# KNEE JOINT LOADING OF SCISSOR-KICK JUMP LANDINGS: A COMPARISON BETWEEN ELITE AND RECREATIONAL BADMINTON PLAYERS

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Badminton players at all levels perform a variety of badminton specific jump-stroke movements during training and match play, which expose their knees to high loads during the subsequent landing phase. Therefore, the purpose of this study was to compare the knee joint kinematics and kinetics of elite and recreational male badminton players during scissor-kick jump landings. Ten Danish national male badminton players and 10 recreational male badminton players completed a series of simulated scissor-kick jumps in a biomechanical laboratory. Three-dimensional knee joint angles and external joint moments were recorded for the non-racket leg during the landing phase. One-dimensional statistical parametric mapping was used to statistically compare the landing kinematics and kinetics of the knee for elite and recreational players. The landing phase was highly similar between groups and associated with high external knee abduction moments, particularly for the recreational players, which resemble those previously reported in sports specific single-leg landing situations with high ACL injury risk. The only significant difference observed between elite and recreational players were found in the push-off phase, where elite players generate more power from the muscles around the knee joint, through greater external adduction and inwards rotations moments, allowing them to accelerate significantly faster forward upon landing compared to recreational players. The high knee loads players experience during scissor-kick landings may contribute to the high incidence of knee injuries observed in both elite and recreational badminton.

**KEYWORDS:** Knee injuries, joint moments, playing level, statistical parametric mapping.

**INTRODUCTION:** Badminton is a popular sport among both recreational and elite players. The game is characterised by a range of badminton specific high-intensity actions including jumps, lunges, sidestepping, decelerations and change in directions, regardless of playing level (Phomsoupha and Laffaye 2015).

The ability to return the shuttlecock from the backcourt is fundamental in badminton, and players performing a range of different forehand and overhead strokes (clear, smash, stick-smash, drop, cut etc.) when returning the shuttlecock (Phomsoupha and Laffaye 2015). Regardless of stroke type, these movements are typically combined with a backwards jump followed by a single-leg landing on the players' non-racket leg (Kimura et al. 2012; Zhao & Li 2019; Hung et al. 2020). The high impact loads experienced during these single-leg landings may contribute to the high incidence of lower limb injuries, particularly knee and ankle injuries, reported in both elite and recreational badminton players (Kaldau et al. 2021; Reeves et al. 2015). Furthermore, the knee joint loading experienced during both overhead and forehand jump strokes landing on the backcourt have been associated with increased risk of Anterior Cruciate Ligament injuries (Kimura et al. 2012).

Nevertheless, the landing mechanics following forehand and overhead jump strokes is still largely unexplored in the biomechanical literature (Kimura et al. 2012; Zhao & Li 2019; Hung et al. 2020). For instance, the badminton-specific scissor-kick jump, which is characterised by an in-air 180 degrees body-rotation along the players' longitudinal axis, followed by a single-leg landing on the players' non-racket leg (Figure 1). The scissor-kick jump enables players to generate additional power in the stroke through the upper body rotation (Zhang et al. 2016), as well as the ability to quickly push-off the ground upon landing and return to the middle of the court. Therefore, the aim of this study was to compare the knee joint kinematics and kinetics between elite and recreational male badminton players during scissor-kick jump landings.

**METHODS:** Ten Danish national male badminton players (age: 28.2 ± 7.6 yr., height: 180.5 ± 4.9 cm, mass: 72.4 ± 6.6 kg), ranked top 100 in the world at the time of testing, and 10 recreational male badminton players (age: 28.1 ± 6.3 yr., height: 182.7 ± 6.0 cm, mass: 79.7 ± 10.5 kg) were invited to participate in this study. All players were injury-free prior to testing and had no history of severe lower limb injuries. The study was approved by the regional ethical committee (VD-2019-40) and written consent was obtained from all participants.
All participants completed a series of submaximal simulated scissor-kick jumps (Figure 1), until five successful trials were recorded (landing with their non-racket leg on the force platform). Players initiated the jump from a fixed distance in front of the force plate corresponding to 50% of the leg length (measured length from the medial malleolus to the anterior superior iliac spine). Moreover, after each jump participants were instructed to accelerate forward immediately upon landing and reach a target placed 3 meter in front of the force platform. Due to limited floor-to-ceiling height in the biomechanical laboratory, participants were instructed to simulate the stroke movement without a racket in their hands.

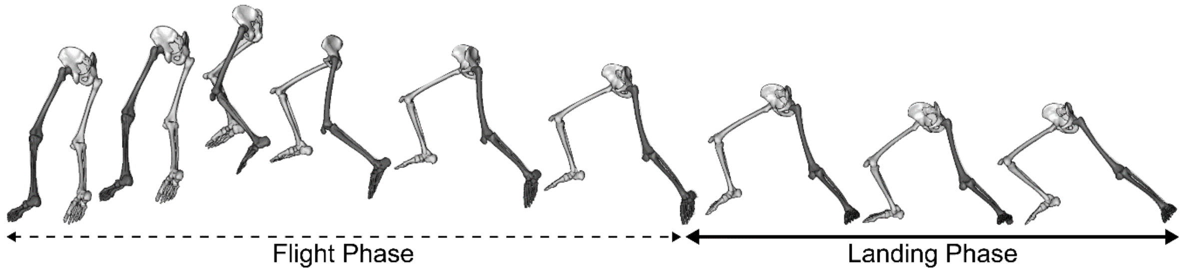


**Figure 1: Illustration of the badminton specific scissor-kick jump movement. Landing knee joint kinematics and kinetics were recorded for the non-racket leg (the dark grey leg).**

Kinematic marker data were recorded at 200Hz using a 8-camera Vicon system (T40 cameras, Vicon Motion Systems Ltd, Oxford, UK), with simultaneous recording of landing ground reaction forces (GRF) of the non-racket leg at 1000Hz (OR-6-7, AMTI, Massachusetts, USA). Lower limb kinematics were computed from a modified Helen Hayes marker set including 24 retroreflective markers (Bencke et al. 2013). Kinematic marker trajectory data were filtered using a Woltering cubic spline filter, whilst GRF data were filter using a zero-lag fourth order low-pass Butterworth filter. Subsequently, 3D knee joint angles and external moments were calculated for the landing phase using Vicon plug-in-gait software. The landing phase was determined from the vertical GRF, where touch down and take off were defined when the vertical GRF crossed a 10 N threshold.
A two-tailed independent t-test ($\alpha$ = 0.05) was used to determine statistical differences in jump height, contact time, $V_{Forward}$ between elite and recreational players in SPSS (version 22.0, SPSS Inc. Chicago, IL, USA). One-dimensional statistical parametric mapping (SPM), two-sample t-tests ($\alpha$ = 0.05), was computed using open-source SPM 1D software (v0.4, www.spm1d.org) in Matlab (Pataky 2012) to compare mean knee joint angles and moments for the landing phase between elite and recreational players.

**RESULTS:** The elite players jumped significantly higher (30.6 ± 9.8 cm, $p = 0.011$) than the recreational players (19.4 ± 7.8 cm), and on average displayed significantly shorter landing phases (368 ± 48 ms, $p = 0.038$) than the recreational players (470 ± 120 ms). Moreover, the elite players were able to accelerate significantly faster forward (average forward velocity: 4.9 ± 0.4 m/s, $p = 0.038$) after the scissor-kick jump than the recreational players (4.0 ± 0.9 m/s).
The knee joint angles and moments were highly similar between elite and recreational players for the majority of the landing phase (Figure 2). However, the elite players utilized significantly higher knee outwards rotation ($p = 0.019$) and displayed significantly greater external knee adduction ($p < 0.001$) and inwards rotation ($p < 0.001$) moments in the last ~20% of stance prior to take-off and the subsequent forward acceleration (Figure 2).

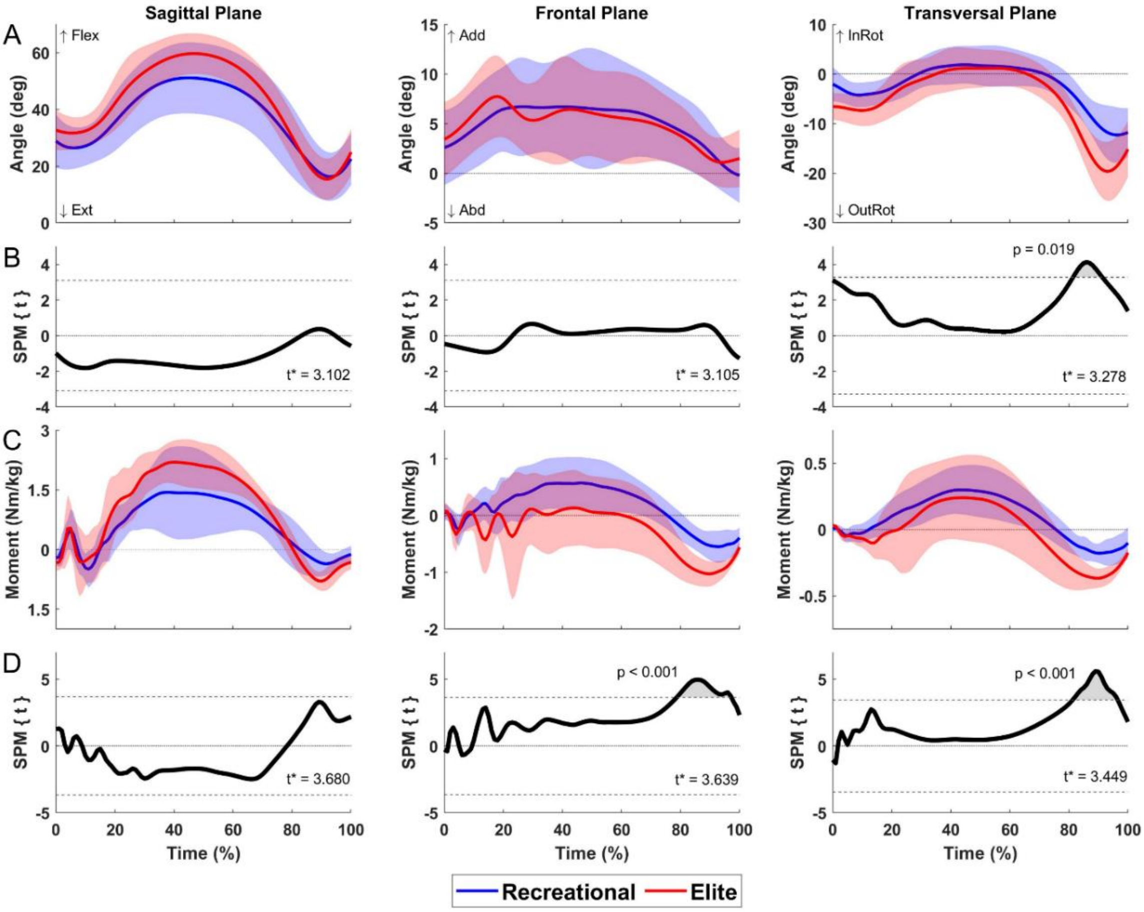


**Figure 1: Mean knee angles (A) and external moments (C) trajectories with SD for the recreational and elite players. The two-sample t-test statistics SPM{t}, for the knee angles (B) and moments (D). The grey shaded areas (supra-threshold clusters) indicate where there is a significant difference (*α = 0.05*) between groups.**

**DISCUSSION:** The knee joint loads observed in the initial landing phase of scissor-kick jump landings generally resemble those previously described for other sports specific single-leg landings. Moreover, the average external peak knee abduction moments, a well-known ACL-injury mechanism, observed for the recreational male badminton players (0.86 ± 0.34 Nm/kg) in the present study exceed those previously reported for female college badminton players during single-leg landings following overhead strokes (Kimura et al. 2012). Whilst, the elite players average external peak knee abduction moments during scissor-kick jump landings (0.60 ± 0.25 Nm/kg) resemble those observed in the study by Kimura et al. 2012 on female players. Unfortunately, the knee joint moments were not reported in two previous studies, that explored the lower limb landing mechanics of lateral jump smash strokes (Hung et al. 2020) and backcourt forehand clear strokes (Zhao & Li 2019) in male badminton players. The results from this study indicates the importance of strong knee adductors for both elite and recreational badminton players to counteract the high external valgus loads observed during the initial landing phase following scissor-kick jumps.

Whilst the elite and recreational players knee joint loading were similar during the initial landing phase (the first 20% of the landing phase), where severe knee injuries typically occur, elite players displayed different push-off strategies. Particularly, through larger outwards knee rotation, greater external knee adduction and inwards rotation moments, allowing them to push-off from the ground more forcefully and accelerate significantly faster forward upon landing. This indicate that elite players are better at making rapid change in directions and already anticipate/prepare for the subsequent movement, thus allowing them to move around the court more effectively and gain more time to reach the shuttlecock and prepare for the next stroke.

Due to the limited laboratory floor-to-ceiling height in the biomechanical laboratory players performed the scissor-kick jumps without a racket in the present study. Nevertheless, we strongly believe both elite and recreational players, after an individual number of familiarisations trials, were able to reproduce their normal scissor-kick jump movements. Though we acknowledge that the pre-planned nature of the scissor-kick performed in the present study might vary from the unanticipated jump landings players perform during gameplay to reach the shuttlecock. Another limitation with our study design and the joint mechanics presented is that ground reaction forces only was recorded for the non-racket leg, though players had double support in the last part of the scissor-kick jump landing. We did however focus on joint kinetics of the non-racket leg in this study because it indisputably is exposed to the highest loads during scissor-kick jump landings. Moreover, the non-racket leg is generally more exposed to severe knee injuries than the racket leg in badminton (Kimura et al. 2012).

**CONCLUSION:** Badminton players exhibit districting knee landing mechanics following the badminton specific scissor-kick jump, which may expose the players to knee injuries. Whilst the associated between scissor-kick jump landing mechanics and knee injuries yet is unknown, this study indicate that strong knee adductors are crucial for both elite and recreational badminton players to counteract the high external valgus loads observed during the initial landing phase following scissor-kick jumps. Moreover, our findings indicate that elite badminton players can generate more power from the muscles around the knee joint in the push-off phase, allowing them to accelerate faster forward upon landing compared to recreational players, and potentially reach the shuttlecock in a better position.

## REFERENCES


Bencke, J., Curtis, D., Krogshede, C., Jensen, L.K., Bandholm, T., Zebis, M.K. (2013). Biomechanical evaluation of the side-cutting manoeuvre associated with ACL injury in young female handball players. *Knee Surgery, Sports Traumatology, Arthroscopy*, 21, 1876-1881.

Kaldau N.C., Kerr, S., McCaig, S., Hölmich, P. (2021). Training and injuries among world elite junior badminton players – identifying the problems. *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology*, 26, 21-26.

Kimura, Y., Ishibashi, Y., Tsuda, E., Yamamoto, Y., Hayashi, Y., Sato, S. (2012). Increased knee valgus alignment and moment during single-leg landing after overhead stroke as a potential risk factor of anterior cruciate ligament injury in badminton. *British Journal of Sports Medicine*, 46, 207-213.

Hung, C.L., Hung, M.H., Chang, C.Y., Wang, H.H., Ho, C.S., Lin, K.C. (2020). Influence of lateral jump smash actions in different situations on lower extremity load of badminton players. *Journal of Sports Science and Medicine*, 16, 264-270.

Pataky, T. C. (2012). One-dimensional statistical parametric mapping in Python. *Computer Methods in Biomechanics and Biomedical Engineering*, 15, 295-301.

Phomsoupha, M. & Laffaye, G. (2015). The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports Medicine*, 45, 473-495.

Reeves, J., Hume, P.A., Gianotti, S., Wilson, B., Ikeda, E. (2015). A retrospective review from 2006 to 2011 of lower extremity injuries in badminton in New Zealand. *Sports*, 3, 77-86.

Zhang, Z., Li, S., Wan, B., Visentin, P., Jiang, Q., Dyck, M., Li, H., Shan, G. (2016). The influence of X-Factor (trunkt rotation) and experience on the quality of the badminton forehand smash. *Journal of Human Kinetics*, 53, 9-22.

Zhao, X. & Li, S. (2019). A biomechanical analysis of lower limb movement on the backcourt forehand clear stroke among badminton players of different levels. *Applied Bionics and Biomechanics*.


**ACKNOWLEDGEMENTS:** We would like to thank the Badminton World Federation Sports Science Commission for partly funding this study.