Manipulation of foot strike and footwear increases Achilles tendon loading during running

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Background: The Achilles tendon is the most common site of tendon overuse injury in humans. There has been a recent interest in running with a forefoot strike pattern and in minimal shoes, yet evidence is currently limited regarding the combined influence of foot strike and footwear on Achilles tendon loading.

Purpose: To investigate the influence of both foot strike and footwear on Achilles tendon loading in habitual rearfoot strike runners.

Study Design: Crossover study design

Methods: Synchronised kinematic and force data were collected from 22 habitual rearfoot strikers (11 male), who habitually run in non-minimal running shoes, during overground running at 3.6 $m.s^{-1}$. Participants ran in three different footwear conditions (standard running shoe; minimal running shoe; barefoot) with both a rearfoot strike (RFS) and an imposed forefoot strike (FFS) in each footwear condition. Achilles tendon loading was estimated using inverse dynamics, where the Achilles tendon moment arm was determined using a regression equation. Conditions were compared using a two-way repeated measures ANOVA.

Results: Achilles tendon impulse was greater when running with a FFS than a RFS in minimal shoes. Achilles tendon loading rates were higher when running either in minimal shoes or barefoot than in standard shoes, regardless of foot strike.

Conclusions: In runners who habitually rearfoot strike in standard running shoes, running in minimal shoes or barefoot increased the rate of tendon loading, and running with a forefoot strike in minimal shoes increased the magnitude of tendon loading. Transitioning to these running conditions may increase the risk of tendinopathy.

What is known about this subject?

It has been shown that when running with a forefoot strike compared with a rearfoot strike, the internal ankle plantar flexor moment increases, but there are conflicting findings regarding whether this results in an increase in Achilles tendon force. Some of these findings may have been confounded by footwear.

What this study adds to existing knowledge

This study considered the influence of both foot strike and footwear on Achilles tendon loading during running, as well as their interactive effect. It has added to the knowledge in this area by identifying that foot strike influences the magnitude of loading, whereas footwear influences the rate, amongst habitual rearfoot strikers who are accustomed to running in standard running footwear.

Introduction

Running to increase physical activity levels has long been advocated as a beneficial and cost effective method of preventing the onset of chronic diseases[15,18,38]. Despite decades of extensive research investigating potential causes of running-related injury, prevalence remains high, with up to 74% of runners sustaining an injury in a given year[6]. The Achilles tendon is the strongest tendon in the human body, but is the most common site of tendon overload injuries[16], likely due to the high loading it undergoes. It is reportedly the site of 10% of all running-related injuries[35]. Almonroeder[1] suggest that Achilles tendon injury may result from submaximal, repetitive loading or from repeated high rates of loading.

Foot strike pattern has been the focus of much of the running injury discussion in recent years, particularly following Lieberman et al.'s finding[19] that habitually barefoot runners often land with a forefoot strike (FFS), unlike the majority of habitually shod runners, who typically land with a rearfoot strike (RFS). There are well-established differences in the mechanics of running with a RFS and a FFS. Despite lower initial GRF loading when running with a FFS than a RFS[19], there is a larger internal plantar flexor moment about the ankle[17,25,27], which can result in increased Achilles tendon forces. Non-RFS running has been associated with an increased risk of Achilles tendinopathy in female runners[6], which may be the result of greater tendon loading. Three previous studies have investigated the influence of running with different foot strike patterns on Achilles tendon loading, with conflicting findings[1,17,25]. These findings may have been influenced by the footwear worn during the assessment of Achilles tendon loading.

In addition to foot strike, footwear has been found to influence running mechanics[26]. These differences in mechanics likely influence the Achilles tendon force, the rate of loading, and therefore potentially the risk of Achilles tendon injury[1]. Existing literature assessing the influence of footwear on Achilles tendon loading [7,8,25,31] and Achilles tendon strain (indicated by ankle dorsiflexion)[7,25] is similarly confounded by the effects of foot *strike*. This provides evidence of an interactive effect between footwear and foot strike which warrants assessment. Despite much uncertainty within the scientific literature regarding the merits and risks of transitioning from a RFS to a FFS or altering running footwear, recent popular media publications such as McDougall's 'Born to Run'[23] have resulted in many runners experimenting with a novel FFS pattern or running in minimal shoes or barefoot.

The aim of this study was to investigate the influence of running with both a RFS and a FFS in three distinct footwear conditions on Achilles tendon loading in habitual RFS runners. The three footwear conditions included standard running shoes; minimal running shoes; and barefoot. It was hypothesised that when running with a FFS compared with a RFS, there would be greater Achilles tendon loading and a greater internal plantar flexor moment. It was also hypothesised that Achilles tendon loading would be greater when running in minimal shoes or barefoot compared with standard shoes. Finally, it was hypothesised that peak dorsiflexion would be greater when running in minimal shoes or barefoot than in standard shoes, and that peak dorsiflexion would be influenced by foot strike. The study was approved by the University of Exeter Sport and Health Sciences Ethics Committee.

Methods

Participants

Twenty-two habitual rearfoot strikers (11 male, Table 1) participated in the study. All habitually wore non-minimal running shoes, which were defined as those with minimal cushioning and heel-toe drop, and had no prior experience of running in minimal shoes or barefoot. Participants were eligible if they confirmed that they performed an average of at least thirty minutes a day of moderate-to-vigorous physical activity[9], and were injury-free at the time of, and for three months prior to, data collection. Foot strike modality was assessed during an initial visit. This required participants to perform running trials in their habitual running shoes, whilst striking a pressure plate (200 Hz, RSscan USB plate, RSscan International, Belgium) positioned 8.3 m along a 16.5 m runway, with their right foot. They were given no instructions on how to run or on foot strike modality, maximising the likelihood of capturing their natural running gait. Following familiarisation, five trials were collected. Foot strike modality was then determined using the procedures outlined by Nunns et al.[24]. Participants were excluded if they were not classified as a rearfoot striker.

Table 1: Mean (SD) demographics for participants

	Mean (SD)		
	Total	**Males (n = 11)**	**Females (n = 11)**
Age (years)	22.7 (3.2)	22.7 (2.5)	22.7 (4.0)
Height (m)	1.72 (0.09)	1.77 (0.08)	1.66 (0.08)
Body mass (kg)	68.0 (13.13)	74.3 (13.2)	61.0 (9.4)
Leg length (m)	0.82 (0.05)	0.85 (0.04)	0.80 (0.04)

Data Collection

Kinetic and kinematic data of the right lower extremity were simultaneously collected using four aligned Coda CX1 units (200 Hz, Codamotion, Charnwood Dynamics Ltd, Leicestershire, UK), and a force plate (1000 Hz, Advanced Manufacturing Technology Inc., Watertown, MA, USA) positioned 8.3 m along a 16.5 m concrete runway. Concrete was chosen to replicate running on roads. Leg length was measured as the distance between the greater trochanter and the lateral malleolus, using a measuring tape. Active Coda markers were positioned on ten anatomical landmarks of the right lower limb, in order to develop a joint coordinate system based on the principles of Grood and Suntay[11] and Soutas-Little et al.[33]. The landmarks were as follows: the greater trochanter; the lateral and medial femoral epicondyles; the most prominent points of the lateral and medial malleoli; the superior Achilles tendon; two markers on the posterior calcaneus; the lateral articulation of the fifth metatarsophalangeal joint and on the distal third metatarsal. A marker was also positioned on the posterior calcaneus of the left foot to determine step length. Step length was monitored because manipulating step length is known to alter lower limb loading[12]. All markers were securely held in position with double-sided adhesive tape and Micropore tape (3M, USA).

Ten running trials were collected per condition at 3.6 $m.s^{-1}$ (± 5%). Running speed was monitored using Brower (Brower TC Timing System, Draper, Utah, USA) timing gates positioned 2 m apart. Participants ran in three different footwear conditions: standard shoes (Asics Gel-1150 Duomax, Kobe, Japan - midsole Shore A 43 and insole Shore A 23), minimal shoes (VibramFivefinger, Albizatte, Italy) and barefoot. For all three footwear conditions participants were required to run using both a RFS and a FFS. The RFS was defined as initial heel contact followed by contact of the rest of the foot, whilst the FFS was initial forefoot contact followed by contact of the rest of the foot[24]. The FFS was described to participants using pictures and videos, as well as being physically demonstrated. Participants were given as many familiarisation trials as required to ensure they were able to maintain the correct footstrike modality for the duration of the trials. Footstrike was monitored using two methods: visual assessment at ground contact; and using a pressure plate positioned towards the end of the runway. A trial was deemed successful if a right foot contact was within the edges of the force plate, the speed was within the required range, no alterations were made to running gait in order to reach the force plate, and the correct foot strike was performed. A single static trial was also obtained in the standard shoe condition, with participants in a relaxed, neutral stance. This allowed joint angles to be normalised to a neutral position, thus providing anatomically meaningful data.

Data Analysis

Kinetic and kinematic data underwent a low pass, fourth order Butterworth filter at 50 Hz and 12 Hz respectively[32], and were analysed using a customised MATLAB script (Mathworks, Natick, MA, USA). A threshold of 20 N in the vertical force data was used to determine ground contact[17,22]. Instantaneous vertical loading rates were calculated as the derivative of the vertical GRF with respect to time. Peak value was the maximum value during stance.

Ankle plantar flexor moments were calculated using Newton-Euler inverse dynamics. Achilles tendon force was the internal ankle plantar flexor moment divided by the Achilles tendon moment arm throughout stance. Achilles tendon moment arm was estimated using a regression equation which accounts for changes in moment arm length during stance[29]:

Achilles tendon moment arm = $- 0.5910 + 0.082297\theta - 0.0002606\theta^2$,

where θ was the non-normalised sagittal plane ankle angle.

The peak Achilles tendon force during stance was obtained. Instantaneous Achilles tendon force loading rate was the first derivative of the Achilles tendon force with respect to time. The peak value throughout stance was obtained. Achilles tendon impulse was the area underneath the force-time curve, estimated using cumulative trapezoidal numerical integration. All GRF and Achilles tendon force values were normalised to bodyweight. Peak ankle dorsiflexion was determined after adjustment for the value obtained during the standing trial in the standard shoe. Step length was the displacement between the right and left calcaneus markers in the transverse plane, and was normalised to leg length. Step length was presented in dimensionless units.

Statistical Analysis

For each variable the average of ten trials was calculated per participant. Statistical analyses were conducted using SPSS (v.23, SPSS INC., Chicago, IL, USA) software. Extreme outliers were identified using boxplots, and were removed prior to analysis. Achilles tendon force loading rates included seven extreme outliers out of 132 values (22 participants x 6 conditions), whereas all other variables included zero, one or two. A two-way repeated measures ANOVA was used to assess the influence of foot strike and footwear on Achilles tendon force and associated variables, with $P < 0.05$ indicating a significant main effect. The Greenhouse-Geisser correction factor was used where Mauchley's test of sphericity was violated. Post-hoc pairwise comparisons with consideration of Bonferroni-corrected alpha were used to identify where significant effects occurred. Effect sizes were calculated for these comparisons as the mean difference divided by the standard deviation.

Results

Mean (SD) values and outcomes from the two-way repeated measures ANOVA are presented in Table 2. Significance levels (P values) presented throughout the text represent the unadjusted outcomes from the post-hoc pairwise comparisons.

Table 2: Kinetic, kinematic and spatiotemporal variables for each foot strike and footwear condition

Variable	Mean (SD)						Main and Interaction Effects (P)		
	Standard Shoe		Minimal Shoe		Barefoot				
	RFS	FFS	RFS	FFS	RFS	FFS	Foot strike	Footwear	Interaction
ATF (BW)	4.51 (0.93)	4.74 (0.87)	4.68 (2.18)	4.62 (2.23)	4.46 (1.08)	4.25 (1.50)	0.957	0.536	0.598
ATF Impulse (BW.s)	0.49 (0.12)	0.53 (0.12)	0.47 (0.21)	0.58 (0.21)	0.49 (0.12)	0.52 (0.14)	**P < 0.001**	0.774	**0.022**
ATF ILR ($BW.s^{-1}$)	97.1 (25.5)	119.5 (35.4)	134.5 (66.9)	214.4 (123.1)	203.5 (83.5)	170.1 (85.6)	0.194	**P < 0.001**	**0.007**
PF moment ($Nm.kg^{-1}$)	1.92 (0.36)	2.04 (0.32)	2.03 (0.32)	2.13 (0.54)	1.91 (0.36)	1.95 (0.42)	**0.007**	0.147	0.351
DF at TD (°)	10.3 (5.5)	-18.4 (8.4)	3.3 (8.1)	-18.7 (13.1)	8.8 (5.96)	-5.2 (9.5)	**P < 0.001**	**P < 0.001**	**P < 0.001**
Peak DF (°)	19.5 (3.8)	15.9 (5.5)	17.0 (8.9)	13.5 (9.0)	19.7 (5.0)	16.1 (6.8)	**P < 0.001**	0.278	0.987
GRF ILR ($BW.s^{-1}$)	83.47 (14.36)	68.29 (20.69)	142.76 (20.43)	92.28 (30.81)	214.04 (52.04)	95.56 (46.65)	**P < 0.001**	**P < 0.001**	**P < 0.001**
SL’	1.62 (0.20)	1.59 (0.19)	1.53 (0.15)	1.50 (0.17)	1.50 (0.16)	1.44 (0.15)	**P < 0.001**	**P < 0.001**	0.31

Note: Significant effects are highlighted in bold. ATF: Achilles tendon force; ILR: instantaneous loading rate; SL’: normalised step length; GRF: ground reaction force; DF: dorsiflexion; TD: touchdown. A negative dorsiflexion angle indicates plantar flexion from neutral.

Achilles Tendon Force

Peak Achilles tendon force was not significantly influenced by foot strike or footwear (Table 2).

Achilles Tendon Impulse

There was an interaction effect on Achilles tendon impulse (Table 2), with a significantly greater impulse when running with a FFS than a RFS in minimal shoes ($P < 0.001$), but not in standard shoes ($P = 0.041$) or barefoot ($P = 0.214$).

Achilles Tendon Force Loading Rates

There was an interaction effect on Achilles tendon force loading rates (Table 2, Figure 1). Post-hoc pairwise comparisons revealed that Achilles tendon force loading rates were lower in standard shoes than in either minimal shoes or barefoot, regardless of foot strike (Table 3).

Figure 1: Interaction effect demonstrating the influence of both footwear and foot strike on mean Achilles tendon force loading rates.

Table 3: Post-hoc pairwise comparisons of Achilles tendon force loading rates in standard running shoes compared with minimal shoes and barefoot

Comparison	P value	Effect size
RFS		
Standard shoe vs. minimal shoe	0.025	0.58
Standard shoe vs. barefoot	P < 0.001	1.23
FFS		
Standard shoe vs. minimal shoe	0.007	0.67
Standard shoe vs. barefoot	0.006	0.68

Ankle Dorsiflexion Touchdown Angle

There was an interaction effect on dorsiflexion angle at touchdown (Table 2). Touchdown angle was greater when running with a RFS than a FFS in all footwear conditions (all $P < 0.001$), and touchdown angle was closer to neutral when running with a FFS barefoot, than in either standard or minimal shoes ($P < 0.001$).

Peak Ankle Dorsiflexion Angle

There was a main effect for foot strike on peak dorsiflexion angle (Figure 2), with a more dorsiflexed ankle at peak when running with a RFS than a FFS. There was no main effect for footwear, nor was there an interaction effect.

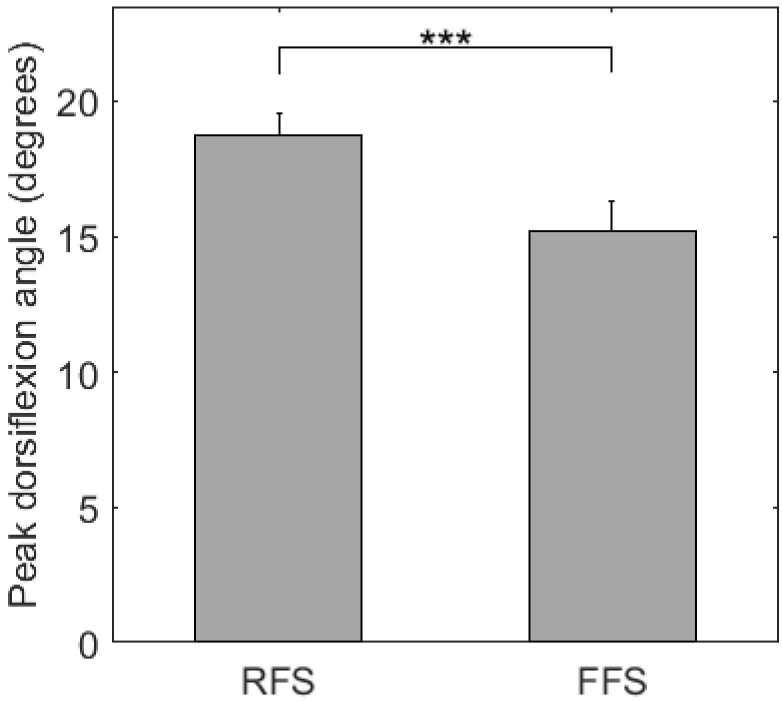

Figure 2: Peak ankle dorsiflexion angle for each foot strike. Error bars represent standard errors. Asterisks represent significant differences between conditions (*P < 0.001).**

GRF Loading Rates

There was an interaction effect on GRF loading rates (Table 2). When running with a RFS, loading rates were increased from standard shoes to minimal shoes to barefoot (all $P < 0.001$). However, when running with a FFS loading rates were lower in standard shoes than either minimal shoes or barefoot ($P \leq 0.003$), but were not different between minimal shoes and barefoot. Post-hoc pairwise comparisons confirmed that GRF loading rates were higher when running with a RFS than a FFS in all footwear conditions (all $P \leq 0.001$).

Step Length

There were main effects for both foot strike and footwear on normalised step length. Step length was longer when running with a RFS than a FFS. Step length was longest when running in standard shoes and shortest when running barefoot. There was no interaction effect.

Discussion

This study was the first to determine the influence of footwear and foot strike on Achilles tendon loading during running. All runners were able to acutely transition to a FFS from their habitual RFS, in every footwear condition, as evidenced by the plantar flexed ankle at landing when running with a FFS compared with a RFS.

In contrast with our hypothesis, Achilles tendon forces were not different between foot strikes. Kulmala et al.[17] reported 24% greater Achilles tendon force values when running with a habitual FFS compared with a habitual RFS. However, our findings support those of Almonroeder et al.[1] who found no difference in Achilles tendon force with different foot strikes when running with their habitual foot strike. These previous studies reported Achilles tendon force values which were ~1.3 and ~1.4 times greater respectively than those of the present study. In the study by Kulmala et al.[17], this was influenced by the higher plantar flexor moments (~1.4 times higher) than in the present study, which may have been partly due to the faster running speed (4.0 $m.s^{-1}$) and therefore increased GRF. Almonroeder et al.[1] explained that their approach, where ankle dorsiflexion muscle activity was not assumed to be zero, resulted in greater force estimates than when using inverse dynamics (as in the present study). It is well established that there are greater internal plantar flexor moments when running with a FFS compared with a RFS[17,25,27], and this was also the case in the present study, where the plantar flexor moments were 4% greater when running with a FFS compared with a RFS. Despite these greater internal moments, there was no difference in Achilles tendon force between foot strikes, which must be influenced by the moment arm length. The estimated moment arm was longer when running with a FFS than a RFS, as a result of the more plantar flexed ankle throughout stance, and this negates the differences in the plantar flexor moments.

Contrary to our hypothesis and to findings by Sinclair[31], footwear did not independently influence Achilles tendon force. This is likely related to the fact that the plantar flexor moment was not influenced by footwear in the present study. Sinclair observed greater Achilles tendon force when running in minimal shoes or barefoot than in standard shoes. However, comparing the dorsiflexion angle time histories presented by Sinclair with those histories presented by Kulmala et al.[17], it appears that runners transitioned to a more anterior foot strike when running barefoot or in minimal shoes than standard shoes in the study by Sinclair. This suggests that the differences observed were not independent of foot strike, which may explain why they were not replicated in the present study.

Achilles tendon impulse considers both the magnitude and duration of tendon loading during stance, thus providing an indication of the total loading. Impulse was greater when running with a FFS compared with a RFS in minimal shoes. Almonroeder et al.[1] reported a higher impulse when running barefoot with a preferred FFS compared with a preferred RFS, which only approached significance ($P = 0.05$), but was not supported in the present study. Perl et al.[25] reported a greater impulse when running with a FFS compared with a RFS in both standard and minimal shoes. This was amongst runners who habitually ran with a FFS in minimal shoes or barefoot, who had all formerly run in standard shoes. In the present study, the greater impulse when running with a FFS compared with a RFS in standard shoes only approached significance using a Bonferroni-corrected alpha. The differences in findings may be influenced by habituation. Perl et al.[25] also observed a greater impulse when running in minimal compared with standard shoes, which was not supported in the present study. In summary, the findings in the present study along with existing findings show that Achilles tendon impulse is greater when running with a FFS than a RFS in minimal shoes, regardless of habituation. Achilles tendon impulse may also be higher when running with a FFS than a RFS in standard shoes.

Tendon loading rates were influenced by footwear. Considering the conservative nature of Bonferroni-corrected alpha values, where in this case $P < 0.025$ would have indicated a significant difference, it is reasonable to state that Achilles tendon loading rates were lower when running in standard shoes than either minimal shoes or barefoot, regardless of foot strike. Tendon loading rates were not influenced by foot strike. Almonroeder et al.[1] similarly found no significant difference in loading rates between foot strikes, although loading rates were 15% higher ($P = 0.06$) when running with a non-RFS than a RFS.

Overall, the findings of this study show that foot strike influences the magnitude of loading, whereas footwear influences the rate, and this has implications for Achilles tendinopathy. Loading of tendons is beneficial to their structural properties and their ability to resist injury[4,36,37,39,40], particularly if this loading is gradually increased over time[14]. However, excessive loading may result in tendinopathy, and it is not known what levels of loading are advantageous and excessive for tendons in vivo. Furthermore, it is unclear whether the magnitude of loading, or the rate of loading, is most important in terms of protective adaptation and injury development. In humans, cross-sectional studies have found a greater (22 – 36%) Achilles tendon cross-sectional area (CSA) in distance runners compared with controls[16,21,28], and a greater Achilles tendon width in older athletes compared with age-matched controls[28], indicating that running is a suitable stimulus to elicit beneficial adaption within the tendon. Given that the majority of runners run in standard shoes, and land with a rearfoot strike, these conditions are likely sufficient to elicit the beneficial structural adaptations in the Achilles tendon that have been observed. As such, an increase in loading beyond these values may increase the risk of tendinopathy, particularly if not introduced gradually. Running with a RFS in standard shoes was considered the control condition, and running with a FFS in minimal shoes or barefoot resulted in increased Achilles tendon loading, above the 'normal' values for these participants. This may increase the risk of tendinopathy. The findings of this study may partly explain why non-RFS running has previously been associated with increased risk of Achilles tendinopathy[6], and why a 2.3 times greater incidence of Achilles tendinopathy was reported amongst habitually barefoot compared with habitually shod runners in a prospective study[2]. Further research is required to understand the effects of magnitude and rates of loading on the risk of Achilles tendinopathy, in vivo.

The more dorsiflexed ankle at peak when running with a RFS than a FFS was influenced by the greater dorsiflexion touchdown angle, which is characteristic of a RFS. Peak dorsiflexion provides an indicator of Achilles tendon strain, and as such the findings of this study indicate greater tendon strain when running with a RFS than a FFS. It is not clear whether the increase in strain with this foot strike is sufficient to be physiologically meaningful. Contrary to the hypothesis, there was no effect of footwear on peak ankle dorsiflexion. Dixon and Kerwin[7] found reduced peak ankle dorsiflexion when running with a heel lift, but only in midfoot strikers. These earlier findings, combined with those of the present study suggest that footwear does not independently influence Achilles tendon strain during running.

The lower GRF loading rates when running with a FFS compared with a RFS were consistent with previous findings[3]. However, loading rates were lower when running with a FFS in standard shoes than in minimal shoes and barefoot which conflicts with existing findings to an extent[26]. Loading rate values were generally higher in the present study than those reported from recreational runners in their habitual footwear condition[26]. These differences are likely the result of the unaccustomed nature of FFS running and running in non-standard shoes in the present study. Similar GRF loading rates were presented when comparing only those who habitually run in standard footwear with a RFS. The same point can be made regarding the fact that *tendon* loading rates were lower in the habitual footwear condition than the novel conditions, and these findings support previous reports that an acute change of foot strike results in exaggeration of the adopted foot strike characteristics[3]. The increased loading rates may be influenced by the unaccustomed nature of the different footwear conditions in the present study. However, this was not the case for the magnitude of the Achilles tendon loading.

Increasing step rate (and therefore reducing step length) has been identified as a means of reducing lower limb loading during running[12]. A prospective study of high school runners found that those who habitually ran with a higher step rate had a reduced likelihood of shin injury[20]. Step length was longer when running with a RFS compared with a FFS, which is likely associated with the more extended knee at touchdown when running with a RFS[30]. Consistent with existing findings[34], step length was longer when running in standard shoes than either minimal shoes or barefoot, independent of foot strike. These findings regarding step length highlight the important point that although running with a RFS in standard shoes results in the lowest Achilles tendon loading, it may result in increased risk of other lower limb injuries. This should be considered when providing recommendations.

Achilles tendon moment arm was assessed using the regression equation presented by Self and Paine[29], as previously used in the assessment of Achilles tendon force[17]. Additional existing studies have used a fixed value of 0.05 m[1,13], or measured the Achilles tendon moment arm length using x-ray images[10], or palpation[25]. Whilst greater accuracy may be obtained using imaging techniques, this approach does not account for the changes in moment arm that occur throughout stance, and as such the regression equation used in the present study was deemed most appropriate. The participants in this study were all habitually standard shod RFS runners, which allowed for a rigorous assessment of the influence of changing foot strike and footwear on Achilles tendon loading. Alternative results may be observed when comparing groups who habitually run in each different condition, and investigation of this is warranted.

The findings of this study may have important implications for Achilles tendinopathy in runners. Achilles tendon impulse increased when changing from a habitual RFS to a FFS pattern in minimal shoes, with a tendency for this to also occur in standard shoes. Tendon loading rates increased when changing from standard running shoes to minimal shoes or barefoot. This increased loading may be above the levels required for beneficial tendon adaptation, particularly if a transition to these conditions is not gradual. A gradual increase in tendon loading may be beneficial for the tendon[14], if it is not excessive, whereas reactive tendinopathies are known to occur as a result of a burst of unaccustomed physical activity[5]. Those with a history of Achilles tendinopathy may consider RFS in standard shoes most suitable for minimising the risk of recurrence. Those transitioning to FFS running and/or running in minimal shoes or barefoot are advised to do so progressively.

Conclusions

This study assessed the influence of both foot strike and footwear on Achilles tendon loading in habitually standard shod rearfoot strike runners. Greater tendon impulse was observed when running with a forefoot strike compared with a rearfoot strike in minimal shoes, and higher tendon loading rates were observed when running in minimal shoes or barefoot than in standard shoes. Running with a novel forefoot strike, or in minimal shoes or barefoot, may increase the risk of Achilles tendinopathy. Further research is required to determine whether those accustomed to running in minimal shoes or barefoot demonstrate higher tendon rates of loading than those accustomed to running in standard running shoes.

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