GENDER DIFFERENCES IN MUSCLE CONTRACTION AND CO-CONTRACTION ACTIVITIES DURING THE IMPACT PHASE OF SINGLE-LEG LANDING TASK IN BADMINTON

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Our study aimed to explore ACL injury risk factors in females versus males during badminton single-leg landings. Sixteen players (8 male, 8 female) participated, with lower limb kinematics, ground reaction forces, and muscle activity measured using motion capture, force plates, and electromyography (EMG). Independent samples t-test analyzed gender differences in leg kinematics, mean normalized leg muscle activation (MVC%), and muscle co-contraction post-landing. Females, compared to males, exhibited higher rectus femoris, medial hamstring, and gastrocnemius muscle activity during the post-landing phase. Additionally, males had a higher co-contraction ratio in the medial and lateral gastrocnemius than females. Female badminton players' neuromuscular control strategies may lack ACL protection, posing a potential risk for higher ACL injury incidence.

KEYWORDS: badminton, single-leg landing, ACL injury, EMG.

INTRODUCTION: Badminton is gaining popularity as an adversarial racket sport, attracting many female athletes. Despite its popularity, there's limited research on badminton-related injuries. Due to the non-contact nature of the sport, injuries often occur during maneuvers like jumping, landing, and change of direction, with lower limb injuries being the most common (Jeon & Cho, 2023). ACL injuries, accounting for 26% of knee injuries, are a serious concern, especially for female athletes who experience 2-6 times higher incidence rates than males (Kimura et al., 2010; Sutton & Bullock, 2013). In a Japanese study spanning over a decade, female junior and senior high school badminton players had ACL injury rates 4.2 and 4.8 times higher than males, respectively (Takahashi & Okuwaki, 2017). Comprehending why females are more injury-prone is vital for prevention. Researchers explore factors like hormones, anatomy, genetics, and neuromuscular control. Mechanisms causing ACL injuries may vary with exercise and landing methods. Compared to males, female badminton players have a higher ACL injury risk, possibly due to different kinematics and muscle activity in specific landings. Less research addresses gender differences in badminton landings. Our study focuses on gender disparities in muscle activity during high-risk single-leg landings in female badminton players, analyzing potential non-contact ACL injury risks. We hypothesize differences in muscle activity, co-activation, and kinematics during landing. This research aims to offer insights for coaches, athletes, and rehabilitation.

METHODS: In this study, 16 badminton players (8 males, 8 females) aged 21.50 (±2.45) years for females and 20.63 (±0.92) years for males participated. Females were 1.67 m (± 0.05) tall, weighing 59.50 kg (±5.71), while males were 1.78 m (±0.03) tall and weighed 71.63 kg (±9.97). We collected trial data using 13 infrared cameras (OptiTrack, LEYARD, Buffalo Grove, IL, USA) to capture kinematic data for each subject. These cameras had a sampling rate of 120 Hz. whole-body kinematic data were tracked through 57 marker points throughout the body, with reflective marker points located at anatomical locations referenced to the study with Huzhe et al (Zhe Hu et al., 2023).Ground reaction force data, sampled at 1200 Hz, were collected using an OR6-6-2000 force platform (AMTI Inc., Newton/Maryland, US) with a maximum latency of 6 ms. EMG data acquisition utilized the Trigno Avanti Sensor system (Delsys, USA). EMG position and maximum volitional isometry (MVIC) test methods as referenced in the study by Zhe Hu et al. (Z. Hu et al., 2023).The shuttlecock is sent to the designated area in the same state using Fengcai's badminton server SPT6000 (SPTLOOKER, China). Competitors wear uniform shorts, individual socks and shoes and use uniform

rackets.The participants engaged in a 10-minute warm-up exercise (including jogging and swinging), followed by a single-leg landing test after performing a backhand side overhead stroke, which is considered to have the highest incidence of ACL injuries. Starting from the initial position, the participants simulated a backhand side step towards the left rear of the court, performed an overhead stroke, landed on the force plate with their left leg, and quickly returned to the starting position (Zhe Hu et al., 2023). The participants hit the shuttlecock to the back side of the opposite court in their usual manner. Participants were allowed to perform several exercises, followed by three to five consecutive trials. Kinematics, Muscle Activity and Co-Contraction Processing with Reference to Zhe Hu's Study (Zhe Hu et al., 2023).Independent samples t-test was used to test for statistical differences between male and female badminton player groups. The outcome variables were as follows: normalized electromyographic activity (MVC%) of the lower limb muscles; co-contraction index of the lower limb muscles; and hip-knee-ankle joint angle. Statistical analyses were performed using SPSS 26.0 software (SPSS for Windows, Chicago, IL, USA) with a significance level of $p < 0.05$.

RESULTS: Figure 1 illustrates mean and standard deviation (in degrees) for knee flexion and varus/valgus angles during badminton single-leg landing impact. In the post-landing phase, females exhibited a 7-degree smaller mean flexion angle than males at the posterior peak GRF, showing a significant difference ($p<0.05$). Simultaneously, females had a 5-degree greater mean knee valgus angle than males at the posterior peak GRF, with a highly significant difference between genders ($p<0.05$).

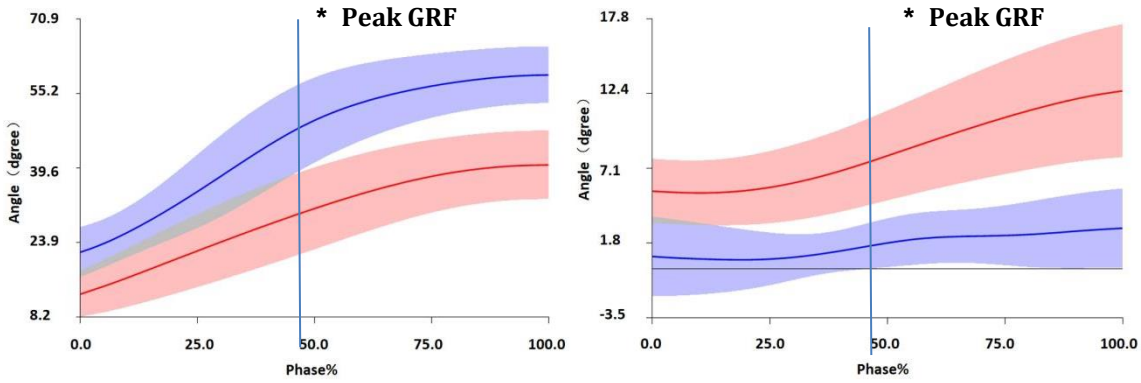

Figure 1. Means and standard deviations (degrees) of knee flexion (left) and varus/valgus (right) angles at the moment of peak GRF in the badminton single-leg landing task. Red represents females, blue represents males.* Represents statistically significant differences.

The mean and standard deviation of lower limb muscle activity and co-contraction activity ratio during the post-landing impact phase of a badminton single-leg landing task after a backhand side overhead stroke are presented in Figure 2.

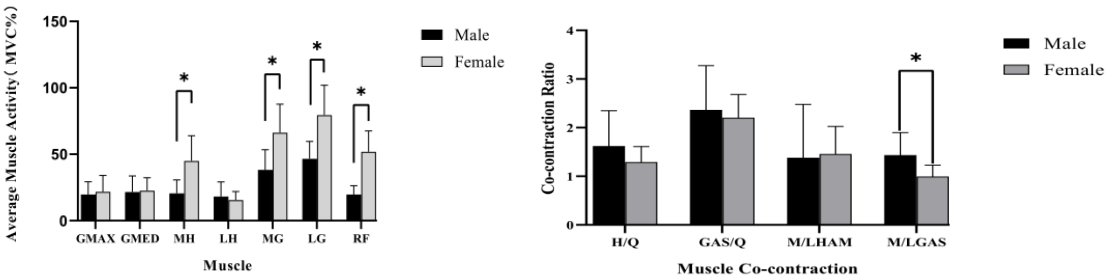

Figure 2. Badminton single-leg landing task, mean and standard deviation of lower limb muscle activity（MVC%） and co-contraction activity ratio (Value of Ratio) during the post-landing impact phase. * Represents statistically significant differences.

In badminton single-leg landing, females showed medial hamstring activity at 44.88±19.07, while males had 20.54±10.16 early in post-landing. Female medial hamstring activity was 24.34% higher than males, a significant difference ($p<0.05$). Standardized medial gastrocnemius activity was 66.23±21.42 in females and 38.21±15.16 in males, with female activity 28.02% higher and a significant difference observed ($p<0.05$). Lateral gastrocnemius activity was 79.43±22.54 in females and 46.53±13.17 in males, indicating 32.90% higher activity in females with a significant difference ($p<0.01$). Rectus femoris muscle activity values were 51.85±15.68 in females and 19.73±6.63 in males, showing a 32.12% higher activity in females with a significant difference ($p<0.05$). The co-activation ratio of medial and lateral gastrocnemius muscles was 0.99±0.24 in females and 1.44±0.46 in males, displaying a 0.45 higher ratio in males with a significant gender difference ($p<0.05$).

DISCUSSION: The results supported our hypotheses, revealing significant gender differences in neuromuscular control during badminton single-leg landings. Females demonstrated greater activity in rectus femoris, medial hamstring, and gastrocnemius than males, with reduced co-activation in medial and lateral gastrocnemius during landing impact.

In the impact phase, female badminton players exhibit greater rectus femoris activity than males, aligning with prior research findings (Dwyer et al., 2010). Increased rectus femoris activity is associated with an elevated risk of anterior cruciate ligament (ACL) injuries. The contraction of the rectus femoris, connected to the proximal anterior side of the tibia via the patellar ligament, amplifies pressure on the ACL when the knee joint angle is reduced. Research indicates that rectus femoris activation contributes to ACL load and proximal anterior shear force on the tibia. Compared to another movement, in our study, both male and female participants had smaller knee joint flexion angles and larger knee extension lever arms at the moment of peak ground reaction force. Coupled with higher rectus femoris activation in females, this could lead to increased ACL load and a higher risk of ACL injury.

In the post-landing impact phase, female badminton players also exhibit greater medial hamstring activity than males, consistent with previous research(de Britto et al., 2014). Gender differences in factors such as knee varus angle, trunk frontal plane asymmetry, or medial-lateral muscle balance may contribute to this increased activity. While the hamstrings play a role in providing posterior force to the tibia and are generally considered protective of the ACL, isolated hamstring contraction has minimal impact on ACL strength, especially at knee flexion angles below 22-30 degrees. Despite greater medial hamstring activity in females in our study, their landing angles were typically below 20 degrees, suggesting limited protection for the ACL during the peak ground reaction force.

Furthermore, in the post-landing impact phase, compared to males, female badminton players demonstrate greater activity in both medial and lateral gastrocnemius muscles. Previous research has reported gender differences in neuromuscular control during landing (Beaulieu et al., 2009). Contraction of the gastrocnemius muscle has been linked to the risk factors for anterior cruciate ligament (ACL) injuries according to models and in vivo studies (Navacchia et al., 2019). The contribution of the gastrocnemius muscle to peak anterior shear force on the tibia is substantial, increasing stress on the ACL. Activation of the gastrocnemius muscle may lead to anterior tibial displacement, potentially acting as an antagonist to the ACL (Teng et al., 2021). This association could be due to the gastrocnemius muscle's position and its ability to generate compressive forces, resulting in increased anterior shear force and displacement of the tibia. On the other hand, some perspectives suggest that gastrocnemius muscle activity is protective of the cruciate ligaments (de Britto et al., 2014). Studies indicate that increased gastrocnemius muscle force is associated with decreased anterior shear force on the tibia or stress on the cruciate ligaments. Additionally, differential co-contraction of medial and lateral gastrocnemius muscles is observed, with females showing a smaller proportion of co-activation compared to males. Co-contraction of these muscles helps balance inversion and eversion moments, maintaining stability in the sagittal plane. Greater co-contraction in males may contribute to preventing larger eversion loads and angles, enhancing knee joint stability, and potentially reducing the risk of ACL injuries (Besier et al., 2003).

In conclusion, our study identified gender differences in neuromuscular control during the landing preparation phase of badminton single-leg landing tasks. However, limitations in the data collection process (including electromyography and three-dimensional motion analysis) may impact the results (Kollmitzer et al., 1999). Additionally, this study was conducted in a controlled laboratory environment, and findings may not entirely replicate the risk of ACL injuries in actual gameplay. Also the sample size is one of our limitations. Further research should explore muscle activation onset times, gender differences in trunk neuromuscular control, and their associations with lower limb injury risk factors.

CONCLUSION: During the impact phase of badminton single-leg landing tasks, there are evident gender differences in neuromuscular control (muscle activity patterns, movement strategies) among badminton players. Female badminton players exhibit neuromuscular control strategies that may not be sufficient to protect the anterior cruciate ligament (ACL), and the development of appropriate neuromuscular control training strategies may be beneficial for injury prevention in females.

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