The effect of low-Dye taping on peak plantar pressures of normal feet during gait

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This study investigated whether low-Dye anti-pronation taping altered peak plantar pressures of normal feet during gait. The Emed-AT-2 platform system was used to measure peak plantar pressures. Forty subjects performed two sets of six walks over the Emed-AT-2 forceplate. One set of walks was performed barefoot whilst the other set was performed with the low-Dye tape applied to the right foot. Computer software divided the heel, midfoot and forefoot into six areas (masks) for analysis. The mean for the peak plantar pressures (N/cm^2) of each of these masks was determined for both sets of walks. Paired *t*-tests found a significant difference between the barefoot and taped peak plantar pressures in each of the six masks. Overall, low-Dye anti-pronation taping significantly altered the peak plantar pressures of normal feet during gait. Of particular interest was that a significant reduction in mean peak plantar pressure was observed in the medial midfoot (1.4 N/cm^2) whilst a significant increase occurred in the lateral midfoot (2.6 N/cm^2). **[Russo SJ and Chipchase LS (2001): The effect of low-Dye taping on peak plantar pressures of normal feet during gait. *Australian Journal of Physiotherapy* 47: 239-244]**

Key words: Bandages; Foot; Pressure; Pronation

Introduction

Low-Dye taping is commonly used by physiotherapists and podiatrists for the treatment of symptoms in the lower leg related to altered or excessive pronation (Ator et al 1991). Excessive pronation occurs when the subtalar joint remains pronated beyond the midstance phase of the gait cycle (Brukner and Khan 1997, Donatelli 1987). Low-Dye taping is applied below the ankle and is hypothesised to generate a supinating force that controls the amount of pronation occurring at the subtalar joint (Ator et al 1991, Childs et al 1996). Very little is known about whether this anti-pronation effect is achieved, although anecdotally, clinical observations suggest that the technique is effective in reducing symptoms associated with excessive pronation (Ator et al 1991, Brukner and Kahn 1997, Saxelby et al 1997, Vicenzino et al 1997).

One of the main reasons for this lack of knowledge is that clinical measurements of the true amount of subtalar pronation and supination during gait have not yet been made (Nawoczenski et al 1998). Dynamic measurement methods have been studied, however their validity has been found to be questionable (Hunt et al 2000). In the clinical setting, calcaneal eversion, a static measure, is often used as a general indicator of subtalar joint pronation (Astrom and Arvidson 1995). Most recently, plantar pressure measurement during gait has been assessed as a means of measuring subtalar pronation and supination.

Rosenbaum et al (1994) measured dynamic plantar pressures to determine whether a relationship existed between plantar pressure patterns and static calcaneal eversion angles. Feet displaying greater loading in the medial midfoot region were found to display the greatest amount of calcaneal eversion. These findings do not infer that the plantar pressure pattern directly represents subtalar joint motion. However, they do tend to indicate that the plantar pressure pattern may provide an indirect measure of the effect of pronation on plantar pressures during gait.

Plantar pressure patterns have been used in previous studies which have investigated the effect of low-Dye taping (Childs et al 1982, Graf 1992, Scranton et al 1982). Scranton et al (1982) found that low-Dye taping supported the medial longitudinal arch by reducing the amount of time that pressure was exerted through the midfoot. However, the generalisability of the results was limited by a small sample of five subjects. Furthermore, the results were based on the line of pressure of one subject only. Statistical analyses were not included and it appears that conclusions were generalised from visual analysis of photographs (from a cholesterol crystal force plate) and points plotted on graphs (from a Kistler force platform). Pressures were not able to be measured by either force plate, therefore any pressure alterations that occurred with the application of low-Dye taping were not stated.

Two studies using Emed force platforms have evaluated plantar pressure patterns in the forefoot, with conflicting results (Childs et al 1982 , Graf 1992). Whilst the findings from these studies may be worthwhile, they did not focus on the midfoot and rearfoot, which are areas directly influenced by the subtalar joint. Consequently, the aim of this study was to determine whether low-Dye taping affected the peak plantar pressures of all areas of the normal foot during gait. An overall lateral shift in pressure was expected because it is believed that low-Dye taping provides an anti-pronation effect, thereby reducing the pressure exerted through the medial side of the foot (Ator et al 1991).

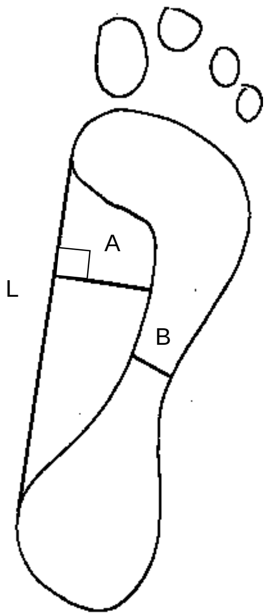


Figure 1. Imprint Index calculation. L = line drawn along medial border of footprint, A = largest distance between L and medial contour of foot, B = smallest distance between medial and lateral border of footprint. Imprint Index = A/B.

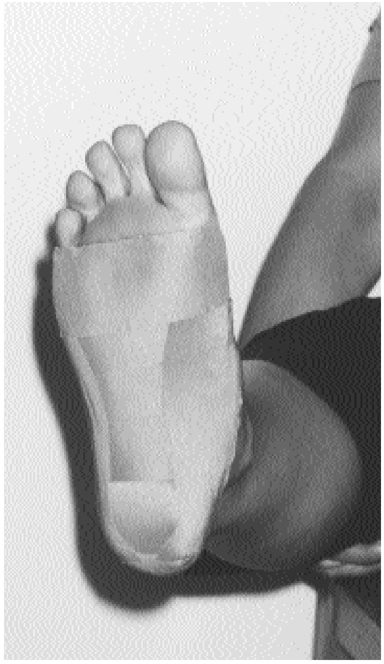
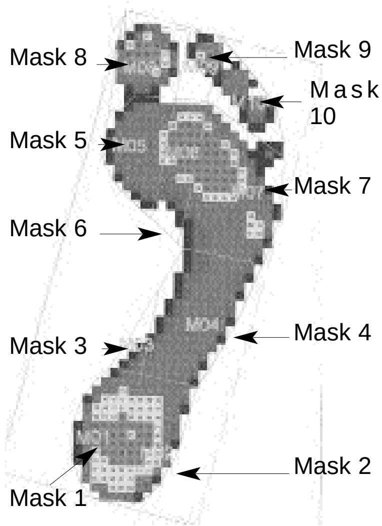


Figure 2. The LD taping technique.



Key:

PRC MASK	Study Masks
Mask 1	Medial heel
Mask 2	Lateral heel
Mask 3	Medial midfoot
Mask 4	Lateral midfoot
Mask 5 and 6	Medial forefoot
Mask 7	Lateral forefoot
Mask 8-10	Not evaluated in this study

Figure 3. A maximum pressure pattern with the PRC mask applied.

Method

Subjects The study was approved by the Divisional Ethics Committee at the University of South Australia. Forty subjects (males and females) volunteered to participate in the study. This was considered to be the largest number of subjects able to be tested, taking into consideration time constraints and subject availability during data collection. It was decided to use a sample of normal feet, as this study appeared to be the first of its kind to directly measure the effects of low-Dye taping on the entire plantar surface of the dynamic foot. Normal foot alignment was determined by the Imprint Index (Addison 1980), using a Harris Mat. Subjects were included if they were aged between 18 and 45 years. Subjects were excluded if their gait was affected by pain and/or injury.

Foot alignment was determined by obtaining an ink footprint from walking over a Harris Mat. With the ink footprint, the Imprint Index was calculated. This involved drawing a line (L) along the medial border of the footprint. Line A was the greatest distance from line L to the medial contour of the footprint. Line B was the shortest distance from the medial to the lateral border of the footprint (Fig. 1). Measurement A was then divided by measurement B. Values of less than one indicated a flat foot during the stance phase of gait and a measurement of greater than three indicated a high arch. Values between one and three were considered normal feet (Addison 1980).

Apparatus A standard low-Dye taping technique was used, similar to those outlined by other clinicians (Ator et al 1991, Scranton et al 1982, Vincenzo et al 1997). Smith and Nephew (New South Wales) 5cm brown rigid adhesive tape was used. Distal and proximal anchors were applied, followed by three plantar fascia strips, then three transverse strips and final anchors (Fig. 2). The ability of the principal investigator to consistently and accurately apply the tape was tested on eight subjects. This involved measuring taped peak plantar pressures over two consecutive days. As the principal investigator was a final year physiotherapy student, it was also deemed important to assess the ability to apply tape compared with an expert taper with more than 20 years of clinical experience. Thus the expert taper taped all subjects on the third day. The taped peak plantar pressures from the expert taper were compared with Day 2 of the principal investigator's taped pressures. Intraclass correlation coefficients ($ICC_{(1,1)}$, using a single factor ANOVA) were used for analysis.

Dynamic plantar pressures were measured with the Emed-AT-2 platform system and WinEmed software (Novelgmbh, Munich) which was attached to a personal computer

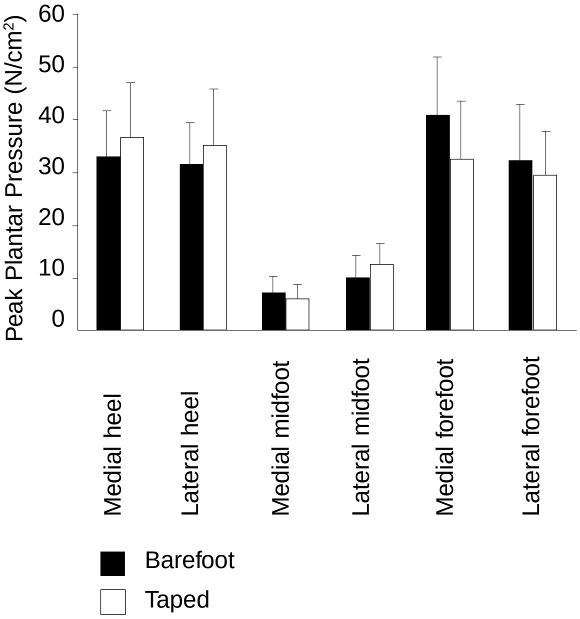


Figure 4. Comparison of the barefoot and taped peak plantar pressures of each mask (means and SDs).

running Novel-Ortho software. The pressure-sensitive area of the force plate measured 24 centimetres wide by 40 centimetres long, and was two centimetres above ground level. It contained 2736 homogenously distributed capacitive sensors, with four sensors/cm^2, which sampled at a frequency of 25-30 samples/second. The platform system automatically calibrated when switched on.

Reliability of this model has not yet been determined. Test-retest procedures were performed to determine the reliability of the platform system. Barefoot peak plantar pressures were collected over two consecutive days. The pressures measured on each day were averaged, and then paired *t*-tests were performed to determine whether a significant difference existed between the pressures from each day.

Procedure Subjects performed two sets of six walks over the force plate with their right foot. One set of walks was performed barefoot and the other set was performed taped. The order of the sets was randomised. Subjects rested for five minutes between the two sets. Subjects practised striking the force plate with the right foot on the fourth step and took at least two steps further on from the platform. This method of plantar pressure measurement has been described previously as the midgait method (ie a single foot contact while a patient is walking down a runway) The midgait method is an accepted protocol for use in studies evaluating non-pathological subject populations (Meyers-Rice et al 1994). Subjects were also instructed to walk at a normal pace that was not too fast and not too slow until he/she could strike the force plate on the fourth step whilst looking straight ahead with a normal arm swing. This usually involved three to five minutes of practice.

Plantar pressure analysis was performed using Novel-Ortho software. The Automask program of the Novel-Ortho software divided the plantar pressure into 10 areas (called masks). This was called the "PRC" mask which halved the rearfoot and midfoot, and divided the forefoot into three areas (first metatarsal, second metatarsal and the lateral metatarsals; Figure 3). For consistency and ease, the first and second metatarsals were considered to be the medial forefoot mask and the lateral metatarsals were considered to be the lateral forefoot. To determine the peak pressure of the medial forefoot, the greater pressure value of the first and second metatarsals was used. The PRC mask also masked the toes (masks 8-10 in Figure 3), however there is minimal accuracy in measuring pressure beneath the toes with an earlier Emed system (Hughes et al 1993). Thus only six regions or masks were evaluated in this study: medial and lateral heel, medial and lateral midfoot and medial and lateral forefoot. It was believed that halving the rearfoot, midfoot and forefoot would allow evaluation of shifts in pressure across these regions of the foot. The barefoot and taped peak pressures in each mask were averaged. Paired sample *t*-tests were then carried out to determine if a significant difference existed between corresponding barefoot and taped masks.

Rosenbaum et al (1994) found that an increase in velocity affected peak plantar pressure patterns. Thus the velocity of each subject's walk was measured in order to investigate whether this variable may have confounded the final results. The velocity was calculated by dividing the distance walked (from step one to step four) by the time taken (using a stopwatch). Velocity analysis was carried out using paired sample *t*-tests.

Results

Demographic data Of the total 40 subjects, there were 16 males and 24 females. The age of subjects ranged from 18–32 years, with a mean of 22 years (SD = 3.5).

Investigators' taping accuracy over two consecutive days Table 1 presents the ICC values for each mask. All ICC values for testing between Session 1 and Session 2 are greater than 0.75. Thus good to excellent reliability was obtained for each mask (Munro 1997).

Investigators' taping ability in comparison to an expert taper Table 1 presents the ICC values for each mask between the investigator and an expert taper. From this table it is evident that excellent correlations (ICCs greater than 0.75) resulted between the two tapers in their ability to tape the medial and lateral heel masks. Moderate to good correlation resulted in the medial and lateral midfoot masks and lateral forefoot mask. Only a fair relationship was found for the medial forefoot.

Reliability of platform system Table 2 indicates that the *p*-values of all masks were greater than or equal to 0.05.

Table 1. Intra-rater and inter-rater correlation values (ICC using a single factor ANOVA) for each mask.

Mask	ICC values Session 1/Session 2 (intra-rater)	ICC values investigator/expert (inter-rater)
Medial heel	0.91	0.88
Lateral heel	0.93	0.84
Medial midfoot	0.81	0.50
Lateral midfoot	0.82	0.50
Medial forefoot	0.88	0.28
Lateral forefoot	0.83	0.69

Table 2. Results of *t*-tests for reliability of the testing procedure analysis (n = 8).

Mask	*t*-value	*p*-value
Medial heel	1.49	0.09
Lateral heel	1.09	0.16
Medial midfoot	0.64	0.27
Lateral midfoot	0.72	0.25
Medial forefoot	0.85	0.21
Lateral forefoot	1.85	0.05

Table 3. Mean and standard deviations (SD) of barefoot and taped peak plantar pressures (PPP) and the differences for each mask.

Mask	Mean (± SD) of barefoot PPP (N/cm^2) n = 40	Mean (±SD) of taped PPP (N/cm^2) n = 40	Mean peak pressure difference (taped – barefoot) (N/cm^2)	*t*-value	*p*-value
Medial heel	33.1 (8.6)	36.7 (10.3)	3.7	3.47	0.001*
Lateral heel	31.6 (7.9)	35.6 (10.1)	4.0	4.46	< 0.001*
Medial midfoot	7.6 (2.8)	6.2 (2.6)	-1.4	-5.95	< 0.001*
Lateral midfoot	10.0 (4.3)	12.6 (3.9)	2.6	3.85	< 0.001*
Medial forefoot	40.9 (11.1)	32.6 (10.8)	-8.3	-5.61	< 0.001*
Lateral forefoot	32.2 (10.8)	29.6 (8.1)	-2.6	-2.58	0.007*

* Difference between barefoot and taped is significant ($p < 0.05$)

Hence there was no significant difference between the pressure differences found on both days.

Analysis of peak plantar pressure data: The averaged barefoot and taped peak pressures recorded in each of the six masks for each subject were tabulated and the difference found. The mean peak pressures and differences for each mask are displayed in Table 3.

If an overall lateral shift in peak pressure was to occur, it was theorised that a positive difference would result for the lateral masks (lateral heel, midfoot and forefoot masks), and a negative difference would result for the medial masks (medial heel, midfoot and forefoot masks). According to Table 3, it is evident that the lateral heel, medial midfoot, lateral midfoot and medial forefoot masks followed this trend, whilst the medial heel and lateral forefoot masks did not. Thus an overall lateral shift in peak pressure did not occur. Figure 4 depicts this graphically.

From Figure 4 it is evident that low-Dye taping gave rise to an overall increase in peak plantar pressure under the heel (medial and lateral heel masks) and an overall decrease in the forefoot (medial and lateral forefoot masks). A reduction in peak pressure occurred with taping in the medial midfoot, whilst the opposite occurred in lateral midfoot. The medial midfoot had a mean peak pressure decrease of 1.4 N/cm^2 whilst the lateral midfoot had a mean increase in peak pressure of 2.6 N/cm^2.

To determine if the difference in peak pressure was significant, a *t*-test (paired two sample for means) was carried out on the peak pressure data for each mask. Table 3 presents a summary of the results. From the table it is evident that the difference in peak pressure between barefoot and taped feet was significant for each mask.

Analysis of velocity There was no significant difference in velocity found between the barefoot and taped walks of subjects during reliability testing and final data collection. The mean (SD) velocity for the barefoot walks was 1.34 (0.22) m/s and the taped walks was 1.32 (0.42) m/s ($p = 0.21$).

Discussion

Initial test-retest procedures found two important results. Although the overall taping ability of the principal investigator did not correlate highly with that of the expert taper, good intra-rater correlation had been established. It was thus deemed appropriate that the principal investigator tape all subjects during data collection. However, it is acknowledged that the discrepancies between the taping ability of the expert and the principal investigator may affect final interpretation of the results. The second important result was that the Emed-AT-2 platform system was found to be a reliable tool to use in order to measure plantar pressures.

Velocity analysis found no significant difference between the barefoot and taped walks of each subject. Thus no evidence was found to indicate that taping significantly changed the velocity of subject walks. From this, the probability of velocity being a potential confounding factor on the results obtained was reduced.

Plantar pressure analysis found that a significant difference existed between the barefoot peak plantar pressures and taped peak plantar pressures. However, an overall lateral shift of plantar pressure did not appear occur. Lateral shift of plantar pressures was only observed in the midfoot, whilst pressure changes decreased in the forefoot and increased in the heel. Thus the research hypothesis was only partially supported.

A lateral shift in peak plantar pressures was found to occur with application of low-Dye taping in the midfoot area. That is, less pressure was exerted in the medial midfoot (1.4 N/cm^2) and more pressure in the lateral midfoot (2.6 N/cm^2) with the application of tape. The clinical hypothesis for the application of low-Dye taping, particularly in the midfoot, is that the tape attempts to create a supinating force. Whilst supination and pronation movement was not measured in thus study, the reduction in pressure exerted through the medial midfoot tends to indicate that the medial longitudinal arch may have been prevented from lowering towards the ground as normal during the loading response and midstance phases of gait. This may have been compensated for by greater pressure being exerted through the lateral midfoot. Thus low-Dye taping was effective at reducing medial midfoot plantar pressure and increasing lateral midfoot pressure. The size of this effect, while statistically significant, is small, and it is not known whether this effect is likely to be large enough to be clinically worthwhile. However, it does highlight the potential use of this taping procedure in clinical conditions that may benefit from reduced pressure in the medial midfoot.

In the heel, the peak plantar pressures exerted in both the medial and lateral masks when the foot was taped were greater than when barefoot. This result is similar to that found by Scranton et al (1982) and was expected for the lateral heel mask but not for the medial heel mask. The lateral shift of peak pressure in the midfoot may have affected the pressure occurring in the heel. This effect may have transferred to the heel, reducing the amount of eversion possible at the calcaneus. Consequently, less calcaneal eversion was able to occur during the loading response, and so greater pressure was exerted through the lateral heel.

Alternatively, the low-Dye taping technique involved tape being applied around and over the entire heel. This may have reduced the tactile sensation of the ground against the heel during heel strike. Many subjects remarked on the sock-like feel of the tape. Subjects may have unconsciously struck the force plate harder with the heel in an attempt to create awareness of heel strike, thereby increasing the peak pressure measurements in both lateral and medial areas.

The forefoot demonstrated opposite results to that found in the heel. In the forefoot, peak pressure significantly decreased in both medial and lateral areas. This indicated that low-Dye taping decreased the peak pressure exerted through the forefoot. The reasoning behind the reduction in mean peak pressure over the forefoot may have been due, once again, to the taping technique. Six plantar fascia strips were applied to the plantar surface of the foot, mimicking the fanned-out shape of the plantar fascia. The role of the plantar fascia is to tighten when toe dorsiflexion occurs during heel-rise, thereby supporting the longitudinal arches of the foot. This tightening of the plantar fascia during gait normally goes unnoticed. The addition of six strips of tape extending the length of the plantar fascia may have intensified its effect. To minimise this abnormal, perhaps uncomfortable, sensation, less time may have been spent in toe dorsiflexion and heel-rise. Similarly, less pressure may have been exerted through the forefoot.

There are several limitations to this study. Firstly, the sample was one of convenience and overall had a mean age of 22 (range 18-32, SD = 3.5), which made the sample less representative of the population of normal individuals. Secondly, the testing protocol made subjects very aware of the way they walked. Not only was the principal investigator observing each set of walks but the subjects also had the difficult task of striking the force plate without looking at it. This may have resulted in unnatural barefoot walks over the force plate. The difficulty of this task may have been further magnified when low-Dye taping was applied. Not only were subjects aware of how they walked over the force plate, but they were also more conscious of the taped foot. This could have resulted in the changes in plantar pressure pattern exerted.

Conclusion

The results of this study indicate that low-Dye taping increased mean peak pressure exerted through the heel, and caused an increase through the lateral midfoot (2.6 N/cm^2), and a decrease in through the medial forefoot (1.4 N/cm^2), whilst decreasing the mean peak pressure exerted through the forefoot. These results can only be extrapolated to the population of individuals with normal feet in their early to mid twenties. Whilst the results cannot be extrapolated to excessive pronators, medially-located peak plantar pressures have previously been found to occur in the midfoot of excessive pronators (Rosenbaum et al 1994). Thus the decrease in pressure that occurred in the midfoot of normal feet may also occur in excessively pronated feet. Obviously, this must be assessed in a pronated and symptomatic population before any clinical inferences can be made. The results of this study provide initial insight for the underlying mechanisms of low-Dye taping on the foot as a whole.

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References

Addison DE (1980): The flexible flatfoot. An investigation into the incidence of 'Joint Signs' in the rear-foot complex of the flexible flatfoot. Unpublished Graduate Diploma Thesis. South Australian Institute of Technology.

Astrom M and Arvidson T (1995): Alignment and joint motion in the normal foot. *Journal of Orthopaedic and Sports Physical Therapy* 22: 216-222.

Ator R, Gunn K, McPoil TG and Knecht HG (1991): The effect of adhesive strapping on medial longitudinal arch support before and after exercise. *Journal of Orthopaedic and Sports Physical Therapy* 14: 18-23.

Brukner P and Khan K (1997): Clinical Sports Medicine. Sydney: McGraw-Hill.

Childs RA, Olson BA, McPoil TG and Cornwall MW (1996): The effect of three treatment techniques in reducing metatarsal head pressures during walking. *The Lower Extremity* 3: 25-29.

Donatelli R (1987): Abnormal biomechanics of the foot and ankle. *Journal of Orthopaedics and Sports Physical Therapy* 9: 11-16.

Graf PM (1992): A study of the effects of the low-Dye immobilization strapping on foot function in walking. *Emed Newsletter* 3: 7.

Hughes J, Phil M, Clark P, Linge K and Klenerman L (1993): A comparison of two studies of the pressure distribution under the feet of normal subjects using different equipment. *Foot and Ankle* 14: 514-519.

Hunt AE, Fahey AJ and Smith RM (2000): Static measures of calcaneal deviation and arch angle as predictors of rearfoot motion during walking. *Australian Journal of Physiotherapy* 46: 9-16.

Meyers-Rice B, Sugars L, McPoil T and Cornwall MW (1994): Comparison of three different methods for obtaining plantar pressures in nonpathologic subjects. *Journal of the American Podiatric Medical Association* 84: 499-504.

Munro BH (1997): Statistical Methods for Health Care Research. Philadelphia: Lippincott.

Nawoczenski DA, Saltzman CL and Cook TM (1998): The effect of foot structure in the 3-dimensional kinematic coupling behaviour of the leg and rear foot. *Physical Therapy* 78: 404-416.

Rosenbaum D, Hautmann S, Gold M and Claes L (1994): Effects of walking speed on plantar pressure patterns and hindfoot angular motion. *Gait and Posture* 2: 191-197.

Saxelby J, Betts RP and Bygrave CJ (1997): Low-Dye taping on the foot in the management of plantar fasciitis. *The Foot: International Journal of Clinical Foot Science* 7: 205-209.

Scranton PE, Pedegana LR and Whitesel JP (1982): Gait analysis: alterations in support phase forces using supportive devices. *American Journal of Sports Medicine* 10: 6-11.

Vicenzino B, Feilding J, Howard R, Moore R and Smith S (1997): An investigation of the anti-pronation effect of two taping methods after application and exercise. *Gait and Posture* 5: 1-5.