THE INFLUENCE OF LOWER LIMB MUSCLE PRE-ACTIVATION ON KNEE JOINT DYNAMIC CONTROL DURING A SINGLE-LEG LANDING TASK IN BADMINTON

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Purpose: Lower limb neuromuscular strategies impact knee biomechanics, crucial for ACL injury prevention. Yet, the link between them remains unclear. In our randomized trial with 34 badminton players, we examined lower limb muscle preactivity during single-leg landings. Findings revealed that increased rectus femoris preactivation correlated with heightened knee valgus angle. Moreover, higher lateral hamstring/quadriceps co-contraction ratios predicted increased knee extension moments. These outcomes suggest potential benefits in ACL injury prevention through reduced quadriceps pre-activation and optimal lateral hamstring/quadriceps co-contraction ratios. Understanding these relationships aids in developing targeted prevention strategies for anterior cruciate knee injuries.

KEYWORDS:badminton; single-leg landing; ACL; kinematics; kinetics; EMG

INTRODUCTION: Badminton is a widely popular racket sport with over 160 national associations worldwide, attracting a considerable number of players. Similar to other sports, badminton players face the risk of injuries, with lower extremity injuries, particularly anterior cruciate ligament (ACL) injuries, being a significant concern. Non-contact ACL injuries, often occurring during complex movements in sports like badminton, pose a substantial risk (Marchena-Rodriguez et al., 2020; Pardiwala et al., 2020). Research indicates that single-leg landings after overhead strokes, a common action in badminton, are associated with a higher ACL injury incidence (Kimura et al., 2010). Understanding the relationship between neuromuscular activation and knee biomechanics is crucial in preventing such injuries.Recent studies highlight the correlation between lower extremity muscle activity and knee kinematics and kinetics (de Britto et al., 2014). Various factors, including muscle co-contraction, influence ACL loading during specific tasks. Yet, a research gap persists in electromyography (EMG) studies on high-risk landings in badminton players. This study explores the correlation between lower limb muscle activity (quadriceps, medial hamstring, lateral hamstring, MH/Q, LH/Q) and knee kinematics (flexion angle, valgus angle) and kinetics (proximal tibial anterior shear, extension moment, valgus moment) during a single-leg landing after a backhand overhead stroke in badminton. Hypotheses include correlations between gastrocnemius activity and peak extension moment, rectus femoris activity and knee extension moment, and co-contraction ratios with knee biomechanics. Filling an EMG research gap in badminton, this study offers insights into preventing injuries through targeted training.

METHODS: We obtained trial data using 13 infrared cameras (OptiTrack, LEYARD, Buffalo Grove, IL, USA) to capture kinematic data for each participant. These cameras had a sampling rate of 120 Hz. Whole-body kinematic data were tracked through 57 marker points across the body, with reflective markers placed at anatomical locations referenced to the study by Huzhe et al (Hu et al., 2023). Ground reaction force data were collected at 1200 Hz using an OR6-6-2000 force platform (AMTI Inc., Newton/Maryland, US). The maximum latency was 6 ms. The EMG data acquisition device chosen was the EMG acquisition system (Trigno Avanti Sensor, Delsys, USA). Electrodes were situated on the surfaces of the gluteus maximus (GMAX), gluteus medius (GMED), rectus femoris (RF), medial semitendinosus (MH), lateral biceps femoris (LH), medial gastrocnemius (MG), and lateral gastrocnemius (LG) muscles. The electrode placement and methodology for the maximum volitional isometry (MVIC) test were referenced from the prior study of Huzhe et al (Hu et al., 2023). The shuttlecock was delivered to the designated area in the same manner using Fengcai's badminton server SPT6000 (SPTLOOKER, China). Competitors wore standardized attire, individual socks, and shoes, using prescribed rackets. After a 10-minute warm-up involving jogging and swinging, participants underwent a single-leg landing test post backhand side overhead stroke, known for its high ACL injury incidence. A seasoned badminton coach with approximately 10 years of competitive play demonstrated footwork and the overhead stroke task to each participant. Starting from the initial position, participants simulated a backhand side step toward the left rear of the court, executed an overhead stroke, landed on the force plate with their left leg, and quickly returned to the starting position. Participants hit the shuttlecock to the backside of the opposite court in their usual manner. They were allowed to perform several exercises, followed by three to five consecutive trials.Kinematic data were processed using Visual 3D (C-Motion, Inc., Germantown, MD, USA). EMG activity data were analyzed by the software accompanying the EMG collection system (Trigno Avanti Sensor, Delsys, USA). A band-pass filter of 10-400Hz and an RMS with a 20ms window for signal correction and smoothing were applied. The mean RMS amplitude for each muscle over three trials was normalized based on the RMS of the MVIC. Co-contraction duration was calculated as the activity time of a pre-defined muscle pair, yielding two co-contraction indices: 1) co-contraction of the medial hamstrings and quadriceps (LH/Q); and 2) co-contraction of the medial hamstrings and quadriceps (MH/Q).Linear regression analyses in SPSS (18.0, SPSS Inc., Chicago, IL) identified muscle activation patterns predicting knee kinematic and kinetic outcomes post-landing, factors influencing ACL injury risk. Analyzed variables included pre-activation levels of the gluteus maximus, gluteus medius, medial hamstrings, lateral hamstrings, and the MH/Q and LH/Q synergistic contraction ratios during the pre-landing preparation phase. Biomechanical variables encompassed peak angles and moments of knee flexion, extension, and abduction, along with peak anterior tibial shear forces within 50ms of the post-landing phase, a crucial period for ACL injuries. Regression analyses assessed the preactivation of the gluteus maximus, gluteus medius, medial hamstring, lateral hamstring, and the MH/Q and LH/Q synergistic contraction ratios to understand their relationship with knee kinematics and dynamics. An alpha level of 0.05 was selected to determine the model's significance in predicting response variables.

RESULTS: Pre-activation and partial co-contraction of lower limb muscles in badminton players before landing as shown in Table 1.

Table 1:Pre-activation or co-contraction of lower limb muscles in the preparatory phase of single-leg landing in badminton

Variable	Mean±SD
Gluteus maximus (% of MVIC)	36.08±28.88
Gluteus medius (% of MVIC)	26.44±16.94
Medial Hamstring(% of MVIC)	17.69±20.12
Lateral Hamstring (% of MVIC)	9.09±4.07
Medial Gastrocnemius(% of MVIC)	29.89±13.11
Lateral Gastrocnemius (% of MVIC)	28.55±14.41
Rectus femoris (RF) (% of MVIC)	30.38±14.2
LHAM:Q	0.80±0.52

The knee angles of badminton players at the moment of initial touchdown after landing and at the moment of peak GRF are shown in Table2.

Table 2:During the badminton single-leg landing task, knee joint angles at the moment of initial contact and at the moment of peak posterior GRF.

Variables	Mean±SD
Initial contact moment	
Knee Flexion（+）/extension（-）	18.78±6.88
Knee Valgus（+）/varus（-）	4.00±3.00

Knee External（+）/internal rotation（-）	-4.24±4.48
Peak posterior GRF moment	
Knee Flexion（+）/extension（-）	20.31±4.62
Knee Valgus（+）/varus（-）	3.52±2.71
Knee Internal（+）/external rotation（-）	-2.24±4.33

The data on the knee kinetics of badminton players after landing are shown in Table 3

Table 3:Ground reaction forces and knee joint dynamics data during a badminton single-leg landing task

Variable	**Mean±SD**
Peak posterior GRF(BW)	4.93±1.65
Peak proximal tibia anterior shear force（N/kg）	1.80±0.53
Peak extension moment（N/kg/m）	1.58±0.35
Peak valgus moment（N/kg/m）	0.08±0.11
Peak varus moment（N/kg/m）	0.21±0.12
Peak internal rotation moment（N/kg/m）	0.10±0.06
Peak external rotation moment（N/kg/m）	0.03±0.02

The relationship between muscle pre-activation and co-contraction pre-knee biomechanics in badminton players before landing is shown in Figure 1.Greater rectus femoris preactivation was associated with greater knee valgus angle (R^2 = 0.501, b = 0.399, P = 0.003), and greater lateral hamstring/quadriceps co-contraction ratios predicted greater knee extension moments (R^2 = 0.399, b = -0.646, P = 0.002).

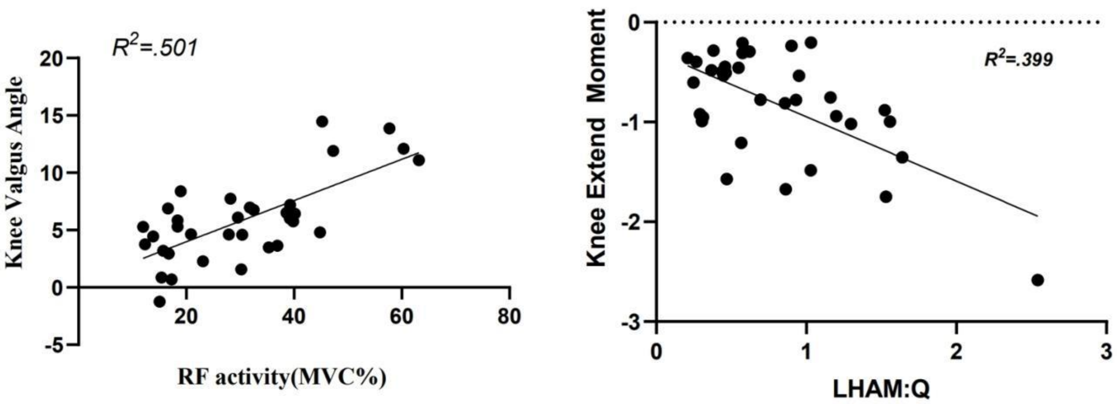

Figure 1: Relationship between knee valgus angle (deg) and rectus femoris preactivation during single-leg landing (left), and between peak knee extension moment (N.m/kg.m) and lateral hamstring to quadriceps co-contraction ratio (right).

DISCUSSION: The experimental results support our hypothesis and confirm that the pre-activation of lower limb muscles prior to single-leg landing in badminton players is related to the dynamic control of the knee joint. Our study showed that greater rectus femoris pre-activation predicted a large knee valgus angle. Our study showed that greater rectus femoris pre-activation predicted a large knee valgus angle.This is consistent with previous studies that large valgus angles are associated with ACL injuries (Ellenberger et al., 2021) (Tseng et al., 2021)]. Observations of ACL injury videos, cadaveric studies, and prospective studies of athletes have consistently shown that a large knee valgus angle predicts a higher risk of ACL injury. In addition, a study specifically on female badminton players showed larger knee valgus angles in a high-risk landing task compared to a low-risk single-leg landing task (Kimura et al., 2010). It is therefore reasonable to believe that large quadriceps with activation may be associated with a large risk of ACL injury. Our other major finding is that lham/quad co-activation is associated with large knee extension moments.Serpell, B. G. et al. showed that large lham/qua coactivation is associated with ACL lengthening(Serpell et al., 2015), and that large lateral lham/qua coactivation may increase ACL strain and thus the risk of ACL injury. It is well known that the function of neuromuscular contraction is to maintain body balance and, to a lesser extent, body stabilisation. When a badminton player lands in the early stages of a task, the impact force is high, and in order to maintain body balance and control the rate at which the body's centre of gravity falls during landing, it is necessary for internal muscle contractions to generate sufficient extension moments to counterbalance the flexion moments generated by external forces. Studies have shown that the quadriceps is the main contributor to the extension moment (Teng et al., 2021). In maintaining balance, poor neuromuscular control patterns may over-rely on greater extension moments generated by contractions produced by quadriceps activation, and greater extension moments are one of the determinants of increased anterolateral knee strength, which may lead to increased loads on the anterior cruciate ligament (de Britto et al., 2014).

CONCLUSION: Reducing quadriceps preactivation and lateral hamstring/quadriceps co-contraction ratios may be beneficial in the prevention of anterior cruciate ligament injuries of the knee in badminton players.

REFERENCES

de Britto, M. A., Carpes, F. P., Koutras, G., & Pappas, E. (2014). Quadriceps and hamstrings prelanding myoelectric activity during landing from different heights among male and female athletes. *J Electromyogr Kinesiol*, *24*(4), 508-512. https://doi.org/10.1016/j.jelekin.2014.04.009

Ellenberger, L., Casutt, S., Frohlich, S., Frey, W. O., Snedeker, J. G., & Sporri, J. (2021). Thigh muscle activation patterns and dynamic knee valgus at peak ground reaction force during drop jump landings: Reliability, youth competitive alpine skiing-specific reference values and relation to knee overuse complaints. *J Sci Med Sport*, *24*(12), 1230-1234. https://doi.org/10.1016/j.jsams.2021.06.006

Hu, Z., Kim, Y., Dong, T., Meng, X., Dong, M., & Kim, S. (2023). Correlation between gluteus muscle activity and dynamic control of the knee joint in a single-leg landing task in badminton. *International Journal of Performance Analysis in Sport*, *23*(6), 429-440. https://doi.org/10.1080/24748668.2023.2249760

Kimura, Y., Ishibashi, Y., Tsuda, E., Yamamoto, Y., Tsukada, H., & Toh, S. (2010). Mechanisms for anterior cruciate ligament injuries in badminton. *Br J Sports Med*, *44*(15), 1124-1127. https://doi.org/10.1136/bjsm.2010.074153

Marchena-Rodriguez, A., Gijon-Nogueron, G., Cabello-Manrique, D., & Ortega-Avila, A. B. (2020). Incidence of injuries among amateur badminton players: A cross-sectional study. *Medicine (Baltimore)*, *99*(18), e19785. https://doi.org/10.1097/MD.0000000000019785

Pardiwala, D. N., Subbiah, K., Rao, N., & Modi, R. (2020). Badminton Injuries in Elite Athletes: A Review of Epidemiology and Biomechanics. *Indian J Orthop*, *54*(3), 237-245. https://doi.org/10.1007/s43465-020-00054-1

Serpell, B. G., Scarvell, J. M., Pickering, M. R., Ball, N. B., Newman, P., Perriman, D., Warmenhoven, J., & Smith, P. N. (2015). Medial and lateral hamstrings and quadriceps co-activation affects knee joint kinematics and ACL elongation: a pilot study. *BMC Musculoskelet Disord*, *16*, 348. https://doi.org/10.1186/s12891-015-0804-y

Teng, P. S. P., Leong, K. F., Yi Xian Phua, P., & Kong, P. W. (2021). An exploratory study of the use of ultrasound in the measurement of anterior tibial translation under gastrocnemius muscle stimulation. *Res Sports Med*, *29*(2), 103-115. https://doi.org/10.1080/15438627.2020.1840378

Tseng, H. J., Lo, H. L., Lin, Y. C., Liu, W. C., Lin, S. Y., Chou, P. H., & Lu, C. C. (2021). Analyze the Differential Rates of Anterior Cruciate Ligament Injuries Between Men and Women by Biomechanical Study of Single-Leg Landing in Badminton. *Indian J Orthop*, *55*(Suppl 2), 409-417. https://doi.org/10.1007/s43465-021-00421-6

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