Effect of habitual foot strike patterns on muscle and bone properties of the foot

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Introduction

Although a large body of evidence exists on the biomechanical differences between runners with different foot strike patterns, whether adopting one or the other foot strike pattern may prevent or enhance long-term anatomical foot adaptations is still unknown. Use of minimalistic shoes has been associated with a thicker abductor halluces muscle, a thinner proximal plantar fascia and thicker Achilles tendon compared to other shoe types (Zhang et al., 2018). Conversely, transitioning into minimalistic footwear has shown to produce a greater risk of bone marrow edema in the metatarsals (Ridge et al., 2013). However, these studies have focused on footwear, rather than foot posture at ground impacts per se. Changes to bone, muscle and tendon have been documented in response to altered loading patterns; therefore, we hypothesized that foot bone and soft tissue morphology might adapt to the loading patterns imposed by foot-strike pattern.

Purpose of the study

The purpose of this study was to investigate whether the size of foot and ankle muscles and tendons, or calcaneal and metatarsal bone density or trabecular structure differ between habitual forefoot and rearfoot strike runners.

Methods

Using ultrasound imaging and a novel toe flexor strength dynamometer, we quantified differences in foot muscle size (cross-sectional area and thickness), and toe flexor strength in 20 male, experienced, recreational long distance runners (age: 31.2 ± 6.9 yr, height: 1.77 ± 0.07 m, weight: 73.4 ± 7.9 kg). Participants were classified as rearfoot strikers (RFS, n=10) or forefoot strikers (FFS, n=10) based on their habitual foot strike pattern tested on an instrumented treadmill; running at preferred speed and wearing their habitual running shoes.

We also investigated foot bone microstructure using a high resolution peripheral computed tomography, on a small sub-sample of participants (5 x RFS, 5 x FFS). Standardised volumes of interest for the calcaneus and metatarsal were selected , and bone volume was then separated into cortical and trabecular regions with a threshold-based algorithm (Laib and Rüegsegger, 1999).

Statistical comparisons were made using an independent t-test for muscle's parameters; and two-way ANOVA with factors (i) group (two levels: RFS, FFS) and (ii) bone (two levels: calcaneus, metatarsus) for bone parameters (alpha = 0.05).

Results

We found no differences in muscle or tendon size (see Figure 1), or strength of toe flexors (FFS = 0.019 ± 0.008; RFS =0.021 ± 0.008 BW/m), indicating that foot strike does not affect the size of foot muscles and their ability to produce force. Compared to FFS, the RFS have a lower trabecular area (-67%, p = 0.003) but similar cortical area (-1%; p=0.980) in the

first metatarsus, while no differences were found in the calcaneus.

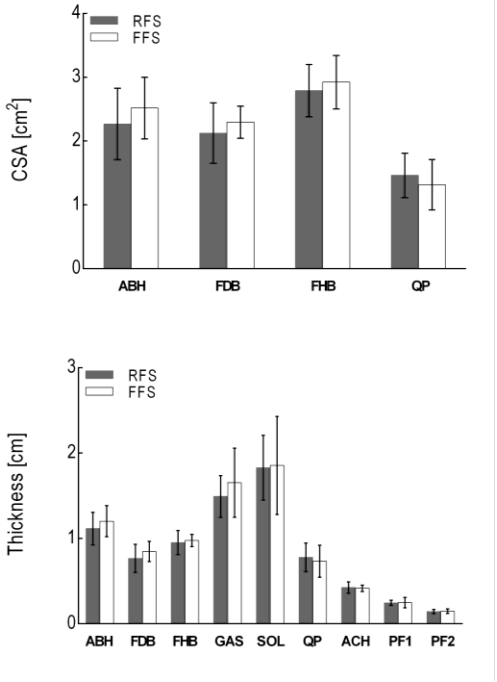

Figure 1. Cross-sectional area (CSA) and thickness measurements of foot and ankle muscles and tendons for RFS and FFS. ABH = abductor halluces; FDB = flexor digitorum brevis; FHB = flexor halluces brevis; GAS = medial gastrocnemius; SOL = soleus; QP = quadratus plantae; ACH = Achilles tendon; PF = plantar fascia.

Discussion and conclusion

Similarity in the size of the intrinsic foot muscles is in agreement with recent research from Farris et al. (2019) who suggested that the intrinsic foot muscles have minimal effect on the stiffness of the arch when absorbing high loads. Given the experience of our runners, it is likely that the muscles were fully adapted and contribute equally to propulsion independent of foot strike.

Preliminary data suggests habitual RFS have similar bone microstructure with lower 1st metatarsal bone volumetric density, so we infer that RFS have similar bone stiffness but lower bone elasticity in the metatarsals. Similar bone density at the calcaneus may suggest an equal force experienced; although this is likely to be from two distinct origins: external force from ground (RFS) or internal force from the plantarflexors and plantar fascia (FFS).

Our findings add to the current knowledge on the effect of running on health and adaptation of the human foot, and footwear companies as well as coaches may benefit from implementing this evidences to their practice in order to improve runners' health and performance.

References

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