JUMP-LANDING MECHANICS IN PATELLAR TENDINOPATHY IN ELITE JUNIOR BASKETBALL ATHLETES

Meaghan Harris[1], Mick Drew[3], Adrian Schultz[1, 2], Ebonie Rio[4], Paula Charlton[3], Suzi Edwards[1, 2]

[1]University of Newcastle, School of Environmental and Life Sciences, Ourimbah NSW, Australia
[2]University of Newcastle, Priority Research Centre for Physical Activity and Nutrition, Callaghan, NSW, Australia
[3]Physical Therapies, Australian Institute of Sport, Bruce, ACT, Australia
[4]Australian Centre for Research into Injury in Sport and its Prevention, La Trobe University, Bundoora, VIC, Australia.

The purpose of this study was to identify key modifiable jump-landing variables associated with patellar tendinopathy (PT). Thirty-six junior elite basketball players (18 men, 18 women) were recruited (8 PT*, 11* controls*, 17* excluded from statistical analysis). Three-dimensional (3D) landing technique during a stop-jump task and patellar tendon ultrasounds were recorded. A series of mixed-design factorial analyses of variance were used to determine any significant between-group differences. Athletes with PT utilised a lower ground reaction force (GRF) loading rate (LR) via increasing their time duration from initial foot-ground contact (IC) to peak vertical GRF (F_V). This strategy of a lower LR did not lead to those athletes with PT decreasing their peak GRF nor patellar tendon forces (F_{PT}) in comparison to the controls.

KEYWORDS: Biomechanics, kinematics, kinetics, patellar tendon, landing strategies.

INTRODUCTION: Jumper's knee, clinically known as patellar tendinopathy (PT), is an overuse injury of the patellar tendon. The prevalence of PT has been reported as high as 36% in elite basketball players (Lian, Engebretsen, & Bahr, 2005) and 7% in 14-18 year old youth basketball players from both sexes (Cook, Khan, Kiss, Purdam, & Griffiths, 2000). In terms of injury severity, it has been shown that athletes with PT may continue to play despite pain and dysfunction. Therefore, morbidity costs of PT can be substantial and include reduced performance and attrition from physical activity.

Identification of altered landing strategies in those athletes with PT may be beneficial in developing an expedient strategy for reducing the risk of re-injury. Altered lower limb mechanics during landing have previously been reported to be associated with adult elite dancers with symptomatic PT during a *sauts de chat* (Fietzer, Chang, & Kulig, 2012), elite and sub-elite male volleyball players with a history of PT during drop landings (Bisseling, Hof, Bredeweg, Zwerver, & Mulder, 2007), and sub-elite male junior basketballers with patellar tendon abnormality (PTA) during a stop-jump horizontal landing (Mann, Edwards, Drinkwater, & Bird, 2013). Although Mann et al. 2013 previously investigated jump-landing techniques as a prediction of the absence or presence of a PTA in sub-elite junior basketball, currently no jump-landing research on elite junior basketball players and PT risk exists. The purpose of this study therefore, was to determine whether elite junior basketball players with symptomatic PT alter their landing strategies during a stop-jump task compared to asymptomatic participants with normal patellar tendons.

METHODS: Thirty-six junior elite basketball players (♂*n*=18, ♀*n*=18; age 16.3±0.7yr, 186.3±11.8 cm, 78.9±16.9 kg) were recruited from a Basketball Australia five-day development camp. Each participant's injury history and Victorian Institute of Sport Assessment Questionnaire, Patellar Tendon (VISA-P) scores (Visentini et al., 1998) were documented where a score of <80 is considered part of a clinical diagnosis of PT. Patellar tendon pathology was recorded using a standardised ultrasound protocol (Docking & Cook, 2016). Thirteen participants were excluded from statistical analysis as they reported current

anterior knee pain (VISA-P <80) without PTA, had previous lower limb knee surgery, equivocal ultrasound scan(s) and/or had less than three successful stop-jump trials recorded. The remaining 23 participants were stratified based on the following criteria: i) normal patellar tendons (♂*n*=3, ♀*n*=8, termed controls); ii) symptomatic PT (VISA-P <80 with hypoechoic regions present) (♂*n*=6, ♀*n=2*); and iii) asymptomatic (VISA-P >80) with hypoechoic regions present (♂*n*=3, ♀*n*=1) excluded from statistical analysis due to small sample size).
Anthropometric measurements were taken and a 50-retroreflective marker set was attached to each participant on the shoe, shank, thigh, pelvis, and trunk (Schaefer, O'dwyer, Ferdinands, & Edwards, 2018)After familiarising all participants with the stop-jump task (Mann et al., 2013), 3D kinematic data and GRF data was captured using 16 Oqus 700+ camera system (300 Hz, Qualisys AB, Göteborg, Sweden) and two multichannel Kistler force platforms (Type 9287C, Kistler, Winterthur, Switzerland) recorded GRF of the stop-jump. Analyses of the horizontal phase of the stop-jump (landing and take-off) was performed for the 3D kinematic data using Visual 3D software (v6, C-Motion, Germantown, MD, USA), and for the GRF data using a customised LabView software (National Instruments Corporation, Austin, TX, USA). Temporal events during the stop-jump identified included initial foot-ground contact (IC), first peak vertical GRF (F_{V1}), subsequent local minimum (F_{V2}), peak patellar tendon force (F_{PT}), second peak vertical GRF (F_{V3}) and take-off (TO). Kinematic variables analysed at these temporal events included; ankle, knee, hip, L5S1 and T12L1 joint angles for all three axis. GRF variables were calculated between IC and TO. Once normality and equal variance of the data was confirmed, mixed model factorial analyses of variance were calculated in Statistica (v13, Statsoft Inc, Tulsa, OK, USA) to determine any significant changes ($p<0.05$) between-groups (symptomatic PT, controls) in the means of all outcome variables. When main effects were found, *Tukey post hoc tests* were conducted to identify if any significant interactions were present.

RESULTS: Main effects of group were not significant for joint angles ($F_{1,16}=1.45$, p=0.25; Figure 1A), peak force ($F_{1,16}=0.1075$, p=0.75; Figure 1B) or GRF impulse ($F_{1,16}=0.1$, p=0.76; Figure 2C). Yet there was a significant interaction for time to peak force ($F_{1,16}=13.42$, p=0.002; Figure 1C). *Post hoc* Tukey analysis of the timing main effect revealed participants with PT displayed longer duration from IC to peak force compared to those with normal patellar tendons. The timing*group significant interaction further revealed ($F_{6,96}=2.38$, p=0.03) that the time from IC-F_{V2} was significantly longer (p=0.03) and IC–F_{PT} was trending towards significance (p=0.07) for those with PT when compared to the control group. A significant main effect of group was observed for loading rate ($F_{1,16}=6.11$, p=0.03, Figure 1A) however *post hoc* analysis of the significant loading rate*group interaction ($F_{1,16}=0.42$, p=0.52) did not yield further significant results.

DISCUSSION: This study is the first to investigate the relationship between landing strategies during the stop-jump task and PT in elite junior male and female basketball players. In contrast to previous research in adults with PT or junior basketballers at risk of PT (Mann et al., 2013) there was no statistical between-group differences observed for any kinematic variables and only some minor between-group differences for investigated kinetic variables. Previously it has been reported that asymptomatic cohorts with patellar tendon abnormality during the horizontal landing phase of a stop-jump display a different landing strategy in comparison to the controls, contacting the ground with greater knee flexion, then extending their hips rather than flexing them (Edwards et al., 2010). Knee joint angles at IC have also been cited as substantial predictors of the presence or absence of a PTA (Mann et al., 2013). These previous findings are in contrast with the findings of our study in which we did not observe any between-group differences. Despite the disparities of findings in our study and other landing studies for the same variables, these differences in findings can be partially explained by varied cohorts (age, sport, skill level), and jump-landing task selection. For example a whole jump-landing motion as carried out during a game situation (i.e. stop-jump, spike- jump) displays different landing mechanics when compared to land only tasks (i.e. drop land) (Edwards et al., 2010). This highlights the need for further studies to investigate these discrepancies.

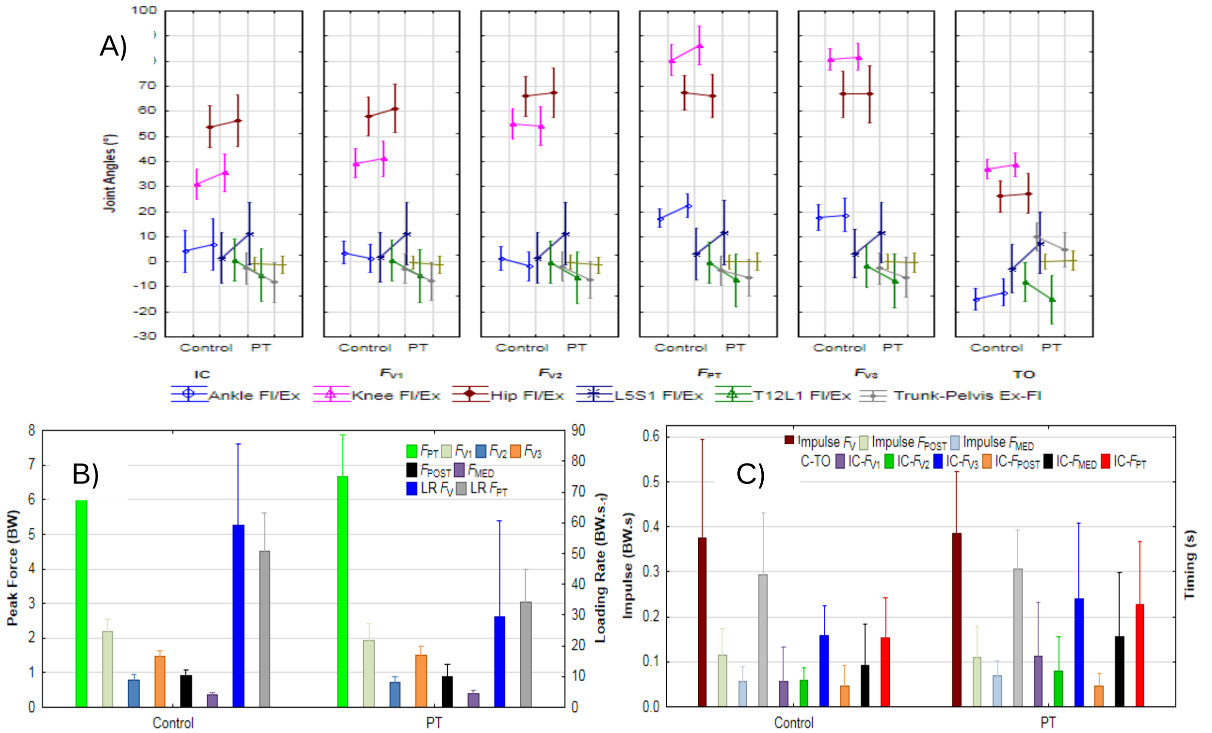

Figure 1. Mean values (± SE) for PT vs. control cohorts for the (A) joint angles (°; note the y,z angles are omitted from this figure), (B) peak force and loading rate, and (C) impulse and timing of peak force timing from initial contact during a horizontal landing in a stop-jump task.

DISCUSSION: The present study is the first to investigate the relationship between landing strategies during the stop-jump task and PT in elite junior male and female basketball players. In contrast to previous research in adults with PT or junior basketballers at risk of PT (Mann et al., 2013) there were no statistical between-group differences for any kinematic variables and only some minor between-group differences for investigated kinetic variables. It has been reported that asymptomatic cohorts with patellar tendon abnormality during the horizontal landing phase of a stop-jump display a different landing strategy in comparison to the controls, contacting the ground with greater knee flexion, then extending their hips rather than flexing them (Edwards et al., 2010). Knee joint angles at IC have been cited as substantial predictors of the presence or absence of a PTA (Mann et al., 2013). These previous findings are in contrast with our study findings of no between-group differences. Despite disparities of findings in our study and other landing studies for the same variables, these differences in findings can be partially explained by varied cohorts (age, sport, skill level), and jump-landing task selection. For example a whole jump-landing motion as carried out during a game situation (i.e. stop-jump, spike- jump) displays different landing mechanics when compared to land only tasks (i.e. drop land) (Edwards et al., 2010). This highlights the need for further studies to investigate these discrepancies.
Participants with PT compared to their control counterparts had a significantly longer duration from IC to F_{V2} whilst still displaying similar peak F_V and F_{PT} values, which in turn contributed to their significantly lower LR F_V. This study's findings of lower loading rates in PT participants are in contrast with current literature that does not implicate the rate at which a structure is loaded with PT during a drop landing (Bisseling et al., 2007). The same findings of this study, however are in agreement with current literature that reports asymptomatic patellar tendon abnormality participants adopt lower rates of loading during a vertical landing but not horizontal landing in a stop-jump (Edwards et al., 2010). Lower loading rates in the PT group during the horizontal landing is further supported by the significantly lower LR F_{PT} due to a trend of a longer duration for IC–F_{PT} and similar F_{PT} force compared to the control

group. This partially supports previous stop-jump research that observed no difference in F_{PT} and IC-F_{PT} between asymptomatic with patellar tendon pathology and control groups but disagrees with their finding of similar LR F_{PT} (Edwards et al., 2010). Given our study's contrasting findings, it is postulated that our PT participants, in response to their mechanically compromised and painful tendon structures, landed with longer stance durations, which lead to the PT cohort sustaining a similar peak F_V and F_{PT} compared to the control group in an attempt to limit pain. By achieving similar peak forces, it then contributed to PT participants displaying a slower F_V and F_{PT} LR compared to players with normal tendons. It is hypothesised that had the asymptomatic PTA group been included in the statistical analysis this cohort would display different kinetics to our symptomatic PT cohort however this remains to be explored. It should be acknowledged that time to peak F_V has previously been investigated by Bisseling et al. (2007) however valid comparisons between the findings of these studies and our research are unable to be drawn due to differences in landing tasks (drop land) and the inherent differences in the landing kinematics of each task.

CONCLUSION: Elite junior male and female basketballers with PT adopt landing mechanics that decrease the loading rate via a longer stance phase duration to achieve similar peak forces during a stop-jump landing task compared with their uninjured counterparts. The findings of this study reinforce the importance of further investigation into jump-landing mechanics, patellar tendon loads, and those at risk of developing PT. It remains unknown if the decreases in loading rate observed in these PT players was a strategy to decrease their pain during landing, while maintaining similar performance to their control counterparts.

REFERENCES

Bisseling, R. W., Hof, A. L., Bredeweg, S. W., Zwerver, J., & Mulder, T. (2007). Relationship between landing strategy and patellar tendinopathy in volleyball. *British Journal of Sports Medicine, 41*(7), e8.

Cook, J. L., Khan, K. M., Kiss, Z. S., Purdam, C. R., & Griffiths, L. (2000). Prospective imaging study of asymptomatic patellar tendinopathy in elite junior basketball players. *Journal of Ultrasound in Medicine, 19*(7), 473-479.

Docking, S. I., & Cook, J. (2016). Pathological tendons maintain sufficient aligned fibrillar structure on ultrasound tissue characterization (UTC). *Scandinavian Journal of Medicine & Science in Sports, 26*(6), 675-683.

Edwards, S., Steele, J. R., McGhee, D. E., Beattie, S., Purdam, C., & Cook, J. L. (2010). Landing strategies of athletes with an asymptomatic patellar tendon abnormality. *Medicine and Science in Sports and Exercise, 42*(11), 2072-2080.

Fietzer, A. L., Chang, Y. J., & Kulig, K. (2012). Dancers with patellar tendinopathy exhibit higher vertical and braking ground reaction forces during landing. *Journal of Sports Sciences, 30*(11), 1157-1163.

Lian, O. B., Engebretsen, L., & Bahr, R. (2005). Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. *American Journal of Sports Medicine, 33*(4), 561-567.

Mann, K. J., Edwards, S., Drinkwater, E. J., & Bird, S. P. (2013). A lower limb assessment tool for athletes at risk of developing patellar tendinopathy. *Medicine and Science in Sports and Exercise, 45*(3), 527-533.

Schaefer, A., O'dwyer, N., Ferdinands, R. E. D., & Edwards, S. (2018). Consistency of kinematic and kinetic patterns during a prolonged spell of cricket fast bowling: an exploratory laboratory study. *Journal of Sports Sciences, 36*(6), 679-690.

Visentini, P. J., Khan, K. M., Cook, J. L., Kiss, Z. S., Harcourt, P. R., & Wark, J. D. (1998). The VISA score: An index of severity of symptoms in patients with jumper's knee (patellar tendinosis). *Journal of Science and Medicine in Sport, 1*(1), 22-28.

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