Baltic Journal of Health and Physical Activity

Volume 9 | Issue 4 Article 6

2017

Effects of court-specific and minimalist footwear on patellar tendon loading during a maximal change of direction task

Jonathan Sinclair
Centre for Applied Sport & Exercise Sciences, University of Central Lancashire, UK, jksinclair@uclan.ac.uk

Paul John Taylor
School of Psychology, University of Central Lancashire, UK

Recommended Citation

Sinclair J, Taylor PT. Effects of court-specific and minimalist footwear on patellar tendon loading during a maximal change of direction task. Balt J Health Phys Act. 2017;9(4):66-73. doi: 10.29359/BJHPA.09.4.06

Baltic Journal of Health and Physical Activity 2017;9(4):66-73
Journal of Gdansk University of Physical Education and Sport in Gdansk
e-ISSN 2080-9999

ORIGINAL

doi: 10.29359/BJHPA.09.4.06

Effects of court-specific and minimalist footwear on patellar tendon loading during a maximal change of direction task

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Jonathan Sinclair[1], Paul John Taylor[2]

[1] Centre for Applied Sport & Exercise Sciences, University of Central Lancashire, UK
[2] School of Psychology, University of Central Lancashire, UK

abstract

Background The aim of the current investigation was to examine the effects of court shoes, minimalist, energy return and athletic footwear on the loads experienced by the patellar tendon during a maximal change of direction task.

Material/Methods Ten male participants performed maximal change of direction movements in court shoes, minimalist, energy return and athletic footwear. Lower limb kinematics were collected using an 8-camera motion capture system; ground reaction forces were quantified using an embedded force platform. Patellar tendon kinetics were examined via a musculoskeletal modelling approach, and the frictional properties of the footwear were examined using ground reaction force information.

Results The results showed that the rate at which the tendon was loaded was significantly larger in minimalist footwear (62.54BW/s) in relation to court (30.41BW/s), energy return (47.17BW/s) and athletic footwear (37.40BW/s). In addition, the coefficient of friction and rotational friction moment were found to be significantly lower in minimalist footwear (0.53 & 15.63Nm) in relation to court (0.57 & 25.04Nm), energy return (0.60 & 18.84Nm) and athletic footwear (0.62 & 19.74Nm).

Conclusions Therefore, the findings from the current investigation indicate that minimalist footwear may place athletes who undertake court-based activities at increased risk from patellar tendinopathy.

Key words footwear, court sports, patellar tendon, change of direction

article details

Article statistics **Word count:** 2,552; **Tables:** 2; **Figures:** 0; **References:** 26
Received: October 2016; **Accepted:** October 2017; **Published:** December 2017

Full-text PDF: http://www.balticsportscience.com

Indexation: Celdes, Clarivate Analytics Emerging Sources Citation Index (ESCI), CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, De Gruyter - IBR (International Bibliography of Reviews of Scholarly Literature in the Humanities and Social Sciences), De Gruyter - IBZ (International Bibliography of Periodical Literature in the Humanities and Social Sciences), DOAJ, EBSCO - Central & Eastern European Academic Source, EBSCO - SPORTDiscus, EBSCO Discovery Service, Google Scholar, Index Copernicus, J-Gate, Naviga (Softweco, Primo Central (ExLibris), ProQuest - Family Health, ProQuest - Health & Medical Complete, ProQuest - Illustrata: Health Sciences, ProQuest - Nursing & Allied Health Source, Summon (Serials Solutions/ProQuest, TDOne (TDNet), Ulrich's Periodicals Directory/ulrichsweb, WorldCat (OCLC)

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest: Authors have declared that no competing interest exists.

Corresponding author: Dr. Jonathan Sinclair, Centre for Applied Sport Exercise and Nutritional Sciences, School of Sport and Wellbeing, College of Health and Wellbeing,University of Central Lancashire; Preston, Lancashire, PR1 2HE; e-mail: jksinclair@uclan.ac.uk

INTRODUCTION

A substantial body of literature has examined the mechanics of linear running in different athletic groups. However, linear running is not an ecologically valid movement in many sports, in particular those undertaken during court-based activities [1]. Court-based sports activities require the execution of a range of different movements which include running, jumping, and rapid changes of direction [2]. The capacity to change direction quickly is essential for effective performance in multidirectional court sports, allowing athletes to gain positional advantage on the court [3].

Previously published work evaluating changes of direction activities is limited. Nevertheless, it has been noted that change of direction tasks places high stresses upon the lower extremity [4], meaning that the potential for injury is high. Patellar tendinopathy is an extremely common pathology in athletic populations accounting for as many as 25% of soft tissue injuries [5]. Patellar tendinopathy is characterized by pain confined to the inferior aspect of the patella in ballistic activities that store and release energy in the tendon itself [6]. Microtrauma occurs when the tendon is subjected to extreme forces without sufficient rest [7], leading to degradation and disorganization of the collagen fibers [8]. Patellar tendinopathy is extremely common in court sports which require numerous decelerations that mediate repetitive loading of the patellar tendon [5]. Patellar tendinopathy is debilitating and results in sustained absence and potentially permanent cessation of athletic activities [9].

The objective of sports footwear for court-based activities is to enhance performance and reduce the likelihood of injury [10]. Sports footwear with mechanical characteristics has been advocated as a mechanism by which the injury risk can be controlled during court sports [11]. The attenuation of impact shock and the enhancement of lateral stability are considered as two important footwear characteristics that are required by those involved in court sports [12]. Athletes who take part in court-based sports typically wear either court-specific or traditional athletic footwear. Court footwear is designed in order to promote lateral stability and also to enhance shock attenuation, whereas athletic footwear can vary considerably and may include cushioned running shoes, minimalist footwear associated with minimal midsole cushioning/ negligible heel to toe drop, and energy return footwear designed to reduce the amount of energy loss associated with each foot contact.

The rapid decelerations that are required during court sports means that friction between the sole of the shoe and the surface is important to prevent slippage [13]. In addition to the promotion of lateral stability and attenuation of shock which are mediated by the upper and midsole of the shoe, court footwear must also promote traction which is generated by the outsole [14]. The frictional characteristics of sports footwear are examined using both the translational coefficient of friction and rotational friction moment [15]. In court sports the traction provided by footwear can influence both the injury risk and performance [13, 16]. Excessive friction can lead to injury caused by overloading of the soft tissues in the lower extremities [17], whereas insufficient friction can lead to undesirable levels of movement of the shoe relative to the surface, which causes decrements in performance [15]. Translational friction coefficients between 0.5–0.8 [18, 19, 20] have been advocated within biomechanical literature, but there are currently no published investigations which have examined the effects of different footwear on frictional characteristics during court specific movements. There is currently no published information relating to the effects of different footwear on loads experienced by the patellar tendon during change of direction movements.

Therefore, the aim of the current investigation was to examine the effects of court shoes, minimalist, energy return and athletic footwear on the loads experienced by the patellar tendon during the maximal change of direction task. Research of this nature may provide important new information to athletes regarding the selection of appropriate footwear for the prevention of injury during court-based activities.

MATERIAL AND METHODS

PARTICIPANTS

Ten male participants volunteered to take part in this study. The mean characteristics of the participants were: age 24.32 ±3.14 years, height 177.65 ±4.60 cm and body mass 74.27 ±6.88 kg. All were free from lower extremity pathology at the time of data collection and provided written informed consent in accordance with the declaration of Helsinki. The procedure was approved by the University ethics committee.

PROCEDURE

Participants were instructed to perform maximal shuttle run cutting manoeuvres whilst striking an embedded force platform (Kistler, Kistler Instruments Ltd., Alton, Hampshire; length, width, height = 0.6 x 0.4 x 0 m) with their right (dominant) foot. The force platform sampled at 1000 Hz. Participants commenced their trials from 6 m away from the force platform, which was delineated using a masking tape. This distance was selected as being approximately half the width of a tennis court and the full width of a squash court which was deemed to be typical of the distances that court players may be expected to run and then change direction. The stance phase of was delineated as the duration over which > 20 N of vertical force was applied to the force platform [21]. Five successful trials were obtained in each footwear condition. A successful trial was defined as one in which the foot made full contact with the force platform and there was no evidence of gait modifications due to the experimental conditions. The order in which participants performed in each footwear condition was counterbalanced.

Kinematics and ground reaction force information were synchronously collected. Kinematic data were captured at 250 Hz via an eight camera motion analysis system (Qualisys Medical AB, Goteburg, Sweden). Lower extremity segments were modelled in 6 degrees of freedom using the calibrated anatomical systems technique [22]. To define the segment co-ordinate axes of the right foot, shank and thigh, retroreflective markers were placed unilaterally onto the 1st metatarsal, 5th metatarsal, calcaneus, medial and lateral malleoli, medial and lateral epicondyles of the femur. To define the pelvis segment, further markers were positioned onto the anterior (ASIS) and posterior (PSIS) superior iliac spines. Carbon fibre tracking clusters were positioned onto the shank and thigh segments. The foot was tracked using the 1st metatarsal, 5th metatarsal and calcaneus markers and the pelvis using the ASIS and PSIS markers. The centres of the ankle and knee joints were delineated as the mid-point between the malleoli and femoral epicondyle markers, whereas the hip joint centre was obtained using the positions of the ASIS markers. Static calibration trials (not normalized to static trial posture) were obtained in each footwear allowing for the anatomical markers to be referenced in relation to the tracking markers/clusters. The Z (transverse) axis was oriented vertically from the distal segment end to the proximal segment end. The Y (coronal) axis was oriented in the segment from posterior to anterior. Finally, the X (sagittal) axis orientation was determined using the right hand rule and was oriented from medial to lateral.

EXPERIMENTAL FOOTWEAR

The footwear used during this study consisted of athletic footwear (New Balance 1260 v2), minimalist (Vibram five-fingers, ELX), court shoes (Hi-Tec Indoor Lite), and energy return footwear (Adidas energy boost) (shoe size 8–10 in UK men's sizes).

PROCESSING

Ground reaction force and marker trajectories were filtered at 50 and 15 Hz using a low pass Butterworth 4th order zero-lag filter and analysed using Visual 3D (C-Motion, Germantown, MD, USA). Kinematics of the knee were quantified using an XYZ cardan sequence of rotations (where X = medial-lateral; Y = anterior-posterior and Z = vertical axes). Knee kinetic and kinematic curves were normalized to 100% of the stance phase. Joint moments were computed using Newton-Euler inverse-dynamics.

To estimate patellar tendon kinetics a predictive algorithm was utilized [23]. The patellar tendon load was determined by dividing the knee extensor moment by the estimated patellar tendon moment arm. The moment arm was quantified as a function of the sagittal plane knee angle by fitting a 2^{nd}-order polynomial curve to the data provided by Janssen et al. [24] showing patellar tendon moment arms at different knee flexion angles. The patellar tendon load was normalized by dividing it by each participant's body weight (BW).

Patellar tendon load = knee extensor moment / patellar tendon moment arm

Patellar tendon load rate (BW/s) was calculated as a function of the change in the patellar tendon load from initial contact to peak force divided by the time to peak force.

In addition, the translation coefficient of friction (μ) of each footwear was determined from the ratio of horizontal and vertical force components during the initial period of shoe motion. The peak free moment of the ground reaction force was to describe the rotational friction characteristics of the footwear.

STATISTICAL ANALYSES

Means, standard deviations and 95% confidence intervals were calculated for each outcome measure for all footwear conditions. Differences in the patellar tendon load parameters between footwear were examined using one-way repeated measures ANOVAs. Effect sizes were calculated using partial eta^2 ($p\eta^2$). 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. Finally, Pearson's correlation coefficients were utilized to test for linear associations between patellar tendon loading parameters and frictional characteristics. An alpha level of $P \leq 0.05$ was used at the criterion for statistical significance [25], and statistical calculations were conducted using SPSS v22.0 (SPSS Inc., Chicago, USA).

RESULTS

Tables 1–2 present the patellar tendon and frictional parameters that were obtained as a function of the different footwear conditions examined as part of this research.

PATELLAR TENDON LOADING

Table 1. Patellar tendon loading parameters (Mean, SD & 95% CI) as a function of footwear

	Energy return			Minimalist			Court			Athletic		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
Peak force (BW)	6.86	2.54	5.05–8.67	7.04	3.34	4.65–9.42	7.69	3.85	4.94–10.45	7.84	3.09	5.63–10.05
Time to peak force (s)	0.23	0.07	0.17–0.28	0.18	0.08	0.12–0.23	0.26	0.06	0.22–0.30	0.23	0.05	0.19–0.26
Load rate (BW/s)	47.17	33.98	22.87–71.48	62.54	53.26	24.43–100.64	30.41	12.30	21.61–39.21	37.40	11.52	29.16–45.64
Impulse (BW·s)	1.74	0.76	1.20–2.28	1.88	1.23	1.00–2.76	1.90	1.15	1.08–2.73	1.95	0.79	1.39–2.52

The results show that a significant main effect ($P < 0.05$, $p\eta^2 = 0.34$) was evident for peak patellar tendon load. Post-hoc pairwise comparisons showed that peak patellar tendon load was significantly greater in the athletic footwear in relation to the energy return and minimalist conditions.

In addition, a significant main effect ($P < 0.05$, $p\eta^2 = 0.48$) was also noted for the time to peak patellar tendon load. The results showed that the time to peak tendon load was significantly shorter in the minimalist footwear in relation to the energy return, athletic and court footwear. In addition, it was also shown that the time to peak tendon load was significantly shorter in the energy return and athletic footwear in relation to the court footwear condition.

Finally, a significant main effect ($P < 0.05$, $p\eta^2 = 0.27$) was also noted for patellar tendon load rate. The results showed that the patellar tendon load rate was significantly greater in the minimalist footwear in relation to the athletic and court footwear. In addition, it was also shown that the patellar tendon load rate was significantly greater in the court and athletic footwear in relation to the energy return condition.

FRICTIONAL CHARACTERISTICS

Table 2. Frictional parameters (Mean, SD & 95% CI) as a function of footwear

	Energy return			Minimalist			Court			Athletic		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
Coefficient of friction	0.60	0.07	0.55–0.65	0.53	0.06	0.48–0.57	0.57	0.08	0.52–0.63	0.62	0.10	0.55–0.69
Rotational friction moment (Nm)	18.84	5.10	15.20–22.49	15.63	4.01	12.76–18.49	25.04	6.43	20.44–29.63	19.74	5.87	15.94–23.94

The results show that a significant main effect ($P < 0.05$, $p\eta^2 = 0.62$) was evident for the coefficient of friction. Post-hoc pairwise comparisons showed that the coefficient of friction was significantly reduced in the minimalist in relation to the energy return, athletic and court footwear.

In addition a significant main effect ($P < 0.05$, $p\eta^2 = 0.56$) was also noted for the peak rotational friction moment. Post-hoc pairwise comparisons showed that the rotational friction moment was significantly reduced in the minimalist in relation to the energy return, athletic and court footwear.

CORRELATIONAL ANALYSIS

No significant ($P > 0.05$) correlations were observed between patellar tendon loading parameters and frictional characteristics.

DISCUSSION

The aim of the current investigation was to examine the effects of court shoes, minimalist, energy return and athletic footwear on the loads experienced by the patellar tendon during a maximal change of direction task. To the Authors' knowledge this represents the first investigation to comparatively examine the effects of different footwear on patellar tendon loads during court specific motions, and research of this nature may provide important new information to athletes regarding the selection of appropriate footwear for the prevention of injury during court-based activities.

The first key finding from the current investigation is that peak patellar tendon loading was significantly reduced in the energy return and minimalist footwear conditions. However, when considering the rate at which the tendon was loaded, the minimalist footwear performed worst in relation to the athletic and court specific conditions. As stated previously, the aetiology of patellar tendinopathy in athletic populations relates to the storage and release of energy by the tendon during ballistic movements [6]. Therefore given the increased rate at which the tendon was loaded in the minimalist footwear condition, this observation may have clinical significance. It appears based on the findings from the current investigation that minimalist footwear may place those who engage in court-based activities at increased risk from patellar tendinopathy.

In addition, it was shown that minimalist footwear was associated with the lowest values for the coefficient of friction and the rotational friction moment. A likely explanation for this observation is available traction based on the tread patterns of each shoe which are dissimilar between the footwear examined as part of the current study. The tread pattern and the extent of the surface area in contact with the surface have been shown to influence frictional characteristics at the shoe-surface interface [19]. The minimalist footwear features a contoured outsole with a negligible tread pattern this is in contrast to the athletic, energy return and court footwear which have a flatter outsole with significant (although distinct) tread patterns. It is proposed that this is the mechanism responsible for the reduction in frictional properties noted in the minimalist footwear condition. However, it is likely that performing court-based activities in minimalist footwear may impede performance due to inadequate traction in the maximal change of direction tasks [19]. Importantly, the current investigation also showed that there were no significant linear associations between indices of patellar tendon loading and frictional parameters for any of the four footwear conditions examined in this investigation. Therefore, whilst previous investigations have indicated that frictional properties may be linked with the aetiology of soft tissue injuries [17], it appears that frictional characteristics and injury risk to the patellar tendon may not be linearly associated.

A potential limitation to the current investigation is that patellar tendon loading was quantified using a mathematical modelling approach. This was a requirement of the current investigation due to the invasive nature of obtaining in vivo measures of patellar tendon loading. Muscle driven simulations of the soft tissue loading parameters using inverse kinematic approaches have improved significantly in recent times and thus may become useful as are search tool for clinical analyses [26]. Musculoskeletal simulations still require a range of mechanical constraints in terms of the number of degrees of freedom, which may lead to incorrectly predicted musculoskeletal loading parameters. Nonetheless, musculoskeletal simulations remain relatively new and with further advancement to improve their precision, further developments in clinical research may be conceivable.

In conclusion, although the biomechanical effects of different footwear has been examined extensively, current knowledge regarding differences in patellar tendon kinetics when performing the change of direction tasks is limited. The current investigation thus adds to the current literature base by performing a comprehensive evaluation of patellar tendon loading parameters when performing a change of direction task in minimalist, athletic, energy return and court-specific footwear. Importantly, the current study showed that the rate of patellar tendon loading was greater in minimalist footwear compared to athletic and court footwear. Therefore, the findings from the current investigation indicate that minimalist footwear may place athletes who undertake court-based activities at increased risk from patellar tendinopathy.

REFERENCES

[1] Spiteri T, Cochrane JL, Hart NH, Haff GG, Nimphius S. Effect of strength on plant foot kinetics and kinematics during a change of direction task. Eur J Sport Sci, 2013;13:646-652. doi: 10.1080/17461391.2013.774053

[2] Hewit JK, Cronin JB, Hume PA. Kinematic factors affecting fast and slow straight and change-of-direction acceleration times. J Strength Cond Res. 2013;27:69-75. doi: 10.1519/JSC.0b013e31824f202d

[3] Baker DG, Newton RU. Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. J Strength Cond Res. 2008;22:153-158. doi:10.1519/JSC.0b013e31815f9519

[4] Schot P, Dart J, Schuh M. Biomechanical analysis of two change-of-direction maneuvers while running. J Orthopaed Sport Phys Ther. 1995;22:254-258.

[5] Lian ØB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports a cross-sectional study. Am J Sport Med. 2005;33:561-567.

[6] Rudavsky A, Cook J. Physiotherapy management of patellar tendinopathy. J Physiother. 2014;60:122-129.

[7] Rutland M, O'Connell D, Brismée JM, Sizer P. Apte G, O'Connell J. Evidence–supported rehabilitation of patellar tendinopathy. North Am J Sport Phys Ther. 2010;5:166-178.

[8] Maffulli N, Wong J, Almekinders LC. Types and epidemiology of tendinopathy. Clin Sport Med. 2003;22:675-692.

[9] Kettunen JA, Kvist M, Alanen E, Kujala UM. Long-term prognosis for jumper's knee in male athletes a prospective follow-up study. Am J Sport Med. 2002;30:689-692.

[10] Shorten MA. Running shoe design: protection and performance pp 159-169 in Marathon Medicine (Ed. D. Tunstall Pedoe). London: Royal Society of Medicine; 2000.

[11] Sinclair J, Chockalingam N, Naemi R, Vincent H. The effects of sport-specific and minimalist footwear on the kinetics and kinematics of three netball-specific movements. Footwear Sci. 2015;7:31-36.

[12] Lake MJ. Determining the protective function of sports footwear. Ergonomics. 2000;43:1610-1621.

[13] Frederick EC. Kinematically mediated effects of sport shoe design: a review. J Sport Sci. 1986;4:169-184.

[14] Valiant GA, McGuirk T, McMahon TA, Frederick EC. Static friction characteristics of cleated outsole samples. Med Sci Sport Exerc. 1985;17:156-159.

[15] Holden JP, Cavanagh PR. The free moment of ground reaction in distance running and its changes with pronation. In: Proceedings of the 1986 North American Congress on Biomechanics. 1986, 209-210.

[16] Reinschmidt C, Nigg BM. Current issues in the design of running and court shoes. Sportverletzung·Sportschaden. 2000;14:72-81.

[17] Wannop JW, Luo G, Stefanyshyn D. Traction properties of footwear in Canadian high school football. Footwear Sci. 2009;1:121-127.

[18] Nigg BM, Segesser B. The influence of playing surfaces on the load on the locomotor system and on football and tennis injuries. Sport Med. 1988;5:375-385.

[19] Valiant GA. Friction-slipping-traction. Sportverletzung·Sportschaden. 1993;7:171-178.

[20] Frederick EC. Optimal frictional properties for sport shoes. In: ISBS-Conference Proceedings Archive. 1993.

[21] Sinclair J, Hobbs SJ, Protheroe L, Edmundson CJ, Greenhalgh A. Determination of gait events using an externally mounted shank accelerometer. J Appl Biomech. 2013;29:118-122.

[22] Cappozzo A, Catani F, Leardini A, Benedeti MG, Della Croce U. Position and orientation in space of bones during movement: Anatomical frame definition and determination. Clin Biomech. 1995;10:171–178.

[23] Herzog W, Read LJ. Lines of action and moment arms of the major force-carrying structures crossing the human knee joint. J Anatomy. 1993;182:213-230.

[24] Janssen I, Steele JR, Munro BJ, Brown NA. Predicting the patellar tendon force generated when landing from a jump. Med Sci Sport Exerc. 2013;45:927-934.

[25] Delp SL, Anderson FC, Arnold AS, et al. OpenSim: open-source software to create and analyze dynamic simulations of movement. IEEE Transactions on Biomedical Engineering. 2007;54:1940-1950.

[26] Sinclair J, Taylor PJ, Hobbs SJ. Alpha level adjustments for multiple dependent variable analyses and their applicability–a review. Int J Sport Sci Engineer. 2013;7:17-20.

Cite this article as:
Sinclair J, Taylor PT. Effects of court-specific and minimalist footwear on patellar tendon loading during a maximal change of direction task. Balt J Health Phys Act. 2017;9(4):66-73. doi: 10.29359/BJHPA.09.4.06