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Effects of high and low cut on Achilles tendon kinetics during basketball specific movements

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The aim of the current investigation was to examine the influence of high and low-cut specific basketball footwear in relation to minimalist and conventional athletic footwear on the loads experienced by the Achilles tendon during basketball specific movements. Ten males performed run and 45° cut movements whilst wearing low-cut, high-cut, minimalist and conventional athletic footwear. Achilles tendon forces were calculated using Opensim software allowing the magnitudinal and temporal aspects of the Achilles tendon force to be quantified. Differences in Achilles tendon load parameters were examined using 4 (footwear) x 2 (movement) repeated measures ANOVA. The results show that a main effect was evident for peak Achilles tendon force, which was significantly larger in the minimalist (run = 5.74 & cut = 5.85 BW) and high-cut (run = 6.63 & cut = 6.01 BW) footwear in relation to the low-cut (run = 5.79 & cut = 5.47 BW) and conventional (run = 5.66 & cut = 5.34 BW) conditions. In addition a main effect was also evident for Achilles tendon load rate, which was significantly larger in the minimalist (run = 48.84 & cut = 43.98 BW/s) and high-cut (run = 54.31 & cut = 46.51 BW/s) footwear in relation to the low-cut (run = 43.15 & cut = 31.57 BW/s) and conventional (run = 44.74 & cut = 31.15 BW/s) conditions. The current investigation indicates that minimalist and high-cut footwear may place basketballers at increased risk for Achilles tendon pathology as a function of their training/ competition. Furthermore, it appears that for basketballers who may be susceptible to Achilles tendinopathy that low-cut and conventional conditions are most appropriate.

Keywords: basketball, Achilles tendon, biomechanics

At all levels of play basketball is becoming a uniquely popular athletic discipline throughout the world [1]. Basketball is regarded as a physiologically demanding sport in which players are required to perform a series of different motions that typically include running, jumping and rapid changes of direction [2]. A typical competitive basketball season will require players to train frequently and perform >60 games, a regimen which serves to place high physical and mechanical demands on those involved [3]. Basketball has in recent years gained more research attention from the scientific community regarding players' susceptibility to injury.

Research investigating the prevalence of injuries in basketball players has shown that in relation to other non-contact sports basketball is associated with a comparatively high rate of injury. Information from aetiological analyses indicates that 11.6 injuries occur per 1000 appearances, and that the vast majority (65 %) are confined to the lower extremities [4]. Athletic disciplines which include frequently jumps, foot strikes and changes in direction such as basketball, place high loads on the Achilles tendon placing it at high risk from injury [5].

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Given the highly physical nature of modern basketball, court footwear must now fulfill a range of biomechanical parameters such as traction, support, stability and shock attenuation [6]. Traditionally basketball specific footwear designs were available only with high-cut ankle supports which are utilized in order to promote mediolateral stability during landing [7]. In recent times however, low-cut footwear models have also been introduced and utilized at all levels of play, meaning court specific footwear can be selected based on individual preference. Recreational level players are also known to use low-cut conventional athletic footwear which may serve to enhance improve impact loading but at the expense of medio-lateral stability [7]. In comparison to other sports such as running there is currently a paucity of scientific research examining the efficacy of basketball footwear.

Appropriate footwear selection has been cited as a mechanism by which the risk from Achilles tendon pathologies during sport can be mediated. Considerable research has examined the effects of different footwear on the forces experienced by the tendon during different sports. Sinclair examined the effects barefoot and in minimalist footwear on Achilles tendon kinetics in relation to conventional running shoes [8]. Their results showed that conventional footwear significantly reduced peak Achilles tendon forces in relation to barefoot and minimalist conditions. Similarly, Sinclair et al., [9] examined the effects of minimalist and netball specific conditions on the forces experienced by the Achilles tendon during running and cutting movements. They showed that the peak force and rate of force application was significantly reduced in the netball specific condition. Finally, Sinclair et al [10] investigated the effects of minimalist energy return and convention athletic footwear on Achilles tendon loads during depth jumping. They showed the footwear did not significantly affect Achilles tendon forces during this movement. However, despite the wealth of peer reviewed literature examining the effects of different footwear on Achilles tendon kinetics there is currently no information available regarding the influence of basketball specific shoes.

Therefore, the aim of the current investigation was to examine the influence of high and low-cut specific basketball footwear in relation to minimalist and conventional athletic footwear on the loads experienced by the Achilles tendon during basketball specific movements. The findings from the current investigation may provide basketball players with important clinical information regarding the selection of appropriate footwear, which may ultimately help to attenuate their risk from developing Achilles tendon pathologies.

Methods

Participants

Ten male participants, volunteered to take part in this study. 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 24.26 ± 4.05 years, height 1.77 ± 0.07 cm and body mass 78.66 ± 7.43 kg. The procedure utilized for this investigation was approved by the University of Central Lancashire, Science, Technology, Engineering and Mathematics, ethical committee.

Footwear

The footwear used during this study consisted of minimalist (Vibram five-fingers Original;), high-cut (Nike Lebron XII), low-cut (Nike Lebron XII Low) footwear and conventional (New Balance 1260 v2) (shoe size 9–10 in UK men's sizes).

Procedure

Participants completed five repeats of two sport specific movements; run and cut in each of the four footwear conditions. To control for any order effects the order in which participants performed in each footwear/ movement condition were counterbalanced. Kinematic information from the lower extremity joints was obtained using an eight camera motion capture system (Qualisys Medical AB, Goteburg, Sweden) using a capture frequency of 250 Hz. To measure kinetic information an embedded piezoelectric force platform (Kistler National Instruments, Model 9281CA) operating at 1000 Hz was utilized. The kinetic and kinematic information were synchronously obtained and interfaced using Qualisys track manager.

To define the anatomical frames of the thorax, pelvis, thighs, shanks and feet retroreflective markers were placed at the C7, T12 and xiphoid process landmarks and also positioned bilaterally onto the acromion process, iliac crest, anterior superior iliac spine, posterior superior iliac spine, medial and lateral malleoli, medial and lateral femoral epicondyles, greater trochanter, calcaneus, first metatarsal and fifth metatarsal. Carbon-fibre tracking clusters comprising of four nonlinear retroreflective markers were positioned onto the thigh and shank segments. Static calibration trials were obtained with the participant in the anatomical position in order for the positions of the anatomical markers to be referenced in relation to the tracking clusters/markers. A static trial was conducted with the participant in the anatomical position in order for the anatomical positions to be referenced in relation to the tracking markers, following which those not required for dynamic data were removed.

Data were collected during the run and cut movements according to below procedures:

Run
Participants ran at 4.0 m.s^{-1} ±5% and struck the force platform with their right (dominant) limb. The average velocity of running was monitored using infrared timing gates (SmartSpeed Ltd UK). The stance phase of running was defined as the duration over > 20 N of vertical force was applied to the force platform[11].

Cut
Participants completed 45° sideways cut movements using an approach velocity of 4.0 m.s^{-1} ±5% striking the force platform with their right (dominant) limb. In accordance with McLean et al.,[12] cut angles were measured from the centre of the force plate and the corresponding line of movement was delineated using masking tape so that it was clearly evident to participants. The stance phase of the cut-movement was similarly defined as the duration over > 20 N of vertical force was applied to the force platform [11].

Processing
Dynamic trials were digitized using Qualisys Track Manager in order to identify anatomical and tracking markers then exported as C3D files to Visual 3D (C-Motion, Germantown, MD, USA).

Ground reaction force and kinematic data were smoothed using cut-off frequencies of 25 and 12 Hz with a low-pass Butterworth 4th order zero lag filter.

Data during the stance phase were exported from Visual 3D into OpenSim software (Simtk.org), which was used give to simulations of muscles forces. Simulations of muscle forces were obtained using the standard gait 2392 model within Opensim v3.2. This model corresponds to the eight segments that were exported from Visual 3D and features 19 total degrees of freedom and 92 muscle-tendon actuators.

We firstly performed a residual reduction algorithm (RRA) within OpenSim, this utilizes the inverse kinematics and ground reaction forces that were exported from Visual 3D. The RRA calculates the joint torques required to re-create the dynamic motion. The RRA calculations produced route mean squared errors <2°, which correspond with the recommendations for good quality data. Following the RRA, the computed muscle control (CMC) procedure was then employed to estimate a set of muscle force patterns allowing the model to replicate the required kinematics [13]. The CMC procedure works by estimating the required muscle forces to produce the net joint torques. Achilles tendon force was estimated in accordance with the protocol of Almonroeder et al [14] by summing the muscle forces of the medial gastrocnemius, lateral, gastrocnemius, and soleus muscles. Achilles tendon load rate was quantified as the peak Achilles tendon force divided by the time to peak force. All Achilles tendon load parameters were normalized by dividing the net values by body weight (BW).

Analyses
Differences in kinetic and kinematic parameters between footwear were examined using 4 (footwear) x 2 (movement) repeated measures ANOVAs, with significance accepted at the P≤0.05 level. Effect sizes were calculated using partial eta^2 ($p\eta^2$). Follow up comparisons on significant interactions were examined using simple main effects and post-hoc pairwise comparisons were conducted on all significant main effects. The data was screened for normality using a Shapiro-Wilk which confirmed that the normality assumption was met. All statistical actions were conducted using SPSS v22.0 (SPSS Inc., Chicago, USA).

	Minimalist				High-cut				Low-cut				Conventional			
	Run		Cut		Run		Cut		Run		Cut		Run		Cut	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Peak Achilles tendon force (BW)	5.74	0.75	5.85	1.03	6.63	1.19	6.01	0.69	5.79	0.78	5.47	1.00	5.66	0.90	5.34	0.68
Time to peak Achilles tendon force (s)	0.12	0.01	0.16	0.04	0.13	0.02	0.16	0.02	0.14	0.01	0.19	0.04	0.13	0.02	0.18	0.03
Achilles tendon load rate (BW/s)	49.84	8.70	43.98	18.68	54.31	17.49	46.51	14.71	43.15	9.16	31.57	11.96	44.74	11.97	31.15	9.28

Table 1 Achilles tendon kinetics as a function of footwear and movement conditions.

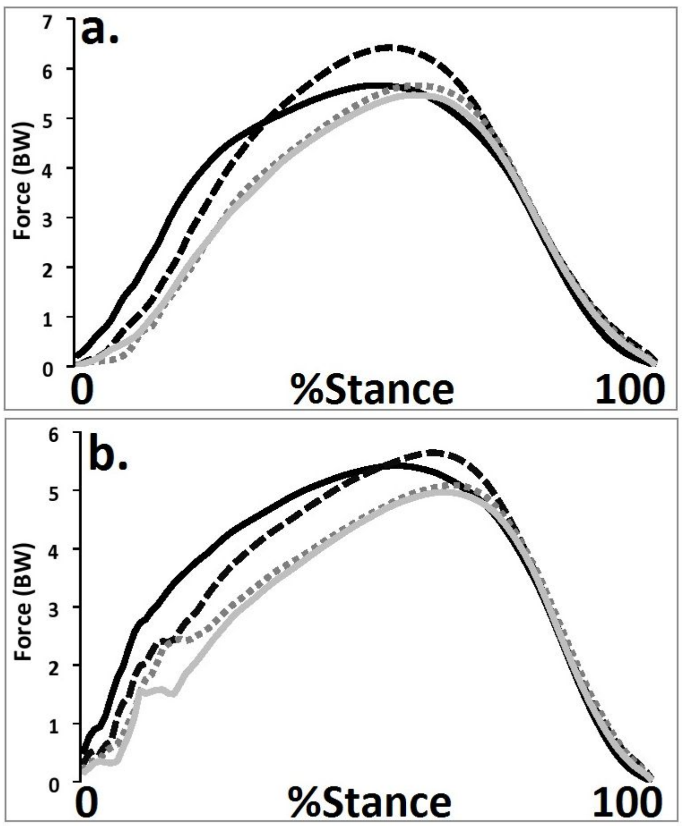

Figure 1 Achilles tendon kinetics during the stance phase (a. = run & b. = cut) (black = minimalist, black dash = high-cut, grey dot = low-cut & grey = conventional).

Results

Tables 1 and Figure 1 present the footwear differences in Achilles tendon kinetics both movements. The results indicate that the experimental footwear significantly affected Achilles tendon load parameters.

For peak Achilles tendon force a significant main effect ($P<0.05$, $p\eta^2 = 0.64$) was observed for footwear. Post-hoc pairwise comparisons showed that peak Achilles tendon force was significantly larger in the high-cut footwear in relation to the minimalist, low-cut and conventional athletic conditions. In addition it was also revealed that peak force was significantly larger in the minimalist footwear in comparison to the conventional condition.

For time to peak Achilles tendon force significant main effects were observed for both footwear ($P<0.05$, $p\eta^2 = 0.55$) and movement ($P<0.05$, $p\eta^2 = 0.70$). Post-hoc analysis for footwear showed that time to peak force was significantly greater in the low-cut footwear in comparison to the minimalist, high-cut and conventional conditions. Furthermore, it was also demonstrated that time to peak force was significantly greater in the conventional athletic footwear in relation to the minimalist and high-cut conditions. Finally, it was shown that time to peak force was significantly greater in the high-cut footwear in comparison to the minimalist condition. In addition post-hoc analysis for movement indicated that time to peak Achilles tendon force was significantly greater when performing the cut movement.

For Achilles tendon load rate significant main effects were observed for both footwear ($P<0.05$, p $\eta^2 = 0.42$) and movement ($P<0.05$, p $\eta^2 = 0.47$). Post-hoc analysis for footwear showed that Achilles tendon load rate was significantly larger in the minimalist and high-cut footwear in relation to the low-cut and conventional conditions.

Discussion

The current study aimed to examine the effects of different basketball footwear on the loads experienced by the Achilles tendon during sport specific movements. To the authors knowledge this investigation is the first comparative examination of the effects of different footwear on Achilles tendon kinetics during basketball specific movement. The findings from this work may provide basketball players with important information regarding the selection of appropriate footwear to attenuate their risk from developing Achilles tendon pathologies.

The primary observation from the current work is that Achilles tendon loading parameters were shown to be significantly larger in the minimalist and high-cut footwear in comparison to the conventional low-cut conditions. This observation is in agreement with those of Sinclair [8] and Sinclair et al [9] who showed that minimalist footwear were associated with significant increases in Achilles tendon loading.

This observation may provide important clinically meaningful information regarding the aetiology of Achilles tendon pathologies. Achilles tendon pathologies are considered to be initiated by high loads which are experienced too frequently by the tendon itself [15]. Tendon loading at an appropriate level can initiate collagen synthesis and positively influence the mechanical properties of the tendon [15]. However, when mechanical loads exceed the physiological threshold for collagen synthesis and the remodeling threshold is exceeded, this facilitates tendon degradation and ultimately leads to injury [15]. Therefore the findings from the current investigation indicate that minimalist and high-cut footwear may place basketballers at a greater risk from Achilles tendon pathologies as a function of their training/ competition.

In conclusion, although the effects of different footwear on Achilles tendon forces have been examined previously, our current knowledge of differences in Achilles tendon kinetics when performing sport specific movements in basketball footwear is limited. The current study therefore sought to provide an evaluation of Achilles tendon forces when performing sport specific movements in different basketball specific footwear. This work shows importantly that peak Achilles tendon force and the rate of Achilles tendon load rate were significantly larger in minimalist and high-cut footwear in relation to the low-cut and conventional conditions. As such given the association between Achilles tendon loading and tendon pathology the current investigation indicates that minimalist and high-cut footwear may place basketballers at increased risk for Achilles tendon pathology as a function of their training/ competition. Furthermore, it appears that for basketballers who may be susceptible to Achilles tendinopathy that low-cut and conventional conditions are most appropriate.

References

1. Cumps, E, Verhagen R, and Meeusen R. "Prospective epidemiological study of basketball injuries during one competitive season: ankle sprains and overuse knee injuries." J Sport Sci Med 6: 204-211, 2007. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3786241/
2. Montgomery PG, Pyne DB and Minahan CL. The physical and physiological demands of basketball training and competition. Int J Sports Physiol Perform. 15: 75-86, 2010. https://www.ncbi.nlm.nih.gov/pubmed/20308698
3. Narazaki K, Berg K, Stergiou N and Chen B. Physiological demands of competitive basketball. Scand J Med Sci Sport. 19: 425-322, 2009. https://www.ncbi.nlm.nih.gov/pubmed/18397196
4. Deitch JR, Starkey C, Walters SL and Moseley JB. Injury Risk in Professional Basketball Players; A Comparison of Women’s National Basketball Association and National Basketball Association Athletes. Am J Sport Med. 34: 1077-1083, 2006. https://www.ncbi.nlm.nih.gov/pubmed/16493173
5. Wertz, J., Galli, M., and Borchers, J. R. Achilles Tendon Rupture Risk Assessment for Aerial and Ground Athletes. Sport Health. 5: 407-409, 2013. https://www.ncbi.nlm.nih.gov/pubmed/24427410
6. Caselli MA. Selecting the proper athletic shoe. Pod Manag. 25: 147-149, 2006.

7. Commons AT and Low DC. Understanding the effect of high-cut shoes, running shoes and prophylactic supports on ankle stability when performing a v”-cut movement. Sport Exerc Med Open J. 1: 1-7, 2014.
8. Sinclair, J. Effects of barefoot and barefoot inspired footwear on knee and ankle loading during running. Clin Biomech. 29: 395-399, 2014. https://www.ncbi.nlm.nih.gov/pubmed/24636307
9. Sinclair, J., Atkins, S., Taylor, P. J., and Vincent, H. Effects of conventional and minimalist footwear on patellofemoral and Achilles tendon kinetics during netball specific movements. Comp Ex Phys. 11: 191-199, 2015.
10. Sinclair, J., Hobbs, S. J., and Selfe, J. (2015). The Influence of Minimalist Footwear on Knee and Ankle Load during Depth Jumping. Research in Sports Medicine, 23(3), 289-301. https://www.ncbi.nlm.nih.gov/pubmed/26053415
11. Sinclair, J., Edmundson, C.J., Brooks, D., and Hobbs, S.J. Evaluation of kinematic methods of identifying gait Events during running. Int J Sport Sci Eng. 5: 188-192, 2011.
12. Thelen, D.G., Anderson, F.C., and Delp, S.L. Generating dynamic simulations of movement using computed muscle control. J Biomech. 36: 321–328, 2003. https://www.ncbi.nlm.nih.gov/pubmed/12594980
13. Almonroeder, T., Willson, J.D., and Kernozek, T.W. The effect of foot strike pattern on Achilles tendon load during running. Annals Biomedical Eng. 41: 1758-1766, 2013. https://www.ncbi.nlm.nih.gov/pubmed/23640524
14. Selvanetti, A.C.M., and Puddu, G. Overuse tendon injuries: basic science and classification. Op Tech Sport Med. 5: 110–17, 1997.
15. Kirkendall, D.T., and Garrett W.E. Function and biomechanics of tendons. Scandinavian. J Med Sci Sport. 7: 62–66, 1997. https://www.ncbi.nlm.nih.gov/pubmed/9211605