returned a third VAS score when the tape was removed. Of these 15, 14 kept the tape in place for 24 hours, and 1 kept it on for 8 hours. The median VAS score on tape removal remained at 6 mm, and the interquartile range was 4–30 mm (see Figure 11).

Nineteen of 20 subjects reported a reduction in pain immediately posttaping. The median pain reduction was 19 mm pretaping to posttaping. For the 15 subjects who reported their VAS scores on tape removal, there was a median pain reduction of 23 mm from pretaping to posttaping. Friedman's test for k-related samples showed a significant difference ($P < .001$) among the 3 trials for VAS. The post hoc Wilcoxon matched-pairs

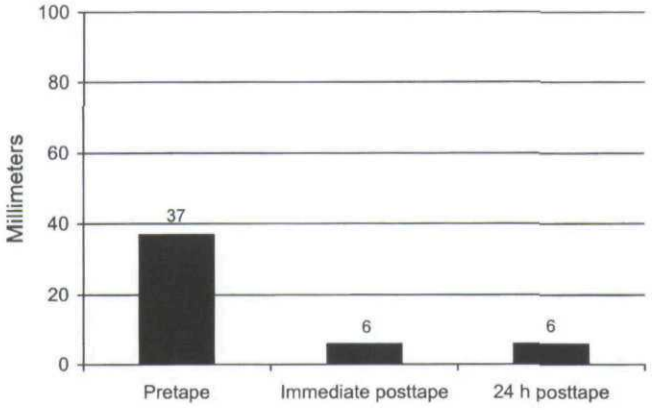


Figure 11 Median visual analog scale scores (millimeters) for pain pretape, immediately posttape, and 24 hours posttape. For pretape and immediate posttape conditions, n = 20. For 24 hours posttape, n = 15.

signed ranks test showed a significant decrease in the VAS score pretaping to immediately posttaping ($P < .001$) for all 20 subjects. The VAS scores pretaping and at the time the tape was removed for the 15 subjects who reported them were also significantly different from one another ($P < .001$). For these 15 subjects, there was no significant difference between the VAS immediately posttaping and on tape removal 8–24 hours later.

The pretaping $ICC_{3,1}$ value for repeated measures of navicular height was .98 (see Table 1). For the same condition, the $ICC_{3,1}$ values for calcaneal angle was .96 and for tibial angle was .86. The posttaping $ICC_{3,1}$ values for repeated measures on the same variables were .99 for navicular height, .97 for calcaneal angle, and .92 for tibial angle. All measurements were considered reliable, so data analysis continued, using the first measurement only.

The mean navicular height was 42 mm (± 9 mm) pretaping and 46 mm (± 8 mm) posttaping, for a mean arch height increase of 4 mm (see Table 2). The mean calcaneal angle was 2.8° eversion (± 3°) pretaping and 1.5° inversion (± 3°) posttaping, for a mean change of 4.3°. The mean tibial angle was 5.8° of varus (± 3°) pretaping and 4.0° of varus (± 2°) posttaping, for a mean change of 1.8°. Paired *t* tests showed a significant difference ($P < .01$) between pretape and posttape measurements for navicular height, calcaneal angle, and tibial angle. Effect size was calculated to be low for navicular height (.44) and calcaneal angle (.43) and to be medium for tibial angle (.6).

Discussion

Windlass taping resulted in an immediate and significant decrease in pain from plantar fasciitis, as shown by a significant drop in VAS scores. VAS

Table 1 Intraclass Correlation Coefficients for Repeated Measures Used in the Study (N = 20)*

Measurement	Pretape	Posttape
Navicular height	.98	.99
Calcaneal angle	.96	.97
Tibial angle	.86	.92

*$ICC_{3,1}$ for intratester reliability.

Table 2 Mean Pretaping and Posttaping Measurements (N = 20)*

Measurement	Pretape	Posttape
Navicular height	42 mm (SD 9 mm)	46 mm (SD 8 mm)
Calcaneal angle	2.8° eversion (SD 3°)	1.5° inversion (SD 3°)
Tibial angle	5.8° varus (SD 3°)	4.0° varus (SD 2°)

*All measurements were taken in resting stance with the subject's feet on a template.

scores indicated that significant pain relief continued from 8 to 24 hours later, when the tape was removed. This continued pain relief over the course of the day makes taping a practical modality for pain relief because it is inexpensive and easy to apply.

The measurements of navicular height, calcaneal position, and tibial position were shown to have good to excellent intratester reliability as used in this study. Sell et al,[23] when using the same closed-chain measurement techniques used in this study for navicular height and calcaneal angle, also found good to excellent intratester reliability (ICC = .95 and .85, respectively). In examining the use of an inclinometer for measuring tibial varum, Lohmann et al[21] found poor intratester reliability for 1 tester (ICC = .46) and good intratester reliability for another (ICC = .83). The clinical experience of the testers used in this study might account for the good reliability found in measuring tibial position.

All 3 measurements of foot and leg position showed a significant change after windlass taping. Navicular height increased with taping by an average of 4 mm. This is a very small difference, and one would question its clinical significance except that it is accompanied by a significant decrease in pain. It appears that using tape to support the arch in this slightly raised position was enough to take the stress off the plantar fascia for symptom relief in this group of patients.

Calcaneal position was, on average, 2.6° of eversion before application of the tape and 1.7° of inversion after taping, resulting in a net position change of 4.3°. This change into a position of greater inversion reflects a less pronated stance for the subtalar joint. Movement of the calcaneus toward inversion in a closed-chain position is normally coupled with increased arch height.[16] The results of this study indicate that the inverse is also true; that is, an increase in arch height is coupled with movement of the calcaneus toward inversion. As with the increase in navicular height, the calcaneal position change is very small.

The mean pretape tibial position was 5.6° varus, and the mean posttape tibial position was 4.2° varus, indicating a mean change of 1.4° in a valgus direction. This change, although statistically significant, might be so small as to be without any real clinical meaning. It does, however, follow the trend of positional changes that occur up the kinetic chain resulting in a less pronated foot and a more vertical tibia. Although there are no normative values published for tibial varum, previous studies by Lohmann et al[21] and by Tomaro[24] suggest that the relationship between tibial position and calcaneal position is critical. When a position of more tibial varum is present, more subtalar pronation and calcaneal eversion are required for the foot to contact the supporting surface during stance.

Windlass taping in this study caused a change in calcaneal position toward inversion and a slight change in tibial position toward valgus, resulting in a more neutral alignment of the tibia to the calcaneus during resting stance. Although pain reduction continued over the 24-hour period that the tape was in place, we are uncertain whether the changes in foot and leg position also continued. Ator et al[25] examined arch height before and after application of arch taping and after 10 minutes of jogging with the tape in place. They found that the arch height was significantly higher (+6 mm) immediately after taping, but after 10 minutes of jogging the arch height returned to within 2 mm of the pretaping height and was not significantly different than arch height without the tape. Although the subjects in our study might have had a similar reversion toward pretape position of the foot and leg sometime during the 24 hours that the tape was in place, they continued to report a decrease in pain.

The measured changes in foot and leg position show that taping the longitudinal arch makes use of closed kinetic chain relationships to alter the foot's position. Taping raises the navicular height, altering the position of the talus into less relative adduction and plantar flexion (less pronation) and positioning the calcaneus toward inversion. Proximally, the tibia is positioned slightly more vertically, even with the feet positioned the same width apart as before taping. If the normal closed kinetic chain relationships occur distally, also, as one would expect, the axes of the midtarsal joint should respond to an increase in arch height by becoming more convergent (less parallel) as the amount of pronation decreases. Such a change at the midtarsal joint should have the effect of making the foot more rigid at

heel rise and throughout terminal stance, resulting in less stress on the plantar fascia. Although they did not take measurements during walking, McPoil and Cornwall[26] found a good correlation (ICC = .83) between relaxed-standing foot posture and maximum rear-foot eversion. Therefore, the changes in position that we measured statically were probably reflected in decreased pronation during normal walking immediately posttaping.

It is interesting to note that the patients in this study, as a group, did not appear by clinical observation to have overly pronated feet. Twelve of the 20 patients had neutral rear-foot position, as defined by a resting-stance calcaneal angle within 2° of vertical. Also, the mean arch height before taping was 42 mm, which is comparable to a mean arch height of 41 mm in 10 normal subjects studied by Ator et al[25] using the same measurement method. Therefore, although the patients in this study experienced a decrease in pain along with a change in foot and leg position after arch taping, many of them did not present with abnormal foot and leg position. Although one might speculate that overstress on the plantar fascia created the inflammation, excessive pronation was not necessarily the cause of that overstress. Some of the patients might have had rear-foot-to-forefoot malalignments that we did not measure. Moreover, it is also possible that many of these patients had normal feet with no measurable alignment problem. It should be noted that the main reason for performing the taping technique on this patient population was to reduce pain, with symptom reduction considered the most clinically relevant outcome of this study.

Kogler et al[27] found that an orthosis that supports the arch can significantly decrease strain in the plantar aponeurosis. In a separate in vitro study of strain on the plantar fascia, Kogler et al[28] found that using a wedge either medially or laterally under the heel did not significantly change plantar-fascia strain, but using a lateral wedge under the forefoot significantly reduced strain. The authors concluded that the lateral forefoot wedge caused loads to be transmitted through the lateral structures of the foot, sparing the plantar fascia from the trusslike loading that occurs when the foot is loaded medially.

It is likely that the windlass taping used in this study decreased pain because it acted to support the arch rather than having any influence on forefoot position. This method of decreasing plantar-fascia strain worked for most patients as an immediate pain-reducing treatment, but it is inconvenient for patients to tape their feet daily. For long-term results, clinicians might wish to use an in-shoe orthosis to decrease plantar-fascia strain. Other conservative treatment methods such as dorsiflexion night splints and plantar-flexor stretching might also be used.

The windlass taping technique that we used was a modification of a standard low-dye arch taping. Standard techniques use tape applied to the foot when it is in a relaxed position with ankle plantar flexion. For the windlass technique, the patient assumes the same plantar-flexed position but also actively dorsiflexes the great toe and, when cued by the therapist,

performs an active contraction of the fibularis (peroneus) longus muscle. These actions by the patient help position the first-ray complex in a more stable position of plantar flexion and eversion and activate the windlass mechanism of the foot. This position more closely mimics the one that the foot should assume in terminal stance. Theoretically, increased plantar flexion and eversion of the first ray during taping should increase the height of the arch, put the foot in a more stable position, and therefore decrease the stress across the plantar fascia. In this study, the windlass taping technique did result in reduction of pain and produced measurable changes in foot and leg position of patients with plantar fasciitis. We did not compare it with standard low-dye taping to determine whether the addition of active contractions makes any difference in pain relief or foot and leg position. Nonetheless, because this change in technique is simple and requires no extra equipment or expense, therapists might want to try it and monitor their results.

Conclusion

Windlass taping was an effective technique for decreasing pain in patients with plantar fasciitis, regardless of foot type. Taping also resulted in increased navicular height, decreased calcaneal valgus, and decreased tibial varus position of our subjects when they were standing in normal resting posture. Although taping continued to provide pain relief over a 24-hour period, the duration of the biomechanical changes was not investigated. It is unclear whether the position changes were related to the decrease in pain.

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