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Effectiveness of neuromuscular taping on pronated foot posture and walking plantar pressures in amateur runners

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ABSTRACT

Objectives: To determine the effect kinesiotaping (KT) versus sham kinesiotaping (sham KT) in the repositioning of pronated feet after a short running.
Design: Prospective, randomised, double-blinded, using a repeated-measures design with no cross-over.
Methods: 116 amateur runners were screened by assessing the post-run (45 min duration) foot posture to identify pronated foot types (defined by Foot Posture Index [FPI] score of ≥6). Seventy-three runners met the inclusion criteria and were allocated into two treatment groups, KT ($n = 49$) and sham KT ($n = 24$). After applying either the KT or sham KT and completing 45 min of running (mean speed of 12 km/h), outcome measures were collected (FPI and walking Pedobarography).
Results: FPI was reduced in both groups, more so in the KT group (mean FPI between group difference = 0.9, CI 0.1–1.9), with a score closer to neutral. There were statistically significant differences between KT and sham KT ($p < .05$ and $p < .01$) in pressure time integral, suggesting that sham KT had a greater effect.
Conclusions: KT may be of some assistant to clinicians in correction of pronated foot posture in a short-term. There was no effect of KT, however on pressure variables at heel strike or toe-off following a short duration of running, the sham KT technique had a greater effect.
Level of evidence: Therapy, level 1b.

1. Introduction

A pronated foot type has been associated with a number of lower limb injuries, including medial tibial stress syndrome[1] and patellafemoral pain syndrome.[2] Extremes of foot posture such as a pronated (flat) foot type can present with an increased medial contact area and greater medial forces and pressures.[3] Consequently there is a greater risk of injury in those with pronated foot types in comparison to normal foot types.[4] A pronated foot type is associated with excessive foot pronation; defined as a flattening or loss of the medial longitudinal arch,[5] where hindfoot and midfoot joints exhibit movement that is greater than those in the comparative normal groups.[6] In the lower limb, there is a high prevalence (79–90%) of running injuries and pronation has been cited as a contributing factor, particularly in collegiate and military populations[7]. For example, long distance runners show greater peak pressure in the medial forefoot during running[8] and static pronated foot posture has been associated with knee injuries.[7]

In sports, taping is widely used as a treatment in the prevention and treatment of foot and ankle disorders. Evidence suggests that traditional (low-dye) taping can be an effective treatment by controlling foot motions, specifically excessive pronation.[9] Rather than utilising firm restrictive traditional tape, there is growing popularity in the use of kinesiotaping (KT). The effect of KT to control foot pronation, however is unclear due to a lack of published studies.

Kinesiotaping is applied using traditional taping techniques and designed to mimic the qualities of human skin; it is as thin as the epidermis and can be stretched between 30% and 40% of its resting length longitudinally.[10] The mechanism of action of KT has been speculated, however only a limited number of studies have investigated the effect of KT on pain and joint motion.[11] In the foot and ankle for instance, a study to assess the effect of KT on ankle proprioception no enhancement of joint proprioception was shown, however the study was limited by a small sample size and an absent control group.[12] More recently there has been a short-term study to examine the effect of KT on plantar fascia clinical outcomes. The results suggest that there were greater clinical improvements in

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Table 1
Characteristics of the sample and per KT and SKT group.

	Experimental group (KT) $n = 49$		Sham group (SKT) $n = 24$		Total group $n = 73$	
	Mean (SD)	CI 95%	Mean (SD)	CI 95%	Mean (SD)	CI 95%
Age in years	29.5 (5.3)	28.0–31.05	27.62 (7.1)	24.60–30.64	28.9 (6.0)	27.50–30.30
Weight in kg	69.3 (9.5)	66.5–72.04	73.20 (7.9)	69.89–76.52	70.6 (9.1)	68.45–72.72
Height in cm	172.7 (7.2)	170.6–174.78	176.0 (5.6)	1.74–1.78	174.0 (7.3)	172.3–1.75
Running hours/week	11.12 (1.9)	10.58–11.66	13.20 (2.5)	12.06–14.18	11.78 (2.29)	11.24–12.31
FPI	7.7 (1.4)	7.13–8.28	7.77 (1.7)	7.27–8.27	7.75 (1.61)	7.38–8.13

the KT group compared to usual clinical care[13], however the study was limited by the absence of a comparative control group. Even in a higher quality study (using a double blind randomised experimental method) of hindfoot KT, the results suggest there was no immediate or lasting (24 h) effect on pronated foot posture.[14] These foot and ankle studies suggest the clinical and biomechanical mechanism of KT is not well understood. This may be due to a lack of high quality clinical KT studies recently highlighted in a meta-analysis, the review concluded that KT may act as a placebo effect[11] and that further biomechanical and clinical studies are needed. To our knowledge no studies have examined the effect of KT on plantar pressures. The aim of this study was to address the lack of biomechanical studies and determine the short-term effect of KT on foot posture and the walking foot pressures in amateur runners with pronated foot type.

2. Methods

The study was a double-blind, two-arm experimental study. At screening, participants were randomised into two groups to receive either KT or sham KT. This biomechanical study was designed to examine the short-term effect of KT, no follow-up was undertaken. This study aimed to recruit a minimum of 20 participants into each group, which is the recommended sample size for preliminary 2-arm studies where precision plateaus after 20 participants.[15]

A convenience sample of amateur runners was approached, who were physically active candidates for entry into the fire department. The potential recruits were asked to attend a screening appointment to examine the post-run foot posture. A group of 116 runners were screened, of which 73 met the inclusion criteria: a pronated foot type (as defined by the Foot Posture Index [FPI][16] confirmed on the right limb), the participant characteristics of the sample are shown in Table 1.

Other inclusion criteria were (i) regular participation in running (continuous running >45 min, a minimum of three times per week, or to practice sports more than 10 h/week); (ii) FPI defined pronated foot type defined as a score of 6–12; (ii) no foot or ankle injury within the previous 6 months; (iv) no foot or ankle pain at the time of the study; (v) age between 18 and 40 years; and (vi) able to provide informed, written consent. Exclusion criteria were: (i) degenerative bone and joint diseases (diagnosed from medical history); (ii) lower limb surgery; (iii) recent knee-ankle injuries or serious foot injury that could have left morphological alterations; (iv) obvious leg length discrepancy; (v) loss of balance measured with Romberg's test; (vi) painful cutaneous conditions such as callus or plantar warts and (vii) oedema on foot-ankle articulation that may make difficult or mask any necessary details for collecting the FPI. All procedures were approved by the Medical Research Ethics Committee of Faculty of Health Science, University of Malaga (ID: 07/2011) and in accordance with the Declaration of Helsinki.

At the screening session, all participants ran continuously for 45 min on a 9 km long circuit, at a paced speed (5 min per kilometre) using a smart phone application (average speed 12 km/h, standard deviation of 4.57–5.02). After the exercise, two assessors measured the FPI (GGN) and plantar pressures (JAV). Both the FPI and plantar pressures were analysed from the right foot only, to avoid selection bias and breaching assumptions of statistical independence in bilateral limb studies.[17] Participants were randomised into the two groups KT and sham KT using a manual method of flipping a coin. After screening, participants who met the inclusion criteria ($n = 73$) were invited back on a separate day to assess the effect of KT upon FPI and walking pressures.

The Foot Posture Index was assessed by a podiatrist (GGN) with an established high intra-rater reliability of FPI scoring (Intraclass correlation coefficient [ICC] = 0.91–0.98),[14] who was blinded to the purposes of the study and the participant's identity. The FPI is a six-item clinical assessment tool used to evaluate foot posture,[16] with an acceptable validity[18] and good intra-rater reliability (ICC = 0.893–0.958).[19] The FPI evaluates the multi-segmental nature of foot posture in all three planes, and does not require the use of specialised equipment. Each item of the FPI is scored between −2 and +2, to give a total between −12 (highly supinated) and +12 (highly pronated). Items include: talar head palpation, curves above and below the lateral malleoli, calcaneal angle, talonavicular bulge, medial longitudinal arch, and forefoot to hindfoot alignment.

Plantar pressure was assessed, using Biofoot (IBV, Valencia, Spain); an instrumented in-shoe insole system over a period of 6 s.[20] This mobile system is commonly used in Spain as a reliable means to capture and analyse walking in-shoe plantar pressures in healthy pain free and foot pain groups (coefficient of variation between two sessions was around 7%, range: 4.6–9%)[20]. The insoles contain 64 piezoelectric pressure sensors (sampling rate of 100 Hz) of 0.5 mm thickness and 5 mm diameter calibrated according to the manufacturer's instructions. The participants were encouraged to acclimatise to the insoles, which were placed in the participants own training shoe for both screening and intervention sessions.

Pressure measurements were taken while walking along a 20 m line, in a single direction and at a self selected walking speed. This procedure was followed for both walking trials. All the participants were asked to walk normally, the measurements began during the middle of the walkway without informing the participants to encourage natural gait. Six steps were recorded and repeated three times, in order to obtain an average. In order to record and analyse data, specific software, Biofoot/IBV 6.0 (IBV, Valencia, Spain) was used to divide the foot into 3 regions: hindfoot, midfoot, forefoot (Fig. 1). The data were gathered and stored in a computer using digital telemetry.

The anti-pronation KT was applied by a specialised sports physiotherapist (MBA) (un-blinded) with more than 8 years of experience (see Fig. 2). Kinesiotaping was applied according to procedures recommended by Pijnappel et al.[21] and using Low-Dye Taping criteria of correction.[22] Standard 5 cm Black Irisana©tape was used for both groups. The taping had two parts: (i) the hindfoot: a single strip, 25 cm in length, was applied from the fibula (lateral malleolus), around the calcaneus, with 75% stretch, to the middle third of the medial tibia. (ii) The midfoot was applied from the base of the 5th metatarsal bone, cross the talo-navicular joint and surrounding the midfoot, and ascending to reach the internal aspect

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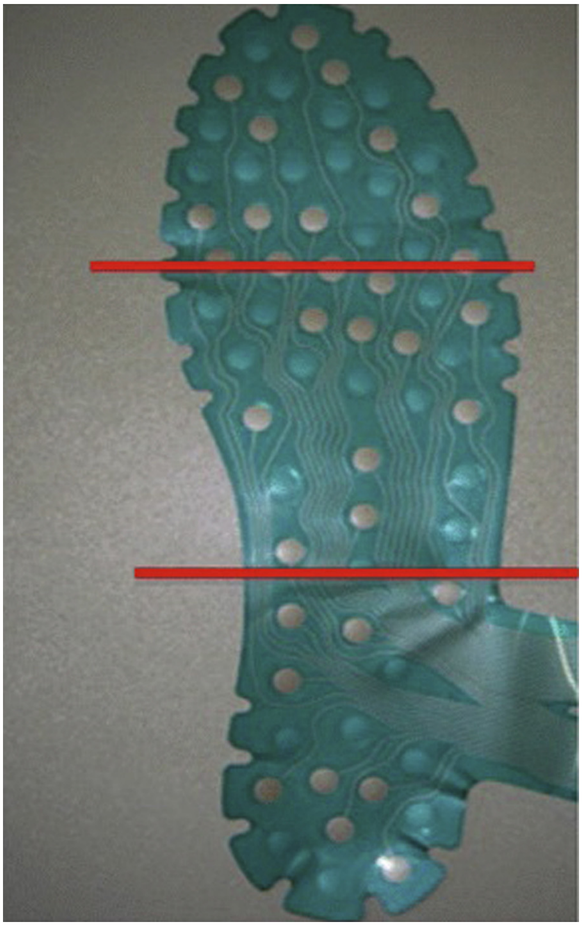

Fig. 1. Biofoot IBV 6.0 (IBV, Valencia, Spain) plantar pressure mask: forefoot, midfoot, rearfoot.

of the middle third of the tibial bone, also with 75% stretch. The first strip was applied with the subject in supine and the hindfoot placed in a supinated position. The second strip was applied with the subject in maximum supinated position following the direction described before to finally place the foot in maximum dorsal flexion ending at the internal aspect of the mid third of the tibial bone as shown in Fig. 2. Once applied, the instructor warmed up the KT strip by rubbing it three times from the fibula (malleolus) to the middle third of the tibia in order to maximise tape adhesion.

In order to simulate the experimental taping technique (KT) but without the mechanical effect, the sham KT was applied in an identical manner but without tension and without any mechanical correction in a similar protocol to a shoulder trial.[23] The sham KT was applied to hindfoot, the first strip positioned the heel in neutral, a longer strip of tape (28 cm) was used as the tape was not stretched. This resulted in the tape travelling the same distance on the patient's skin as the KT group, and enabled blinding of the participant and the outcome assessor.

Both the screening and intervention assessments were undertaken two days apart under the same conditions (at the same time and place to avoid within day variation[24]). Participants repeated the same procedure as the first day (continuous running during 45 min). The same assessors repeated both tests (FPI and plantar pressures) at screening and the intervention appointments of participants after removing the kinesiotape. At the intervention appointment, the FPI assessor was blinded by using a folding screen, which was placed between the subject and the assessor, and only the foot and 10 cm of shank were visible[14]. Participants were assessed while in a relaxed standing position, on a bench 50 cm tall to enable visual and manual inspection.

SPSS v. 19.0 program (IBM Inc., USA) was used to perform the statistical calculations using descriptive and inferential statistical tests. The pressure data was tested for normality by using the Kolmogorov–Smirnov test, set at a significance level of $p < 0.05$. Biofoot baropodometric derives a large number of variables from the in-shoe pressure measurement. In this study key variables were chosen pressure time integral (PTI KPa/s) at heel strike and toe off.[20] Pressure outcomes were calculated as the mean of 3 walking trials[20] and a group mean was calculated pre and post treatment to assess the within group changes and the between groups differences.

All variable in the FPI and plantar pressures were normally distributed therefore ANOVA repeated measures test was chosen to measure differences (2 × 2 factors) the criterion of significance was $p < 0.05$. When multiple significant results were found, Bonferroni's post hoc adjusted method correction was applied. The difference between FPI and pressure data was compared within group post-running without and with taping. Mean between group differences were made comparing KT and sham KT groups and the confidence interval (CI) was calculated.

3. Results

Participants were allocated into two unequal groups, experimental KT ($n = 49$ participants) and sham KT ($n = 24$ participants), with a pronated foot type (FPI score >6). Table 2 shows the effects of active KT compared with sham KT on FPI score and the pedobarography results, presenting the mean differences between the KT and sham KT and associated 95% confidence before and after the treatment. There were significant differences in the change in the post running foot posture scores pre and post treatment. The mean FPI scores reduced in both groups; KT = 3.6 (CI 3.1–4.1) and sham

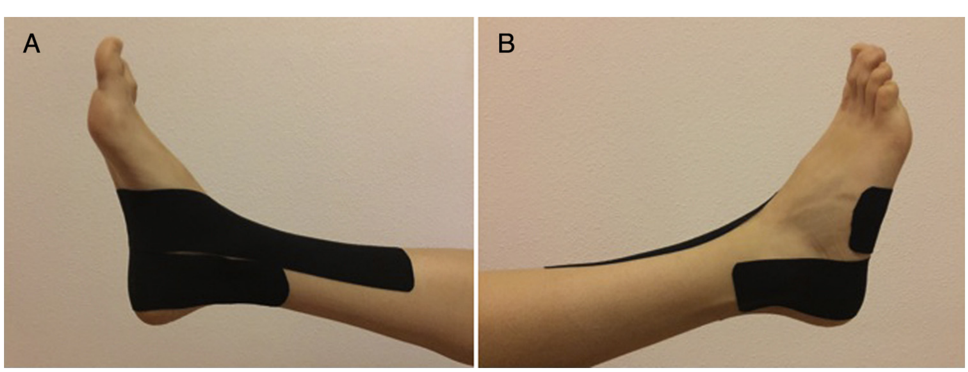

Fig. 2. Placement of the two strips kinesiotaping (a: medial view, b: lateral view).

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Table 2
A comparison of outcome data for FPI and plantar pressure per kinesiotape (KT) and sham.

	Kinesiotape Group (KT) $n = 49$		Sham Group (Sham KT) $n = 24$
Foot Posture Index			
Mean pre-treatment (SD)	7.8 ± 1.7		7.7 ± 1.4
Mean post-treatment (SD)	4.1 ± 2.2		5.1 ± 2.9
Pre/post within-group change scores	**3.6 (3.1,4.1)***		**2.7(1.8, 3.3)***
Pre/post between-group change scores		**0.9 (0.1, 1.9)***	
Heel strike rearfoot PTI			
Mean pre-treatment (SD)	7.4 ± 9.5		9.6 ± 6.8
Mean post-treatment (SD)	6.2 ± 10.7		2.4 ± 3.8
Pre/post within-group change scores	**1.2 (−2.6, 4.9)**		**7.1 (1.8, 12.4)***
Pre/post between-group change scores		**5.9 (11.4, 0.4)***	
Heel strike midfoot PTI			
Mean pre-treatment (SD)	16.2 ± 16.6		17.6 ± 14.0
Mean post-treatment (SD)	11.4 ± 13.9		6.04 ± 8.7
Pre/post within-group change scores	**4.8 (−0.4, 10.0)**		**11.5 (4.1, 18.9)***
Pre/post between-group change scores		**6.7 (15.7, −2.3)**	
Heel strike forefoot PTI			
Mean pre-treatment (SD)	20.8 ± 17.9		18.7 ± 21.5
Mean post-treatment (SD)	19.8 ± 20.3		13.4 ± 11.7
Pre/post within-group change scores	**1.0 (−5.8, 7.9)**		**5.3 (−4.5, 15.1)**
Pre/post between-group change scores		**4.2 (16.2, −7.7)**	
Toe-off rearfoot PTI			
Mean pre-treatment (SD)	79.7 ± 21.7		80.8 ± 21.0
Mean post-treatment (SD)	86.2 ± 18.7		89.4 ± 15.4
Pre/post within-group change scores	**−6.4 (−14.6, 1.8)**		**−8.6 (−20.3, 3.1)**
Pre/post between-group change scores		**−2.2 (12.1, −16.4)**	
Toe-off midfoot PTI			
Mean pre-treatment (SD)	70.9 ± 25.5		60.8 ± 29.7
Mean post-treatment (SD)	73.7 ± 31.9		90.7 ± 10.7
Pre/post within-group change scores	**−2.8 (−13.6, 7.9)**		**−29.9 (−45.2, −14.5)***
Pre/post between-group change scores		**27.0 (8.3, 45.7)***	
Toe-off forefoot PTI			
Mean pre-treatment (SD)	84.0 ± 21.6		73.5 ± 27.4
Mean post-treatment (SD)	83.5 ± 25.1		95.5 ± 6.0
Pre/post within-group change scores	**0.5 (−8.6, 9.6)**		**−21.9 (−35.0, −8.9)***
Pre/post between-group change scores		**22.5 (6.5, 38.4)***	

Kinesiotape (Sham KT) groups presented as mean and confidence intervals (CI).
PTI = pressure time integral reported in KPa per second.
Pre/post = pretreatment to immediately post-treatment, $^{*}p < 0.01$.
Pre and post treatment values are mean ± SD, except for between and within group differences, which are mean and 95% confidence intervals.

KT = 2.7 (CI 1.8–3.3). There was also a difference in between the KT and sham KT group scores of 0.9 (CI 0.1–1.9). In both the treatment and sham groups, the FPI scores were lower after running, with a trend towards a more neutral foot type but with a larger statistically difference ($p < 0.001$) in the experimental group.

The results of the pressure time integrals (PTI) showed small reductions in the pre and post KT group at heel strike for the hindfoot, midfoot and forefoot. At toe-off small increases PTI were shown in the KT group in the hindfoot and midfoot and very little change was shown at the forefoot. Comparatively the sham KT group demonstrated greater decreases in hindfoot, midfoot and forefoot PTI. There was a between group reduction in midfoot pressure in the sham KT group at heel strike of 5.9 kPa/s (CI 11.4–0.4). At toe-off there were similar small increases in PTI at heel, however at the midfoot and forefoot at toe-off there were significant differences between KT and sham groups. At the midfoot there was a large increase in PTI in the sham KT group 29.9 kPa/s (CI 45.2–14.5), while in the KT intervention group showed a small amount of change in PTI 2.8 kPa/s (CI −13.6 to 7.9), resulting in a large between group difference 27 kPa/s (CI 8.3–45.7). At the forefoot there was a similar pattern of small changes in the KT group 0.5 kPa/s (CI −8.6 to 9.6) and a large increase in the sham group 21.9 KPa/s (CI 35.0 to 8.9). Resulting in a large between group difference of 22.5 kPa/s (CI 6.5–38.4).

4. Discussion

The aim of this study was to determine the short-term effect of KT on foot posture and the walking foot pressures in amateur runners with pronated foot posture; as measured by the FPI. To accomplish this we used anti-pronation neuromuscular KT before running and measured walking foot pressures and foot posture after a short run (45 min). The most important result observed in this study was the change of FPI scores, which reduced in both groups towards a neutral position. The KT group showed statistically greater reduction than the sham control group, with results with the closest scores to neutral (mean index score 4.75 ± 2.78). This may be due to the exteroceptive action that this taping method,[25] although this action may occur when applied with no tension, which could have provoked an unconscious mechanism of correction in the participants. This positive effect is not exclusive of neuromuscular taping as similar effects have been reported in other taping methods.[26]

The patient belief in the taping technique is thought to produce a placebo effect has been previously described. Sawkins et al. demonstrated a placebo effect of functional taping in participants with unstable ankles, where comfort and confident sensation was positively reported without a biomechanical effect[27]. Luque-Suarez et al. showed the short-term efficacy of neuromuscular taping and functional taping and found statistically different and important changes in the correction of pronated and supinated hindfoot position when applying placebo neuromuscular taping (sham-tension).[14]

This is the first study to examine the effect of KT on walking pressures (post running of 45 min duration). The results showed that the application of the KT taping had very little effect on hindfoot, midfoot or forefoot pressure (PTI) at heel strike. While in the sham KT group, a small but consistent reduction on PTI in the hindfoot region at heel strike was shown. The greatest effect of the taping was in terminal stance, in the sham KT group there was a large increase of PTI at the midfoot (50%) and forefoot (30%) in terminal stance, while in the experimental KT group there was little to no change in PTI. Taken together these results suggest the sham KT may have a similar and even greater effect on the foot pressure than KT. Although the differences between the groups may be explained by unequal grouping, as the sham KT group was smaller and therefore susceptible to greater variability.

These changes in the plantar pressures shown in this study are not similar to other walking pressure studies of functional low-dye taping in a similar group of participants with a pronated foot posture. Lange et al. showed a significant decrease of pressure under the heel and the medial forefoot, while the midfoot was the only area, which showed there was an increase the peak pressure.[28] Nolan et al. showed low-dye tape reduced the peak pressure in the forefoot, although this effect was lost after 10 min of use.[29] O'Sullivan et al. showed significant increases in plantar pressure in the lateral midfoot and decreases in the medial forefoot and hindfoot.[10] No changes occurred in the medial midfoot or lateral forefoot.[10] These pressure studies of low-dye taping do not suggest that taping causes a systematic change in foot pressures, however it is unclear if these results are the result of poor reliability in the measurement of plantar pressures or differences in Pedobarography systems.

Previous studies have not produced conclusive evidence of the effects of KT. The findings of this study must be interpreted with caution as this was a of short duration study in healthy physically active young individuals. This study was carried out in healthy subjects to understand the potential effect of KT on functional variables, the results of this KT study may differ if we had recruited participants with foot/ankle pain. Further work is therefore recommended to understand the functional and clinical effect of KT in a clinical cohort.

This study did not show that KT had any effect on walking plantar pressures compared to the sham KT, perhaps by measuring plantar pressures during running, a different outcome may have been found. Further studies examining the effect of KT on running plantar pressures would now be recommended.

Methodological issues such as unequal sampling and study limb choice may have biased the study. The right limb was pre-defined in this study as the avoid selection bias; this is a limitation, we would recommend randomisation of the study limb in future studies.

Unequal sampling in this study was unintentional, randomising the groups at the screening appointment and later excluding participants without a pronated foot type led to a larger intervention group (double the size of the sham group). Although unequal sampling may affect group comparisons, this is does not necessarily reduce the power proportionally; approximate 5% power reduction has been previously reported.[30] In future studies we would recommend equal randomisation into each group at the time of the intervention using predefined numerical allocation to avoid bias.

The clinical use of KT now requires further investigation in the foot and ankle, and further mechanism of action studies using kinematic analyses are now required with a sham control. The results of this experimental study suggest there is some gain in applying the tape prior to intense physical activity to change foot posture. Further gait studies would confirm if there was an alteration of hindfoot kinematics as there does not appear to be any effect of KT in plantar pressures and it is not clear if the effect of sham KT is due to the effect of a thicker tape that may reduce the range of motion at the hindfoot.

5. Conclusions

This study suggests KT can modify static pronated foot posture in amateur runners towards a more neutral position after a short run (45 min duration). Kinesiotaping appears to have very little effect in the change of foot pressures, in contrast the sham KT technique (without tension) appeared to have a greater effect by increasing pressure time integral, in midfoot and forefoot regions, in terminal stance. To further investigate these objective outcomes, KT should be tested over a longer period of time and applied in a clinical population to determine clinical significance.

Practical implications

- The use of kinesio®taping after short-term intense exercise can alter standing foot posture, which could be of interest in the correction of the foot posture misalignments.
- The use of kinesio®taping did not have any effect on discrete plantar pressure variables (PTI).
- Sham kinesio®taping technique without the stretch (a greater thickness than traditional KT applications) may have a greater effect on plantar pressures in terminal stance.

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This study did not receive any funding.

Conflict of interest

All the authors declare that they have no conflict of interest derived from the outcomes of this study.

Ethical approval

Institutional Review Board that approved the protocol for the study: Medical Research Ethics Committee of Faculty of Health Science, University of Malaga (ID: 07/2011).

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