JOINT DISPLACEMENTS AND PEAK ACHILLES TENDON FORCE DURING IRISH DANCING-SPECIFIC LANDING TASKS

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Achilles tendinopathy is prevalent among Irish dancers, thought to be due to the high impact, stiff-style landing tasks associated with the sport. This study aimed to investigate the relationship between sagittal plane joint displacements, at the ankle, knee, hip and thorax segment, and peak Achilles tendon force during an Irish dancing ‘leap over’ landing task. Kinetic and kinematic data were collected for 12 participants performing the ‘leap over’, and used to calculate peak Achilles tendon force and joint displacements. Results of the study found a statistically significant positive correlation between ankle dorsiflexion and peak Achilles tendon force during the ‘leap over’. These findings can be used to inform future research into the effect of joint displacement on peak Achilles tendon force, and to develop strategies to help dancers reduce their risk of developing Achilles tendinopathy.

KEYWORDS: Achilles tendinopathy, injury prevention, ankle dorsiflexion

INTRODUCTION: Originally a cultural dance form, Irish dancing is now a popular and highly competitive sport worldwide (McGuinness & Doody, 2006). Achilles tendinopathy is thought to be particularly prevalent among Irish dancers, with 78% of participants (n = 18) in one study diagnosed with the injury (Walls et al., 2010). The high impact and stiff-style landing tasks associated with Irish dancing are believed to be a contributing factor to the high prevalence of Achilles tendinopathy observed (Walls et al., 2010).

During landing tasks, Irish dancers aim to land on the distal end of the hallux, before maximally dorsiflexing the metatarsophalangeal joint, with the ankle in a plantarflexed position, and knees and hips in a neutral or straight position (Beasley, Stracciolini, Tyson, & Stein, 2014; Noon, Hoch, McNamara, & Schimke, 2010). This stiff landing technique is likely to compromise force absorption at the ankle, knee and hip joints, as landing forces are not cushioned by joint flexion, as suggested in the literature for a safe landing strategy (Bressel & Cronin, 2005; Chockley, 2008). Stiff-style landings are believed to contribute to an increased risk of injury, as the landing forces experienced at the ankle joint, and through the Achilles tendon, are reportedly far greater (Devita & Skelly, 1992) due to the reduced time over which force can be attenuated (Bressel & Cronin, 2005; Chockley, 2008).

Despite this, there is limited research investigating the relationship between the stiff-style landing technique and forces at the Achilles tendon during Irish dancing movements. Understanding this relationship will inform coaching strategies and countermeasures to reduce the risk of Achilles tendinopathy in Irish dancers. Therefore, the current study aimed to investigate the relationship between sagittal plane joint/segment displacement (ankle plantarflexion, ankle dorsiflexion, knee flexion, hip flexion, and thorax forward flexion) and peak Achilles tendon force during a landing task common to Irish dancing, the ‘leap over’.

METHODS: Twelve (female = 11, male = 1) open championship level Irish dancers (mean age: 16.5 $\pm$ 2.7 years, body mass: 59.4 $\pm$ 10.0 kg, height: 167.8 $\pm$ 7.5 cm) were recruited to participate in the current study. As the aesthetic requirements for male and female Irish dancers are the same, recruitment was not gender specific. All participants were free from injury, did not require taping or bracing and had not undergone surgery in the previous 12 months at the time of testing. Written informed consent was obtained prior to testing and the

study was approved by the University of Canberra Human Research Ethics Committee (approval number 20191847).
Upon arrival to a laboratory-based testing session, each participants' standing height and body mass were measured to the nearest 0.1 cm and 0.2 kg respectively using a calibrated stadiometer (SECA Corp, MD, USA) and calibrated body weight scales (Wesfarmers Ltd, WA, AUS). Each measurement was repeated three times, with the mean recorded.
Thirty-four retro-reflective markers (14 mm) were placed on participants' thorax, pelvis and lower limbs as per the University of Western Australia lower body marker set (Besier, Sturnieks, Alderson, & Lloyd, 2003). The markers placed on the 1st metatarsal, 5th metatarsal and calcaneal, were placed over the participants' own Irish dancing soft shoes (made of flexible leather) which were worn for the duration of the testing session. Following marker placement, participants completed a standardised warm-up consisting of general movements (e.g. jogging), dynamic stretching, and Irish dancing-specific movements, lasting approximately ten minutes. Once participants had completed the warm-up, they commenced the study protocol. Medial markers located at the knee and ankle joints were removed following a static calibration trial. Participants then completed a landing task common to Irish dancing, the 'leap over' (Figure 1), and participants were instructed to stop after five clean landings (landing in the middle of the force plate) were recorded. All trials were performed to Irish dancing practice and competition music (113 beats per minute) with participants walking back to their starting point between trials.
Three-dimensional marker trajectories were collected using a 12-camera (MX-40) Vicon MX 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 calculate the peak Achilles tendon force, normalised to body weight (BW).

Figure 1: The 'leap over' landing task used in this study, whereby one leg is raised, while jumping off the other leg before landing on the hallux of the raised leg with the ankle plantarflexed and knee straight.

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 12Hz (Winter, 2009). The foot segment was defined by single markers placed on the calcaneal, 1st and 5th metatarsals. The ankle joint centre was defined as the midpoint of the medial and lateral malleoli markers and the knee joint centre was defined as the midpoint of the medial and lateral femoral epicondyle markers (Besier et al., 2003). The hip joint centre was defined relative to the pelvis anatomical coordinate system and estimated using a regression equation (Winter, 2009). The thorax and pelvis segments were defined by single markers placed on the clavicle, sternum, C7, T10 (thorax) and the right and left anterior and posterior superior iliac spines (pelvis) (Besier et al., 2003). A standard Newton-Euler inverse dynamics approach was used to calculate joint kinetics at the ankle, knee and hip and thorax segment (Winter, 2009).
A custom MATLAB program (Mathworks, Inc., MA, USA) was used to extract and normalise the right sagittal plane ankle joint moments and displacements for the ankle, knee, and hip joints as well as the thorax segment. Data were normalised to 101 points between initial contact and peak knee flexion. Peak displacement (ankle plantarflexion, ankle dorsiflexion, knee flexion, hip flexion, and thorax forward flexion) was recorded for each trial and mean data were calculated for each participant. The Achilles tendon moment arm was quantified as a function

of the ankle joint sagittal plane displacement and regression coefficients based on previously validated methods (Self & Paine, 2001). The Achilles tendon force (N) was then calculated by dividing the ankle plantarflexion moment by the Achilles tendon moment arm and normalised to body weight (BW) (Self & Paine, 2001). Peak Achilles tendon force values were then calculated for each participant.
The Statistical Package for the Social Sciences Version 27.0 (IBM Corp., NY, USA) was used for all statistical analyses. Pearson Product-Moment Correlations were performed to examine the strength of the relationship between peak sagittal plane joint displacements (ankle plantarflexion, ankle dorsiflexion, knee flexion, hip flexion, and thorax forward flexion) and estimated peak Achilles tendon force. The strength of association was deemed to be small where r = 0.1-0.3, medium where r = 0.3-0.5, and large where $r > 0.5$ (Lee, 2016) and alpha was set to 0.05.

RESULTS: Peak ankle dorsiflexion angle was statistically significantly positively correlated with estimated peak Achilles tendon force in the ‘leap over’ landing task and had a large strength of association (Table 1). No other variables were statistically significant.

Table 1: Pearson Product-Moment Correlation coefficients between joint displacements at the ankle, knee, hip, and thorax segment, and the peak Achilles tendon force during an Irish dancing ‘leap over’ landing task (n = 12).

Joint displacement	r	p-value
Peak ankle plantarflexion angle	-0.415	0.180
Peak ankle dorsiflexion angle	0.713	0.009*
Peak knee flexion angle	0.389	0.211
Peak hip flexion angle	-0.210	0.513
Peak thorax forward flexion angle	0.108	0.739

Note: * indicates a statistically significant result ($p < 0.05$)

DISCUSSION: The current study aimed to investigate the relationship between sagittal plane displacements at the ankle, knee, and hip joints, and thorax segment, and peak Achilles tendon force during a ‘leap over’ in Irish dancing. The implications of the results are discussed below.
Ankle dorsiflexion angle was positively correlated with estimated peak Achilles tendon force, indicating that increased ankle dorsiflexion during landing may contribute to an increased estimated peak Achilles tendon force. During landing, the plantar flexors (triceps surae and Achilles tendon) contribute to energy absorption and dissipation. Increased dorsiflexion during landing places the plantar flexors at extended and compromised lengths, which has been suggested to contribute to an increased risk of Achilles tendinopathy (Whitting, Steele, Mcghee, & Munro, 2011). However, dorsiflexion at the ankle joint is crucial to force absorption and dissipation during landing as it aids in the rapid deceleration of the body’s momentum (Whitting et al., 2011). Additionally, the triceps surae, via the Achilles tendon, function to control the body’s forward momentum in gait (Le Huec, Saddiki, Franke, Rigal, & Aunoble, 2011). This concept applied to the ‘leap over’ landing task in Irish dancing implies that landing with increased ankle dorsiflexion could function to maintain balance during landing (Le Huec et al., 2011). This requires higher activation of the triceps surae, which could explain the correlation between increased ankle dorsiflexion and increased peak Achilles tendon force.
While not statistically significant, ankle plantarflexion angle had a medium negative correlation, and knee flexion had a medium positive correlation with peak Achilles tendon force. These results, while not significant, suggest a trend for decreased plantarflexion and increased knee flexion to be associated with an increased Achilles tendon force. While an interesting finding, these results were not statistically significant and previous literature has found increased plantar flexion, along with decreased knee flexion, during landing was associated with a higher Achilles tendon force, when compared to softer landing styles (Self & Paine, 2001). As knee flexion decreases, the triceps surae contribute more to absorbing landing forces (Devita & Skelly, 1992). It is possible that after years of training in Irish dancing, requiring maximal plantarflexion and minimal knee flexion during landing, participants of the current study may

have experienced adaptations to their Achilles tendon enabling them to effectively absorb and dissipate energy with a stiff landing style. However, tendon adaptations were not measured in the current study, and further research is required to confirm this.

The findings of the current study are consistent with the technical requirements of Irish dancing, indicating that dancers should continue to minimise ankle dorsiflexion during landing tasks. However, as previously discussed, dancers may adapt to the increased load through the Achilles tendon as a function of the requirements of the sport. Furthermore, the sample size of the current study was small (n = 12), and due to this limitation, further research with a larger sample size is needed to confirm the results of the study before further recommendations can be made. An additional limitation of the current study is the simple statistical approach. Therefore, it is not possible to make recommendations to reduce peak Achilles tendon force based on the results of the current study. However, the findings of the current study indicate that further research is warranted to address the association between ankle dorsiflexion angle and peak Achilles tendon force and the injury risks associated with the stiff-style landing technique used in Irish dancing.

CONCLUSION: This study investigated the relationship between sagittal plane joint displacements and peak Achilles tendon force during an Irish dancing landing task. There was a statistically significant correlation between increased peak ankle dorsiflexion angle and increased peak Achilles tendon force. Future research is required to confirm the findings of the current study, as well as to investigate if joint displacements contribute to the peak Achilles tendon force during landing tasks. This research will benefit dancers and coaches, as it can inform coaching strategies to ensure dancers have the capacity to minimise ankle dorsiflexion during landing to reduce the peak Achilles tendon force, potentially reducing the risk of Achilles tendinopathy.

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