THE ASSOCIATION BETWEEN STATIC FOOT POSTURE AND PEAK PATELLAR TENDON FORCE DURING SINGLE-LEG LANDINGS: PRELIMINARY FINDINGS

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Patellar tendinopathy is particularly prevalent in jumping-sport athletes and develops due to chronic overloading without appropriate load modification. Pronated and supinated foot postures have been suggested to be associated with the development of the injury. This study aimed to investigate the association between static foot posture, measured using the Foot Posture Index (FPI), and peak patellar tendon force during single-leg drop landings. Kinetic and kinematic data were collected during a single-leg landing task and used to estimate peak patellar tendon force. There was no statistically significant association between FPI and peak patellar tendon force during landing (p = 0.910). Further research investigating how foot posture may affect lower limb loading during landing is required to inform pre-screening and rehabilitation protocols for jumping sport athletes.

KEYWORDS: patellar tendinopathy, injury prevention, pronation, supination

INTRODUCTION: Patellar tendinopathy is characterised by pain in the anterior portion of the knee and can occur due to overuse and suboptimal loading (Cook & Purdam, 2009). The injury is particularly prevalent in jumping sport athletes, such as basketballers and volleyballers (Lian et al., 2005). While the aetiology of patellar tendinopathy is multi-factorial (Kountouris & Cook, 2007), the most common theory of pathogenesis is chronic overloading of the knee extensor mechanism (Scattone Silva et al., 2017). This leads to increased strain on the tendon, and over time, without appropriate load modifications, tendinopathy develops (Cook & Purdam, 2009). Exploring ways to optimise load at the patellar tendon is important to reduce injury risk. Measures of foot posture have been associated with the development of patellar tendinopathy, including varus shank-forefoot alignment (Bittencourt et al., 2012; Mendonça et al., 2018), excessive pronation and supination (Kountouris & Cook, 2007; Van der Worp et al., 2011), and lower arch height during static weight-bearing (Van der Worp et al., 2011). Excessive foot pronation and supination is thought to contribute to increased tendon loading, as the force-absorbing function of the lower limbs is reduced when excessive pronation or supination occurs (Kountouris & Cook, 2007). However, there is no research to confirm this. Therefore, this study aimed to investigate the association between static foot posture and estimated peak patellar tendon force during single-leg drop landings.

METHODS: Preliminary data (n = 11/60) was collected from six female, and five male participants (mean age: 25.4 ± 3.5 years, body mass: 68.0 ± 12.7 kg, height: 171.1 ± 9.5 cm). All participants were healthy, active, adults, free from injury and illness at the time of testing and had never undergone surgery to their lower limbs. Written informed consent was obtained prior to testing, and the study was approved by the University of Canberra Human Research Ethics Committee (11895).
Upon arrival to a laboratory-based testing session, participants' standing height and body mass were recorded before static foot posture was measured using the Foot Posture Index (FPI) (Redmond et al., 2006). The FPI is a well-documented, validated and reliable tool commonly used in clinical practice (McLaughlin et al., 2016) that measures static foot posture along a 25-point scale between -12 and +12, where negative values indicate supination, positive values indicate pronation, and a value of 0 indicates a neutral foot posture (Redmond et al., 2006). Following the anthropometric and clinical measures, participants completed a standardised

warm-up consisting of jogging, squats and multidirectional lunges (Janssen et al., 2012), followed by familiarisation of the drop landing tasks.
Thirty-four retro-reflective markers (14 mm) were placed on participants' thorax, pelvis and lower limbs as per the University of Western Australia (UWA) lower body marker set (Besier et al., 2003), and a further 28 markers (9.5 mm) were placed on participants' feet as per the Istituto Ortopedico Rizzoli (IOR) multi-segmented foot marker set (Leardini et al., 2007). Only the UWA marker set was used in the analysis of the preliminary data presented in the current study. The IOR marker trajectories were collected, however, these data will be analysed as part of the broader project. Following a static calibration trial, functional calibration trials were conducted to determine the hip joint centres, and knee axes of rotation (Besier et al., 2003).
Participants completed a series of double and single-leg drop landing and drop jump tasks from a height of 30 cm, however, only the single-leg drop landing tasks were used in the analysis of the current study. Single-leg drop landings are commonly used in similar studies investigating lower limb kinetics during landing (Santamaria & Webster, 2010). While not specific to a single sport, single-leg drop landings are applicable to multiple sports that include landings.
Three-dimensional marker trajectories were collected using a 10-camera (MX-40) Vicon motion analysis system, sampling at 250Hz (Oxford Metrics, Ltd., Oxford, UK). Ground reaction force data was collected using 400 mm by 600 mm AMTI force plates sampling at 1000Hz (Advanced Mechanical Technologies Inc., MA, USA). These data were used to estimate the peak patellar tendon force, normalised to body weight (BW).
Vicon Nexus software (Oxford Metrics Ltd., Oxford, UK) was used to reconstruct and label three-dimensional marker trajectories. Following a residual analysis and visual data inspection, trajectory and analogue data were filtered using a fourth-order zero-lag Butterworth filter with a cut-off frequency of 14Hz (Winter, 2009) and modelled using the UWA lower body model (Besier et al., 2003). A standard Newton-Euler inverse dynamics approach was used to calculate kinetics at the knee joint (Winter, 2009). A custom MATLAB program (Mathworks, Inc., MA, USA) was used to extract and normalise the right and left sagittal plane knee joint moments and angles. Data were normalised to 101 points between initial contact and peak knee flexion. The patellar tendon moment arm was quantified as a function of the sagittal plane knee joint angle and regression coefficients based on previously validated methods (Herzog & Read, 1993). The patellar tendon force was then estimated by dividing the knee joint moment by the patellar tendon moment arm and normalised to body weight (BW) (Herzog & Read, 1993). Mean right and left peak patellar tendon force values were then calculated for each participant.
A Spearman's rank-order correlation was conducted to examine the association between FPI and peak patellar tendon force during single-leg drop landings. To further examine the association, a one-way analysis of variance (ANOVA) was conducted to determine if there were any significant differences in peak patellar tendon force during landing between FPI groups. FPI values were grouped as supinated (-12 to -1), neutral (0 to +5) and pronated (+6 to +12) based on the FPI reference values (Redmond et al., 2006). Effect size (partial η^2) was calculated, and interpreted as small = 0.01, medium = 0.06 and large = 0.14 (Cohen, 2013). All statistical analyses were conducted using RStudio (R Version 4.2.1, R Studio Inc, MA, USA) (R Core Team, 2023) with alpha set to 0.05.

RESULTS: The results of the Spearman's rank-order correlation determined there was no significant association between FPI and peak patellar tendon force (BW) during landing in the current study ($p = 0.910$). Furthermore, the results of the ANOVA determined there were no significant differences in peak patellar tendon force (BW) between supinated, neutral, and pronated FPI ($p = 0.212$), however, there was a large effect size (partial $\eta^2 = 0.15$; Figure 1).

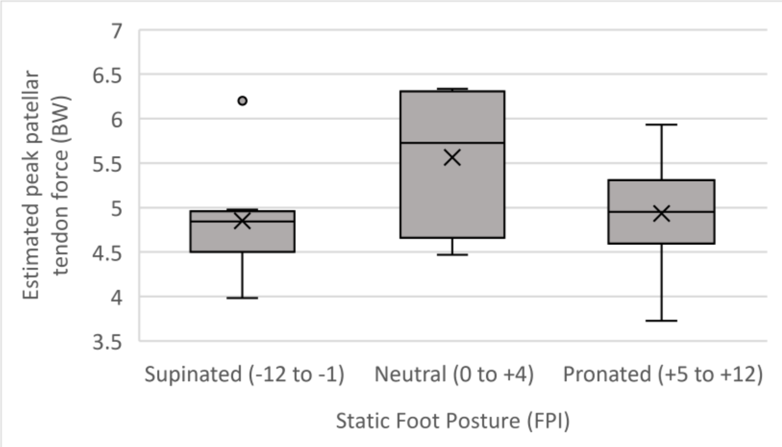

Figure 1: Difference in peak patellar tendon force, normalised to bodyweight (BW), during single-leg landings between static foot posture groups, using the Foot Posture Index (FPI; n = 11; *p* = 0.212, partial η^2 = 0.15).

DISCUSSION: The current study aimed to investigate the association between FPI and peak patellar tendon force during a single-leg drop landing task. Results showed no statistically significant association between FPI and peak patellar tendon force during landing, and no statistically significant differences in peak patellar tendon force between supinated, neutral, and pronated FPI groups.

The preliminary findings do not support the hypothesis that pronated and supinated foot postures may be associated with a greater magnitude of force experienced at the patellar tendon during landing. In this preliminary sample it appears that peak patellar tendon force may be higher in those with a neutral foot posture, compared to pronated and supinated foot postures, and the small sample size and high variance in each group may relate to the nonsignificant findings (Figure 1). This finding is interesting as it is not supported by literature that suggests that pronated and supinated foot postures may be associated with the development of patellar tendinopathy due to a decreased ability to absorb force in these foot postures (Kountouris & Cook, 2007; Van der Worp et al., 2011). It is thought that supinated foot postures are associated with increased foot stiffness, while pronated foot postures are associated with decreased stiffness (Franco, 1987). From a clinical perspective, a linear relationship between foot posture and patellar tendon force during landings would be expected. That is, supinated foot postures may be associated with the greatest magnitude of force at the patellar tendon, followed by neutral foot postures, with pronated foot postures associated with a lower magnitude of force. Due to the increased stiffness, supinated feet may be less optimal for force absorption, transferring the force up the limb (Franco, 1987), however, this force may be being experienced at another lower limb joint, such as the ankle. Pronated feet are thought to be more compliant (Franco, 1987), which may aid in the foots ability to absorb forces via the foot spring mechanism, whereby the arch of the foot compresses under load before recoiling in a spring like manner (Farris et al., 2019; Welte et al., 2021). Research is required to further understand the relationship between static foot posture and lower limb kinetics.

The following limitations must be considered. Firstly, the sample size of the preliminary data set is small (*n* = 11). Further analysis of the broader project (*n* = 60) will be conducted. Secondly, the current study only quantified peak patellar tendon force. As patellar tendinopathy develops as a result of chronic overloading of the tendon (Cook & Purdam, 2009), investigating patellar tendon force over the duration of the landing task may give more insight into the relationship between FPI and patellar tendon force during landing. Finally, only static foot posture was analysed. While there is some evidence to suggest a relationship between measures of static foot posture and dynamic foot posture (Franettovich et al., 2007), static foot posture cannot always be used to infer dynamic foot posture. Static foot posture was used as it is an accessible clinical measure that can be easily implemented into pre-screening programs for athletes. However, understanding the effect of dynamic foot posture on patellar tendon force may inform clinical decisions when interpreting static foot posture.

CONCLUSION: This study investigated the association between FPI and peak patellar tendon force during single-leg drop landing tasks. In this preliminary analysis of 11 participants there was no significant association between FPI and peak patellar tendon force, and no significant differences in peak patellar tendon force between FPI groups. Future research is required to further investigate the relationship between peak patellar tendon force and foot posture, including static and dynamic measures. Further research in this area will inform pre-screening and load management of jumping-sport athletes as well as rehabilitation from patellar tendinopathies.

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