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The influence of semi-custom orthoses on multi-segment foot kinematics in males.

by Jonathan Sinclair*, James Richards, Paul John Taylor, Hannah Shore

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The current investigation aimed to investigate the influence of semi-custom orthoses on multi-segment foot kinematics and plantar fascia strain in recreational runners. Fifteen male runners ran at 4.0 m.s^{-1} with and without orthotics. Multi-segment foot kinematics and plantar fascia strain were obtained using a 3D motion capture system. Differences between orthotic and no-orthotic conditions were examined using paired samples t-tests. The results showed firstly that orthoses did not significantly ($p>0.05$) improve plantar fascia strain. Relative transverse plane ROM rearfoot-tibia articulation was however significantly ($p<0.05$) reduced when wearing orthotics. This indicates that there may be some benefit from orthotic intervention. However, the mean reduction in angulation between orthotic and no-orthotic conditions was very small and thus further prospective investigations regarding the clinical efficacy of semi-custom orthoses are required.

Key words: orthotics, kinematics, plantar fascia, distance running

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Distance running associated with a large number of health benefits, both physical and psychological [1, 2]. However, epidemiological research has shown that chronic pathologies are a frequent complaint amongst runners [3]. As many as 80% of runners will experience a chronic injury as a consequence of their training over a one year period [4].

Foot orthoses are an extremely popular accessory for runners. It has been postulated that foot orthoses are able to attenuate the high rate of injuries in runners. As such they have received considerable research attention. The majority of research into the efficacy of foot orthoses has examined either impact loading or rearfoot eversion. Sinclair et al., [5] showed that an off the shelf orthotic significantly reduced both loading rate and tibial acceleration parameters but did not change rearfoot eversion.

Address correspondence to:
Jonathan Sinclair,
Division of Sport, Exercise and Nutritional Sciences
School of Sport Tourism and Outdoors
University of Central Lancashire,
Preston
Lancashire
PR1 2HE.
e-mail: jksinclair@uclan.ac.uk

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Laughton et al [6] showed similarly that foot orthoses served to significantly reduce the loading rate of the ground reaction force but once again did not affect rearfoot eversion. Dixon, [7] investigated the effects of placing a commercial orthotic inside a military boot. The findings showed that the orthotic device reduced the vertical rate of loading in comparison to running without orthotic intervention, although rearfoot eversion remained unchanged.

The effects of foot orthoses on multi-segment foot kinematics have received only limited attention in biomechanical research. Only a small number of studies have investigated the effects of orthotics on multi-segment foot kinematics. Cobb et al [8] found greater rearfoot dorsiflexion during the stance phase when walking with an orthotic; they concluded that this may promote improved foot kinematics. Sinclair et al., [9] studied the influence of off the shelf orthoses on multi-segment foot kinematics and plantar fascia strain. They showed that whilst the orthotic altered the coronal and transverse plane angles of the foot segments there was no improvement in plantar fascia strain. Ferber & Benson, [10] investigated the effects of semi-custom heat mouldable orthoses on multi-segment foot kinematics and plantar fascia strain during overground walking. Their findings showed that plantar fascia strain was significantly reduced when wearing orthotics, but that no differences in multi-segment foot kinematics were evident. However this investigation only measured a limited number of discrete kinematics parameters from the foot segments. Furthermore there currently remains no information regarding the effects of custom orthoses during running.

The aim of the current investigation was therefore to examine the effects of semi-custom orthotics on 3D multi-segment foot kinematics and plantar fascia strain during the stance phase of running. This work may be helpful to runners who suffer from foot pathologies related to mal-alignment of the foot itself that may be treatable through orthotic intervention. The current investigation tests the hypothesis that orthotic intervention will serve to attenuate plantar fascia strain and reduce coronal and transverse plane motions of the foot segments.

Methods

Participants

Twelve male (age 22.1 ± 3.2 years, height 1.77 ± 0.07 meters, and body mass 73.24 ± 6.07 kg) recreational runners volunteered to take part in the current investigation. All were currently free from musculoskeletal pathology and did not have any history of prior surgery. All participants provided written informed consent and ethical approval was obtained from the University of Central Lancashire STEM ethical committee, in accordance with the principles documented in the declaration of Helsinki.

Orthoses

A commercially available orthotic (Sole, Softec response) was utilized for the current study. To mould the orthoses they were placed into a pre-heated oven (90°C) for three minutes. Following this the orthotics were then placed inside the participants shoes. Participants were asked to stand upright without moving for two minutes to allow the process of moulding the orthotics to take place.

Procedure

Participants completed five trials running at 4.0 $m.s^{-1}$ ± 5% with and without orthotic intervention. The order in which participants ran in each condition was counterbalanced. Multi-segment foot kinematics were obtained at 250 Hz using an eight-camera motion analysis system (Qualisys Medical, Sweden). Participants struck an embedded force platform (Kistler 9281CA, Kistler Instruments, UK) sampling at 1000 Hz with their dominant foot. The stance phase of running was determined as the time over which >20 N of force in the axial direction was applied to the force platform.

The calibrated anatomical systems technique (CAST) was used for modelling the foot and shank segments [11]. Markers were placed on anatomical landmarks in accordance with the Leardini et al [12] foot model allowing the anatomical frames of the rearfoot, midfoot, and forefoot to be defined. Markers were also positioned on the medial and lateral femoral epicondyles to allow the anatomical frame of the tibia to be delineated and a rigid tracking cluster was also positioned onto the tibia. Participants wore the same footwear throughout (Saucony Pro Grid Guide II, Saucony, USA). Windows were cut in the experimental footwear at the calcaneus and first metatarsal locations. The pre-established guidelines for length and width outlined by Shultz & Jenkyn [13] were adhered to.

Data-processing

Data were digitized using Qualisys track manager and exported to Visual 3D (C-motion, Germantown USA). Marker trajectories were filtered at 15 Hz using a low pass zero-lag Butterworth filter. This frequency was selected based on residual analysis [14]. Cardan angles were used to calculate 3D rotations of the foot segments. Stance phase angles were computed using and XYZ cardan sequence of rotations between the rearfoot-tibia, midfoot-rearfoot, forefoot-midfoot, and forefoot-rearfoot. Discrete 3D kinematic measures which were extracted for statistical analysis were 1) angle at footstrike, 2) angle at toe-off, 3) range of motion (ROM) from footstrike to toe-off during stance, 4) peak angle during stance, and 5) relative ROM (representing the angular displacement from footstrike to peak angle). Plantar fascia strain was quantified by calculating the distance between the first metatarsal and calcaneus markers and quantified as the relative position of the markers was altered. Strain strain was calculated as the change in length during the stance phase divided by the original length [10].

Statistical analyses

Differences in multi-segment foot kinematics and plantar fascia strain were examined using paired samples t-tests with significance accepted at the $p<0.05$ level.

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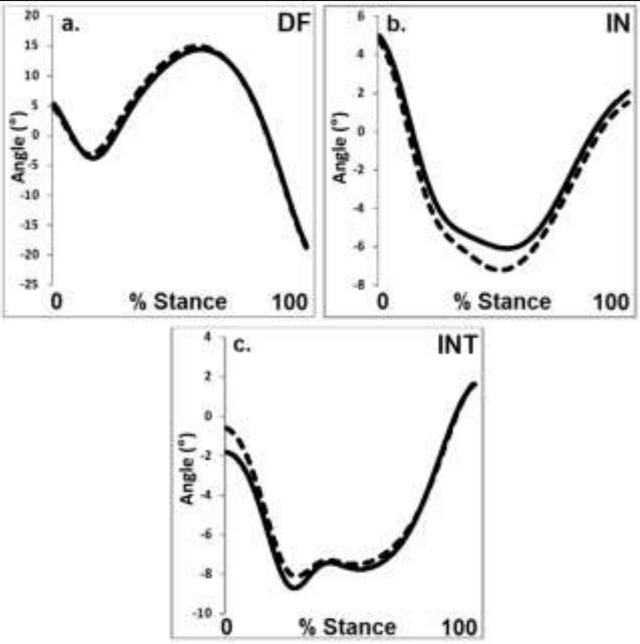

Figure 1 Rearfoot-tibial kinematics as a function of orthotic and no-orthotic conditions (black = orthotic & dash = no-orthotic).

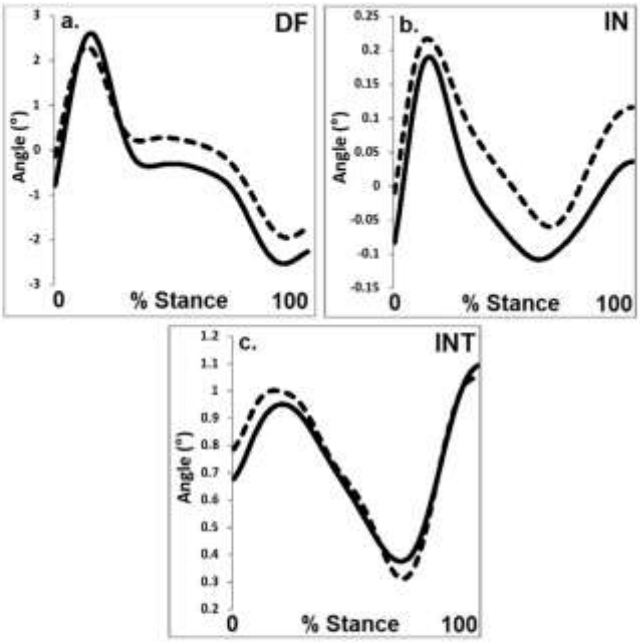

Figure 2 Midfoot-rearfoot kinematics as a function of orthotic and no-orthotic conditions (black = orthotic & dash = no-orthotic).

A Shapiro-Wilk test was used to screen the data for normality, and it was confirmed that the normality assumption was not violated. Effect sizes for all statistical main effects were calculated using eta^2 (η^2). Statistical procedures were undertaken using SPSS v22 (IBS, SPSS Inc USA).

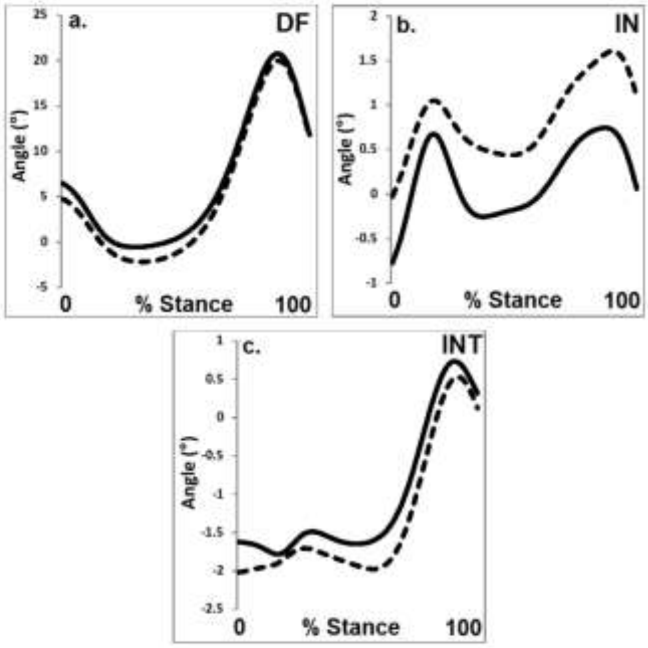

Figure 3 Forefoot-midfoot kinematics as a function of orthotic and no-orthotic conditions (black = orthotic & dash = no-orthotic).

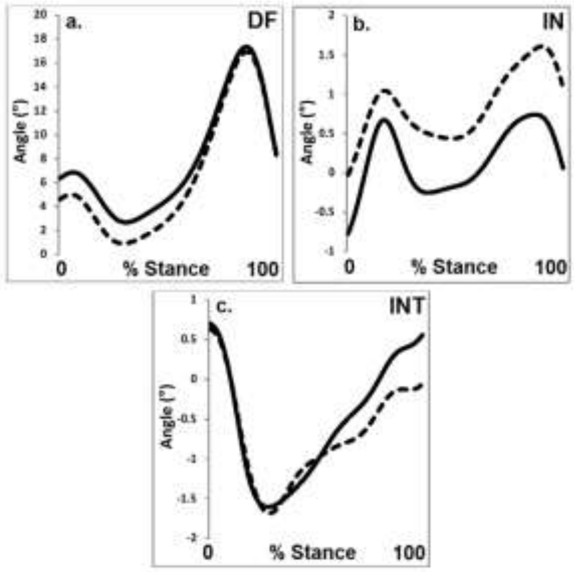

Figure 4 Forefoot-rearfoot kinematics as a function of orthotic and no-orthotic conditions (black = orthotic & dash = no-orthotic).

Results

Figures 1-4 presents the multi-segment foot kinematics obtained as a function of orthotic intervention and tables 1-4 show the discrete kinematic parameters. The results indicate that orthotic intervention significantly influenced multi-segment foot kinematics.

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Rearfoot – tibial angles

In the sagittal plane relative ROM was significantly ($t_{(11)}$ = 2.37, $p<0.05$, η^2 = 0.37) greater in the no-orthotic condition (Table 1; Figure 1a). In the transverse plane there was significantly ($t_{(11)}$ = 2.81, $p<0.05$, η^2 = 0.42) more external rotation at footstrike in the orthotic condition. Finally, relative ROM was significantly ($t_{(11)}$ = 2.37, $p<0.05$, η^2 = 0.38) greater in the no-orthotic condition (Table 1; Figure 1c).

Midfoot – rearfoot angles

In the sagittal plane relative ROM was significantly ($t_{(11)}$ = 2.30, $p<0.05$, η^2 = 0.30) greater in the no-orthotic condition (Table 2; Figure 2a).

Forefoot – midfoot angles

No significant differences ($p>0.05$) were shown between orthotic and no-orthotic conditions.

Forefoot – rearfoot angles

No significant differences ($p>0.05$) were shown between orthotic and no-orthotic conditions.

Plantar fascia strain

No significant differences ($p>0.05$) differences in plantar fascia strain were found between orthotic (8.00 ± 4.14) and no orthotic conditions (8.70 ± 4.69).

Discussion

The aim of the current work was to examine the effects of semi-custom orthotics on 3D multi-segment foot kinematics and plantar fascia strain during the stance phase of running. To the authors knowledge this represents the first study to investigate the effects of mouldable orthoses during running.

The first important observation is that the semi-custom orthoses did not reduce the strain experienced by the plantar fascia during the stance phase of running. This opposes our hypothesis and also the findings of Ferber & Benson [10] in which significant reductions in plantar fascia strain when wearing semi-custom orthoses. This finding does however concur with the results of Sinclair et al [9] who showed that off the shelf orthoses did not reduce plantar fascia strain during running. Plantar fasciitis is considered to be caused by excessive and frequent strain imposed on the plantar fascia itself [15], therefore the current investigation supports the notion proposed by Sinclair et al [9] in that orthoses may not be effective for runners seeking to treat plantar fasciitis. More importantly it also appears based on this study that a semi-custom orthotic does not provide any additional benefits in relation to an off the shelf device, although further comparative work is required before this can be fully substantiated.

In addition, the current investigation showed that the semi-custom orthotic served to mediate reductions in transverse plane relative ROM of the midfoot-rearfoot articulation. This finding concurs with our hypothesis and also those of Sinclair et al [9] who demonstrated that foot orthoses significantly reduced coronal and transverse plane rotations of the foot segments. Excessive transverse plane articulations between the foot segments have been associated with injury aetiology [16]; therefore it appears that there may be some benefit from orthotic intervention to improve foot function during running. However, the mean reduction in angulation between orthotic and no-orthotic conditions was very small and thus further prospective investigations regarding the clinical efficacy of semi-custom orthoses are required.

A limitation of the current investigation is that plantar fascia strain was calculated using markers positioned onto the foot segment. Using this procedure assumes that plantar fascia spans from the calcaneus to the first metatarsal. This technique has been utilized in previous research to quantify and resolve differences in plantar fascia strain [10, 17] and the values obtained during the current study correspond closely with previous values. Nonetheless this clearly represents a simplified approach for which there is certain to be some degree of error [9]. Currently this represents the only non-invasive technique for the quantification of plantar fascia strain; however it is recommended that future analyses consider the efficacy of more direct methods of measuring the kinematics of the plantar fascia during gait.

In conclusion, whilst the effects of foot orthoses on the biomechanics of running have been extensively researched, the current knowledge with regards to the effects of semi-custom orthoses is limited. This study aimed to address this by providing a comprehensive investigation of 3D multi-segment foot kinematics and plantar fascia strain when wearing a semi-custom orthotic device. The findings from the current study show that semi-custom foot orthoses do not serve to influence plantar fascia strain. In addition the transverse plane relative

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ROM of the rearfoot-tibial articulation was shown to be significantly reduced when the orthotic was used. Given the proposed relationship between transverse plane rotations of the foot segments and the aetiology of injury, there may be some benefit from orthotic intervention to improve foot function during running. However, the mean reduction in angulation was very small and thus further prospective investigation regarding the specific clinical efficacy of semi-custom orthoses is required.

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