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Effect of Antipronation Tape and Temporary Orthotic on Vertical Navicular Height Before and After Exercise

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RESEARCH REPORT

Study Design: A randomized controlled, crossover, within-subjects study evaluating 2 antipronation treatments.
Objectives: To investigate the antipronation effect of 2 treatments designed to reduce abnormal pronation, and the effect of an exercise challenge on the treatments.
Background: Control of abnormal pronation in order to ameliorate inappropriate stresses on injured soft tissues is frequently sought in the treatment of overuse injuries of the lower limb. Tape and temporary soft orthotics are used to control abnormal pronation. The effects of these treatments remain largely untested.
Methods and Measures: Fourteen subjects (age = 23.8 ± 3.5 years) who had at least a 10-mm navicular drop were studied. The dependent variable was vertical navicular height. The two independent variables were the treatment conditions (temporary felt orthotics, augmented LowDye tape, and control) and the exercise challenge (0, 10, and 20 minutes of controlled jogging). The subjects' vertical navicular height was measured before and after the application of the treatment conditions, and then after 10 and 20 minutes of jogging.
Results: Tape and orthotic treatments produced approximately a 19% and 14% increase in vertical navicular height, respectively, which were both significantly greater than the control condition (0%). The treatment effect, although significantly diminished following exercise challenge, remained superior to control (6.5% for orthotic and 3.5% for tape compared to −7.3% for control).
Conclusion: Antipronation tape and temporary orthotics help to control excessive foot pronation initially after application and following exercise. These treatments may be useful in the assessment and treatment of lower limb injuries that are associated with abnormal foot pronation. *J Orthop Sports Phys Ther 2000;30:333–339.*

Key Words: *ankle, foot, physical therapy*

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Study protocol was approved by the Medical Research Ethics Sub-Committee of the Human Experimentation Ethical Review Committee, Office of Research and Postgraduate Studies, University of Queensland.
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Overuse injuries of the lower limb are frequently associated with abnormal lower limb biomechanics such as excessive or prolonged foot pronation in the stance phase of gait.[2–5,7,11,15] McPoil and Hunt have proposed a tissue stress model, which uses the load-deformation curve[17] to explain the development of lower limb overuse injuries associated with excessive pronation.[10] Loading of the foot and lower limb, in weight bearing activities, stresses the soft tissues. If the degree of tissue stress remains within the elastic region of the load-deformation curve, no damage occurs. Where there are altered biomechanics such as excessive pronation, the soft tissues of the foot and lower limb may be stressed beyond this elastic region, leading to micro failure. Overuse injuries may result if the rate or amount of tissue loading, deformation and possible breakdown is greater than the rate of regeneration.[10] These injuries tend to occur gradually over a period of time as a result of soft tissue creep and hysteresis from repetitive loading.

The key to successful physiotherapy treatment of overuse injuries relies on the clinical reasoning process employed. In the clinical evaluation of overuse injuries, in which there is excessive or prolonged pronation, antipronation treatments such as rigid sports tape and temporary orthotics are used to test the relationship between the excessive pronation and the patient's symptoms. A reduction in symptoms when the antipronation technique is used is thought to confirm the association between excessive pronation and the patient's symptoms.[16] Clinically we use antipronation tape initially to determine the association between abnormal pronation and symptoms. If an association is confirmed, temporary orthotics are constructed from orthopaedic felt (obtained from Australian Podiatry Suppliers, Australia) to determine the long-term effect of antipronation control prior to the prescription of permanent orthotics. In the treatment of overuse injuries associated with abnormal pronation, antipronation techniques are then used to unload symptomatic structures, thus relieving symptoms.[10,16]

A commonly used taping technique, the LowDye, is designed to control pronation by supporting the medial longitudinal arch. A limitation of this technique is its inability to maintain the correction effectively after weight bearing exercise.[1,16] Ator et al[1] measured the effect of LowDye and double X taping techniques on vertical navicular height after a period of jogging. They demonstrated that while both LowDye and the double X techniques were effective in controlling pronation immediately following application, they were ineffective in controlling pronation following 10 minutes of jogging. Vicenzino et al[16] recently compared the effect on vertical navicular height of the standard LowDye and an augmented LowDye technique following 20 minutes of jogging. The augmented technique involved extending the tape up the distal one third of the leg, with the addition of calcaneal slings and reverse sixes. The results indicate that although the antipronation effect of the augmented LowDye had significantly diminished after 20 minutes of jogging, it still performed significantly better than the standard LowDye and a no tape control condition.[16]

Another method that we use clinically to control pronation is a temporary felt orthotic. Temporary orthotics have a number of advantages over taping. We have observed clinically that temporary orthotics are effective in controlling symptoms associated with abnormal pronation for a longer period of time than does tape. In addition, the use of temporary orthotics avoids the potential skin problems of repeated taping, is less expensive and less labour intensive over a course of several treatments. Few studies have investigated the use of temporary orthotics in controlling pronation. A study by Scranton et al[13] compared felt medial arch supports and LowDye. They investigated forces under the midfoot as subjects walked over a force platform following 10 minutes of exercise. The LowDye significantly reduced pressure under the midfoot compared with the orthotic. This result is not unexpected as the intention of the orthotic is to control pronation by exerting pressure through the arch of the foot. The postural control exerted by the tape or temporary orthotic was not investigated in this study and remains to be investigated.

In summary, current research of antipronation tape techniques and temporary foot orthotics (eg, felt arch supports) has demonstrated that although the LowDye and double X techniques are capable of increasing vertical navicular height immediately after application, they are ineffectual at maintaining this increase in the medial longitudinal arch after jogging. However, an augmented LowDye technique performs better than the LowDye technique at controlling foot position (ie, vertical navicular height) immediately after application and after exercise challenge (ie, a standardized jogging circuit). The influence of temporary foot orthotics on vertical navicular height has not been investigated. The purpose of this study was to compare the effect of antipronation treatment techniques (augmented LowDye, temporary foot orthotic, control) on vertical navicular height immediately following application and an exercise challenge of 20 minutes of jogging. In addition, the robustness of each treatment technique to the exercise challenge was also investigated.

METHODS

Subjects

Eleven men and 3 women whose ages ranged between 18 and 28 years (23.8 ± 3.5 years) were recruited from the University of Queensland's student population. Volunteers were accepted into the study if they had an increase in vertical navicular height of at least 10 mm when the foot was moved from relaxed calcaneal stance to subtalar neutral, determined by the palpation method. Mueller et al[12] have suggested that a change in vertical navicular height of greater than 10 mm is considered abnormal and may be a contributing factor to foot pathology. All subjects regularly participated in fitness activities. Subjects were excluded from the study if they had any coronary risk factors, if they had previously used antipronation taping or foot orthotics, or if they had any current lower limb injuries that had required a decrease in activity or a consultation with a healthcare professional. Subjects who had allergic reactions to previous applied adhesive dressings or tape were also excluded. After subjects were informed of the study protocol, all subjects signed a consent form. The study was approved by the Medical Research

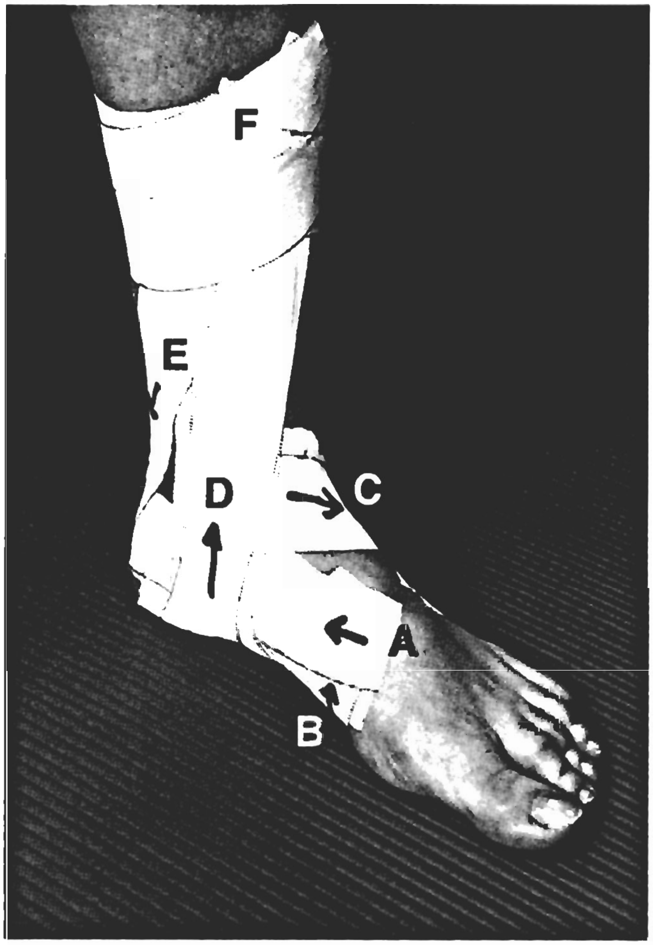

FIGURE 1. The augmented LowDye tape technique. The LowDye technique consists of a spur (A) and mini-stirrups (B). The spur (A) commences antero-medially on the distal first metatarsal, courses in a posterior direction around the calcaneum and then anteriorly from there to anchor on the antero-lateral aspect of the distal fifth metatarsal. Each of about 5 mini-stirrups (B) commence over the lateral aspect of the foot and run transversely around the plantar surface of the foot to anchor on the medial side of the foot. The first one is applied at the level indicated by B. Successive mini-stirrups are applied such that they overlap the previous one by about half the tape width and are applied in a distal to proximal direction. Two spurs are used, one underneath and the other on top of the ends of the mini-stirrups. The LowDye is augmented by several reverse sixes (C and D) and calcaneal slings (E and D). Reverse sixes commence in the region of the medial malleolus and then pass around the midfoot antero-laterally (C) and then under the plantar surface of the midfoot. The calcaneal slings commence in the vicinity of F and course distally in the antero-posterior fashion indicated by E before coursing around the posterior, lateral and plantar surface of the calcaneum. Both the reverse sixes and calcaneal slings emerge from under the plantar surface of the navicular-sustentaculum tali region and run up towards the region indicated by F.

Ethics Committee of the University of Queensland, Human Experimentation Ethics Review Committee.

Vertical Navicular Height

Vertical navicular height is frequently used as a measure of pronation.[1,9,16] Ator et al[1] and Vicenzino et al[16] have reported ICCs of greater than 0.94, and have interpreted this to indicate that the measures of vertical navicular height in the shoeless foot were reliable. As in the study by Vicenzino et al,[16] the vertical navicular height during bipedal stance was measured from the navicular tuberosity to the floor with a vernier height gauge (Mitutoyo, Japan; resolution of 0.02 mm). The vernier height gauge allowed measurement of the vertical navicular height perpendicular to the floor.

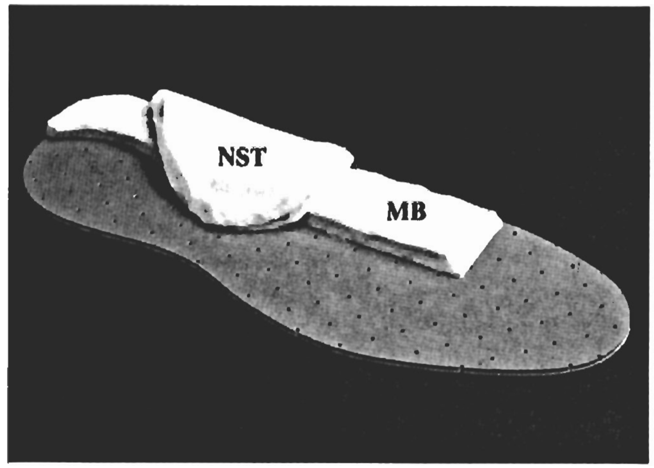

FIGURE 2. The temporary orthotic fabricated from orthopaedic felt consists of 2 parts: the medial buttress (MB) and the navicular-sustentaculum tali (NST) support.

Treatment Conditions

The treatment conditions for this study were the augmented LowDye taping, temporary felt orthotics, and control. The augmented LowDye technique has previously been described in detail by Vicenzino et al.[16] The technique involves applying a LowDye consisting of a spur and mini-stirrups, and adding calcaneal slings and reverse sixes which are anchored one-third up the leg (Figure 1). Rigid sports tape (38 mm) with a zinc oxide adhesive was used.

The temporary orthotic was fashioned from orthopaedic felt (7 mm). The medial buttress was made from one layer of felt and extended from the head of the first metatarsal to the posterior calcaneus and medially to the calcaneal bisection (Figure 2). This was shaped to fit onto the inner sole of the subject's shoe. The navicular-sustentaculum tali support was made to extend from the sustentaculum tali to, and including the navicular. The temporary orthotic was adhered to the inner sole of the subject's shoe. In the control condition, subjects did not have tape or orthotics applied. They wore only the shoes which were worn for the other conditions.

Experimental Procedure

After qualifying for the study, each subject was required to report to the laboratory on 4 separate occasions. The first session was a preparatory session during which consent was obtained, the foot template was constructed, and a tape skin test was performed. To ensure foot position was standardized between trials, a template of the subject's feet was traced onto A4 paper while standing on a platform in their running shoes. The feet were positioned parallel to each other, with 20 cm between the calcaneal bisectors and with the posterior aspect of the heels aligned. The subject's identification details were also recorded on the template which was fixed to the platform for each trial.

This study used a repeated measures design in which all subjects experienced 1 of the 3 conditions on 3 separate days. The order in which the subjects experienced the conditions of taping, orthotic, or control was performed randomly, so that upon completion of the experiment, every subject had experienced each condition once.

For each of the 3 testing conditions a standard protocol was followed. An experienced sports physiotherapist applied the tape to all subjects and constructed all orthotics. The therapist was instructed to apply these treatments as if it were a clinical situation. All measurements taken were from the subject's right foot. On arrival, the subject's right foot and leg were washed with soap and warm water to remove dirt and oils, which would decrease the tape's adhesion. Any hair in the area was removed. The navicular tuberosity was identified by two investigators and then marked. Vertical navicular height was then measured in relaxed calcaneal stance with shoes on. An investigator who was masked to the vernier height gauge measurement scale, reflected the medial aspect of the shoe inferiorly and aligned the gauge to the navicular tuberosity mark (Figure 3). Another investigator then read the measurement scale and recorded it on a data-collection sheet. The vertical navicular height was measured twice. The subjects then had tape, orthotic, or nothing applied in a random order on successive test days. In the taping condition, the navicular tuberosity mark was visible through a layer of tape, and after being checked by palpation to ensure it still represented the navicular tuberosity, it was transferred to subsequent layers of tape.

The vertical navicular height measurements were remeasured before exercise, but following the application of the treatment conditions. Subjects then jogged for two 10-minute periods around a flat, indoor, figure-eight track; 30 meters in length. The vertical navicular height measurements as described above and shown in Figure 3 were repeated after each 10 minute period. On completion of the session, the tape was removed with blunt nosed scissors and the orthotic was removed from the shoe. Subjects returned for 2 further sessions in which the only protocol change was the condition tested.

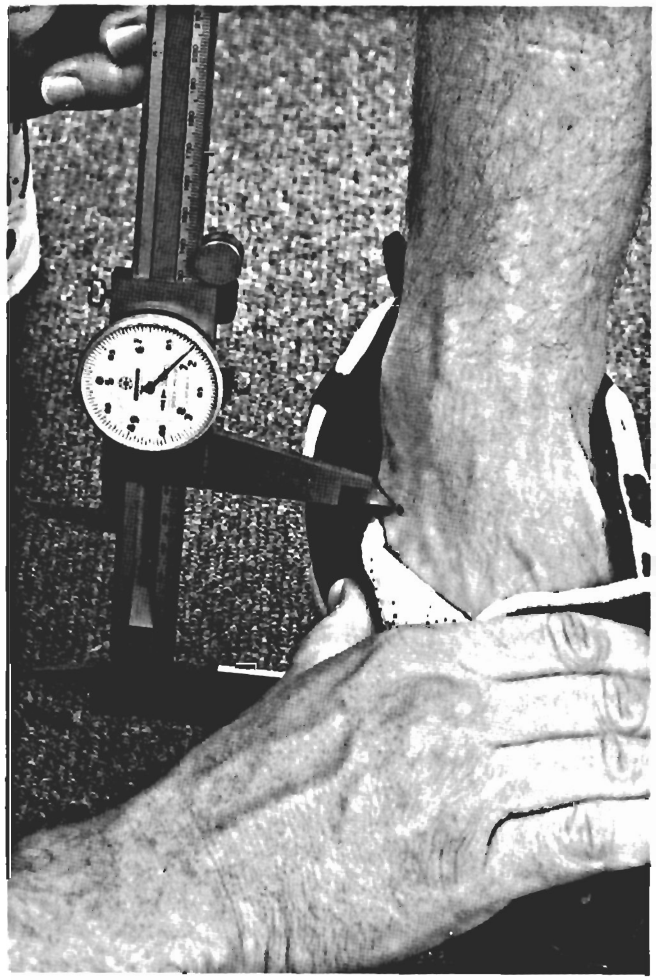

FIGURE 3. Illustration of the medial side of shoe being reflected to allow visualization of the navicular tuberosity and measurement of the vertical navicular height with the vernier height gauge. The base of the vernier height gauge was held flush with the floor.

Data Analysis

An assessment of the reliability of the measure of vertical navicular height used in this study was achieved by analyzing the 2 measures of vertical navicular height for each of the conditions (ie, immediately postapplication of control, tape, and orthotic). The Intraclass Correlation Coefficient (ICC [3,1])[14] and the lower and upper bounds of the 95 percent confidence interval for the absolute difference between the 2 measures for each condition were used as the indices of reliability.

Main Study

At all measurement times in this study, the vertical navicular height was measured while the subjects wore shoes (Figure 3). The data obtained in this manner was the sum total of the height of the sole of the shoe and the navicular height within the shoe. The latter was the measure of interest. To arrive at this measurement, the height of the shoe for each

TABLE 1. Mean percent change in the vertical navicular height ± SEM and, in parentheses, the equivalent vertical navicular height expressed in mm for the tape, orthotic and control conditions, immediately before exercise and after 10 and 20 minutes of exercise.

	Before exercise	After 10 minutes exercise	After 20 minutes exercise
Tape	19.0 ± 2.2% (10.8 ± 1.3 mm)	5.9 ± 1.0% (3.4 ± 0.6 mm)	3.5 ± 1.3% (2.0 ± 0.4 mm)
Orthotic	14.4 ± 0.8 % (8.0 ± 0.4 mm)	7.7 ± 1.3% (4.3 ± 0.7 mm)	6.5 ± 1.4 (3.6 ± 0.8 mm)
Control	−0.8 ± 0.5 % (−0.4 ± 0.3 mm)	−6.4 ± 1.0 % (−3.0 ± 0.5 mm)	−7.3 ± 1.2 (−3.4 ± 0.6 mm)

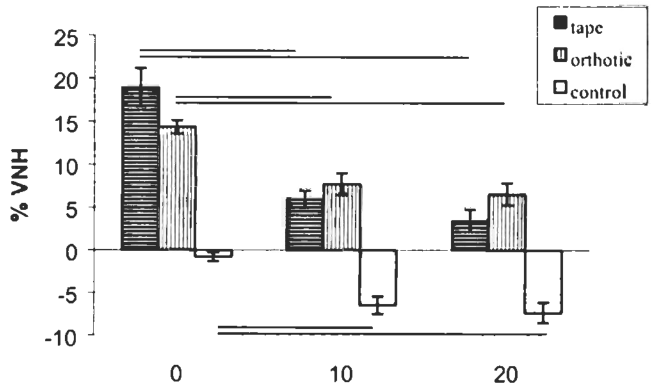

FIGURE 4. The mean (±SEM) percentage change in vertical navicular height (%VNH) for the control, orthotic and tape conditions after application (0 minutes) and after exercise (10 and 20 minutes). Positive values indicate an increase in vertical navicular height and negative values indicate a reduction in vertical navicular height relative to the vertical navicular height, prior to the application of the conditions. Both treatment conditions are significantly greater than control at all measurement times ($P < .05$). Significant reductions in %VNH after 10 and 20 minutes exercise ($P < .05$). Solid horizontal lines indicate the comparisons across time that were statistically different.

subject, which was measured before the experiment session, was subtracted from the total vertical navicular height measured with shoes on. The average of the 2 measurements of vertical navicular height obtained in this manner was used in the statistical analysis. Postapplication vertical navicular height measurements were expressed as a percentage of the preapplication measurements. This was the dependent variable (ie, mean of the percentage change in vertical navicular height from the preapplication vertical navicular height). The independent variables were the treatment condition (tape, orthotic, and control) and exercise challenge (0 minutes [ie, immediately following application], after 10 minutes of jogging, and after a further 10 minutes of jogging). The vertical navicular height data for all 9 factorialized cells (ie, 3 × 3) were tabulated (Table 1) and plotted (Figure 4). Preliminary analysis involved inspection of the tabulated and plotted data. The main effects (treatment condition and exercise challenge) and their interaction were then assessed by a 2-factor, within-subjects Analysis of Variance (ANOVA)[6,8] using the MANOVA procedure of the SPSS (Chicago, Ill) software package for the Macintosh. As each of the factors (treatment condition and exercise challenge) had 3 levels, tests of simple effects (main or interaction) were employed where indicated. The Tukey Honestly Significant Difference (HSD) test for all pairwise comparisons between group means was then used where there were significant tests of simple effects. The type I error rate was set at 0.05 and the type II error rate was set at 0.2 (ie, power = 0.8). Power analysis was conducted as per Keppel.[8]

RESULTS

The absolute difference between the 2 repeated measurements of vertical navicular height for each of the treatment conditions expressed as the lower and upper bounds of the 95% confidence interval was 0.43–0.67 for control, 0.41–0.59 for tape, and 0.73–1.01 mm for orthotic. The ICC for the 2 repeated measures of vertical navicular height immediately after the application of the tape, orthotic and control was 0.99, 0.97, and 0.99, respectively.

Main Study

The mean ± standard error of the mean (SEM) for orthotic, tape, and control at each measurement time are presented in Table 1 and Figure 4. Inspection of the tabulated and plotted data indicated the presence of both main and interaction effects. The omnibus 2 factor repeated measures ANOVA confirmed this, demonstrating significant main effects for the treatment condition and measurement time, as well as for their interaction (Table 2A). In view of the significant interaction effect ($F_{4,52} = 12.18$, $P < .01$), further analysis of the data involved tests of simple effects. This entailed a test of simple effects for treatment conditions nested within each level of exercise challenge (0, 10, and 20 minutes of jogging; Table 2B) and a simple effects test for exercise challenge nested within each of the treatment conditions (control, orthotic, and tape; Table 2C).

Treatment Technique Effect at Each Stage of the Exercise Challenge

There was a significant simple effect of the treatment technique factor at each of the three stages of exercise challenge (Table 2B). Post hoc pairwise comparisons of group means with the Tukey HSD test indicated that at each stage of the exercise challenge (0, 10, and 20 minutes), both tape (expressed as a mean percentage and mean millimeter change in vertical navicular height) and orthotics produced a significantly greater percentage change in vertical navicular height than did control (Figure 4 and Table 2A and 2B). The difference between tape and orthotic was not statistically significant before or after exercise challenge.

TABLE 2. Summary table for Omnibus ANOVA (A) and tests of simple effects: treatment within exercise challenge (B), and exercise challenge within each treatment technique (C).

Source of variation	*df*	MS	*F*
(A)			
Treatment conditions	2	2887.47	59.39*
Error	26	48.62	
Exercise challenge	2	1208.63	85.90*
Error	26	14.07	
Treatment conditions by exercise challenge	4	93.22	12.18*
Error	52	7.66	
(B)			
Treatment conditions after 0 min exercise	2	1499.29	61.51*
Error	26	24.38	
Treatment conditions after 10 min exercise	2	833.97	47.58*
Error	26	17.53	
Treatment conditions after 20 min exercise	2	740.65	33.63*
Error	26	22.03	
(C)			
Exercise challenge on control	2	175.1	32.69*
Error	26	5.36	
Exercise challenge on orthotic	2	251.89	29.59*
Error	26	8.51	
Exercise challenge on tape	2	968.07	62.41*
Error	26	15.51	

* $P < .01$.

Exercise Challenge Effect on Each Treatment Technique

A significant test of simple effects of the exercise challenge on each treatment technique was evident (Table 2C). Post hoc testing revealed the mean percentage change in vertical navicular height, had significantly reduced in each treatment condition over the 20 minute exercise period (Table 2C). The control condition demonstrated a significant reduction of mean percentage change in vertical navicular height from −0.8% to −6.4% over the first 10 minutes and no further significant change in the second 10 minutes (−6.4% to −7.3%). With the tape, there was a significant reduction in the mean percentage change in mean vertical navicular height from 19.0%–5.9% over the first 10-minute period, but not over the second 10-minute period (5.9%–3.5%). The orthotic demonstrated a significant reduction of mean percentage change in vertical navicular height from 14.4%–7.7% in the first 10 minutes with no further significant reduction over the second 10-minute exercise period (7.7%–6.5%).

DISCUSSION

The findings of this study demonstrate that both the augmented LowDye tape and temporary felt orthotics are effective in controlling vertical navicular height following 20 minutes of exercise. Although there was no statistically significant difference in the control of vertical navicular height provided by the tape and orthotic, there was an apparent pattern in Figure 4 which indicated that the tape was more effective in controlling vertical navicular height immediately following application, whereas the orthotic maintained correction more effectively than tape did over the 20-minute period of exercise. These biomechanical findings support the clinical practice of using antipronation taping at the first consultation to control abnormal pronation, so as to determine the association between abnormal pronation and the patient's symptoms. In addition, it supports the use of temporary orthotics as a treatment technique to provide antipronation control over a relatively extended period of time as a means of assessing the effect of an in-shoe device, prior to the prescription and fabrication of more expensive orthotic devices.

The findings of this study and those of Vicenzino et al[16] demonstrate that without the inclusion of the control condition, the taping and orthotic procedures may well have been shown to be ineffectual as both the effectiveness of the tape[1,16] and orthotic significantly decrease over the 20-minute exercise period. The inclusion of a control condition provides essential information from which to make judgements about the effectiveness of the treatment techniques across time and particularly during a period of exercise.

Findings for the augmented LowDye are similar to those reported by Vicenzino et al[16] and support the use of the augmented technique to control pronation in patients who exhibit symptoms related to excessive pronation during jogging.[16] Ator et al[1] proposed that the loss of effectiveness of the LowDye after 10 minutes of jogging may be explained by a reduction in the tape's adhesion to the skin or a loss in tensile strength of the tape. The greater and longer-lasting antipronation effect produced by the augmented LowDye implies that adhesion to the skin and the tensile properties of the tape may not be the only determinates of taping efficacy. The greater surface area of contact of the tape on the distal leg also appears to be implicated as one of the determinants of taping efficacy, possibly by contributing to a larger antipronation moment.

Ator et al[1] suggested that it may be the extremes of pronation range that lead to injury of the soft tissue structures that control pronation. They proposed that antipronation taping may prevent excursion into the extremes of range and thus prevent injury. Based on the tissue stress model of McPoil and Hunt,[10] the antipronation techniques may prevent deformation of the soft tissue beyond the elastic region of the load-deformation curve, and thus provide a means to rest over-stressed tissues. Consistent with previous research, the effectiveness of both the augmented LowDye and temporary felt orthotics in controlling vertical navicular height was reduced following exercise challenge, although not to the same extent as the reduction in vertical navicular height in the control condition. Further research is required to determine the extent to which pronation needs to be controlled in order to prevent excessive soft tissue deformation and to ameliorate symptoms in subjects who have overuse injuries that are associated with abnormal pronation.

Interpretation of the results of this study, particularly when making inferences to the clinical domain, relies to some extent on the reliability of the measures used, the number of subjects that were studied, and the decision to study only the right foot. Consistent with other studies,[1,16] the method of measuring vertical navicular height that was used in this study was found to be reliable over two repeated measures by the same investigator. This finding further strengthens the results of this study. There were 14 subjects in this study. This could be construed as representing a relatively small sample size, and, therefore, a limitation of the study. However, power analysis demonstrated an acceptably low risk of a type II error ($\omega^2 = 0.341$, $\beta < .1$, $\alpha < .01$, $n = 14$), indicating that an adequate sample size was used in this study.

CONCLUSION

This study demonstrated that when compared to a nontreatment control condition, both the augmented LowDye tape, and temporary felt orthotic were effective in controlling pronation immediately following application and after 20 minutes of jogging. The ability of these techniques to control pronation during weight bearing exercise indicates that they may be useful in correcting abnormal pronation as part of the clinical assessment and treatment of overuse injuries.

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