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The influence of barefoot and shod running on plantar fascia strain during the stance phase of running

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The current investigation aimed to examine the influence of barefoot running or barefoot inspired footwear and shod running on the strain experienced by the plantar fascia during the stance phase of running. Fifteen male runners ran at 4.0 $m.s^{-1}$ in four different footwear conditions: barefoot, Vibram Five-Fingers, Nike Free, and conventional trainers. Plantar fascia strain was quantified using a motion capture system and compared between footwear using a one-way repeated measures ANOVA. The results showed that plantar fascia strain was significantly larger in the conventional (12.58 ± 4.65) and Nike Free footwear (10.18 ± 4.44) compared to the barefoot (5.54 ± 3.36) and Vibram five-fingers (6.24 ± 3.23) conditions. Given the proposed relationship between plantar fascia strain and the etiology of plantar fasciitis, it is proposed that runners may attenuate their risk of developing this pathology by training without shoes or using more minimalist barefoot inspired footwear.

Keywords: barefoot, plantar fasciitis, running

Recreational distance running training has been shown to be physiologically beneficial [1]. However, clinical research investigating the prevalence of running pathologies indicates that chronic injuries are an extremely prominent complaint [2]. Over the course of a one year period of training around 70% of runners will experience a chronic injury related to running [3]. Mal-alignment of the foot has been linked to the etiology of a number of chronic injuries [4]. The most common injury associated with abnormal foot mechanics is plantar fasciitis, which affects in excess of 10% of recreational runners [5]. In recent years, research and public attention towards barefoot training has expanded [6-10]. The clinical interest in barefoot running centers is on the supposition that running without shoes is associated with a reduced occurrence of chronic injuries [7,11].

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Based around the current popularity of barefoot training, new footwear models have been conceived that are designed to transfer the potential benefits of barefoot movement into a shod condition [8,9]. Currently a large number of barefoot inspired footwear models are commercially available; although their design characteristics vary considerably between the different models [12].

The mechanics of barefoot running and in barefoot inspired footwear have received extensive research attention [6-10], although a consensus does not yet exist regarding their clinical effectiveness. The majority of research in this area has investigated the kinetic and kinematic biomechanical parameters associated with the etiology of running injuries. Whilst the mechanics of barefoot running, barefoot inspired footwear, and conventional running trainers has received considerable interest, less attention has been paid to the effects of barefoot training on the strain experienced by the plantar fascia. This is surprising given the high incidence of plantar fasciitis in runners and the current interest in barefoot locomotion.

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Therefore the current investigation aims to examine the influence of barefoot running or barefoot inspired footwear and shod running on the plantar fascia. This study may be beneficial to runners who suffer from plantar fasciitis.

Methods

Participants

Fifteen male runners, volunteered to take part in this study. All participants were classified as natural rearfoot strikers by exhibiting a clear first peak in their vertical ground reaction force. All were free from musculoskeletal pathology at the time of data collection and provided written informed consent. The mean characteristics of the participants were age 23.73 ± 2.98 years, height 176.63 ± 6.22 cm, and body mass 72.08 ± 6.24 kg. The procedure utilized for this investigation was approved by the University of Central Lancashire, School of Sport Tourism and Outdoors, ethical committee. No external funding was provided by any of the footwear manufacturers examined in this investigation.

Procedure

Participants ran at 4.0 $m.s^{-1}$, striking a force plate (Kistler, Kistler Instruments Ltd., Alton, Hampshire) embedded in the floor (Altrosports 6mm, Altro Ltd,) with their right foot [13]. Running velocity was quantified using Newtest 300 infrared timing gates (Newtest, Oy Koulukatu, Finland), and a maximum deviation of ±5% from the pre-determined velocity was allowed. The stance phase was delineated as the duration over which 20 N or greater of vertical force was applied to the force platform [14]. Runners completed five successful trials in each footwear condition.

The shoes utilized during this study consisted of a Saucony Pro Grid Guide II (conventional running trainers), Vibram Five-Fingers, and Nike Free 3.0. The shoes were the same for all runners; they differed in size only (sizes 7-10 in men's shoe UK sizes).

Kinematics and ground reaction forces data were synchronously collected. Kinematic data was captured at 250 Hz via an eight camera motion analysis system (Qualisys Medical AB, Goteburg, Sweden). Calibration of the system was performed before each data collection session. Only calibrations which produced average residuals of less than 0.85 mm for each camera for a 750.5 mm wand length and points above 4000 in all cameras were accepted prior to data collection. Retroreflective markers (19 mm) were positioned at the first metatarsal and calcaneus locations, windows were cut in the experimental footwear at these locations. The pre-established guidelines for length and width outlined by Shultz & Jenkyn [15] were adhered to.

Data processing

Retroreflective marker trajectories were identified using Qualisys track manager and then exported to Visual 3D (C-motion, Germantown USA). Marker trajectories were filtered at 15 Hz using a low pass zero-lag Butterworth filter. Plantar fascia strain was determined by calculating the distance between the first metatarsal and calcaneus markers and strain was considered to occur as the relative position of the markers was altered. Plantar fascia strain was quantified as the maximum change in length during the stance phase divided by the original length [16].

Statistical Analysis

Descriptive statistics (means and standard deviations) were calculated for each footwear condition. Differences in plantar fascia strain between footwear were examined using a one-way repeated measures ANOVA with significance accepted at the $p \leq 0.05$ level. Post-hoc pairwise comparisons were conducted on all significant main effects using a Bonferroni adjustment to control type I error. Effect sizes were calculated using partial eta squared ($p\eta^2$). The sphericity assumption was violated and thus the degrees of freedom were adjusted using a Greenhouse Geisser statistic. The Shapiro-Wilk test for each footwear condition confirmed that all data were normally distributed. All statistical procedures were conducted using SPSS v22.0 (SPSS Inc, Chicago, USA).

Results

A significant main effect ($F_{(3.90,\ 54.62)}=19.61$, $p \leq 0.05$, $p\eta^2=0.59$) was observed for the magnitude of plantar fascia strain. Post-hoc pairwise comparisons showed that plantar fascia strain was significantly larger in the conventional (12.58 ± 4.65) and Nike Free footwear

(10.18 ± 4.44) compared to the barefoot (5.54 ± 3.36) and Vibram Five-Fingers (6.24 ± 3.23) conditions. No further significant differences were observed.

Discussion

The current investigation aimed to determine whether differences in plantar fascia strain are present during running in barefoot and barefoot inspired footwear in relation to conventional running shoes. This study represents the first to examine the effects of running barefoot and in different footwear on the strain experienced by the plantar fascia.

The key finding from this current study is that the different footwear were shown to significantly influence the strain experienced by the plantar fascia. It was demonstrated that plantar fascia strain was significantly greater when running without shoes or in minimalist barefoot inspired footwear compared to conventional or more extensive barefoot inspired footwear. This finding may have clinical relevance regarding the etiology of plantar fasciitis in runners. Plantar fasciitis accounts for as much as 10% of running injuries and is believed to be instigated by excessive strain imposed on the plantar fascia itself [17]. The results from the current work may therefore provide insight into the clinical differences between different footwear conditions regarding runners' susceptibility to plantar fasciitis.

Given that increased plantar fascia strain was shown when running in conventional and more extensive barefoot inspired footwear, the findings from this investigation provide evidence to support the adoption of barefoot training for those susceptible to plantar fascial pathology. These observations however must be contextualized by taking into account the enhanced stride frequencies observed when running without shoes [8-10]. Therefore, although increases in plantar fascia strain were shown per step during shod running, it can be speculated that the cumulative strain may not be affected, as the total number of footfalls required to achieve the same running velocity is greater. Currently there is a lack of clinical information regarding the effects of combined and singular loads experienced by the plantar fascia during running. Future trials should seek to prospectively examine the effects of running with and without shoes in terms of their propensity for chronic injury development.

In conclusion, although previous literature has comparatively examined the mechanics of barefoot and shod running, the current knowledge with regards to the differences in plantar fascia strain between the two modalities is limited. The current investigation addresses this by providing a comparison of the strains experienced by the plantar fascia when running barefoot or in barefoot inspired footwear in relation to conventional running trainers. The findings from the current study show that running barefoot and in more minimalist barefoot inspired footwear served to significantly attenuate plantar fascia strain in comparison to both conventional and more extensive barefoot inspired footwear. Given the proposed relationship between plantar fascia strain and the etiology of plantar fasciitis, it is proposed that runners may attenuate their risk of developing this pathology by training without shoes or using more minimalist barefoot inspired footwear.

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