Title: Investigation of knee joint loadings from lunges among Chinese elite badminton athletes: a subject-specific musculoskeletal and finite element analysis

Authors: ***Qichang Mei**, Yaodong Gu

Affiliations: Ningbo University, China; University of Auckland, New Zealand

*Email: qmei907@aucklanduni.ac.nz

Introduction: Knee joint is one of the most injured sites among badminton players (Jérgensen et al., 1987; Shariff et al., 2009; Yung et al., 2007). Athletes with knee pain showed conservative and compensatory movements, which would lead to reduced performance and other potential injuries (Huang et al, 2014; Lin et al., 2015). The high incidence of overuse chronic injuries was reported in the knee (Jérgensen et al., 1987), which may result from repetitive lunge loading accumulations. However, few comprehensive information about the knee joint kinematics, kinetics, contact forces and tissue stress during right-forward, right-backward, left-backward and left-forward lunges was revealed. The computational modelling techniques, such as musculoskeletal (Delp et al., 2007) and finite element (Besier et al., 2005) simulation, provide the approach to solve the above issue. This project was aimed to reveal the knee joint kinematics and kinetics and investigate the contact force and cartilage stress via subject-specific musculoskeletal modelling analysis and finite element simulation.

Methods: Athletes were recruited to perform the lunges in the lab-simulated badminton court facilitated with Vicon motion capture, AMTI force plate and Delsys EMG system. Subject-specific OpenSIM musculoskeletal and Finite Element knee model were created from CT/MRI images. Simulated estimated forces were validated against experimental results, then applied as boundary conditions in the Finite Element simulation. Workflow is presented in the **Figure 1** below.

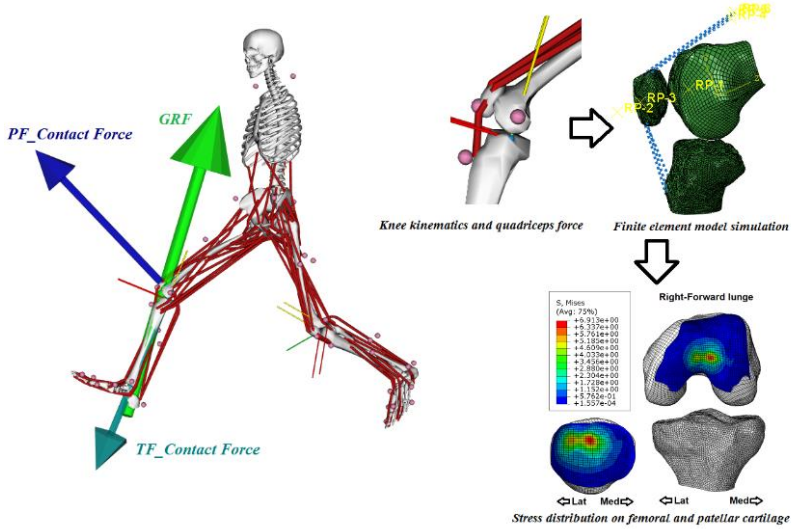

Figure 1 Workflow of Subject-Specific Musculoskeletal Modelling and Finite Element Simulation

Results & Discussion: The adduction/abduction and internal/external rotation of knee were significantly different during the Left-Backward lunges from other lunges. Additional higher patellofemoral joint contact force (Left-Backward: 3.23±0.18BW and Left-Forward: 2.91±0.4BW) and cartilage von Mises stress (patellar cartilage: 7.57MPa and 7.25MPa; femur cartilage: 7.49MPa

and 7.39MPa) loadings were found in the Left-Backward and Left-Forward lunges, which may link to knee pain.

Greater knee flexion moment (-2.62±2.27Nm/kg) was found during Right-Forward lunges, following with larger extension moment (2.26±0.18Nm/kg) in Left-Backward lunges during the weight-acceptance phase. The Right-Backward lunges presented greater adduction moment (0.88±0.53Nm/kg). These should also be noted as potential factors contributing to overuse injury risks.

The Left-Backward (5.94±0.28BW) and Left-Forward (5.72±0.12BW) lunges also exhibited greater total knee contact force, while Right-Forward lunge had larger contact force in the medial compartment (3.53±0.43BW) of knee joint. Left-Backward (3.23±0.18BW) and Left-Forward (2.91±0.4BW) lunges showed larger contact force in the lateral compartment of knee joint. Quadriceps (*vastus lateralis, vastus medialis, vastus intermedius* and *rectus femoris*) muscle force (normalized to body weight, BW) (Right-Forward: 1.77BW, 0.96BW, 1.03BW and 1.1BW, Right-Backward: 1.47BW, 0.68BW, 0.88BW and 0.91BW, Left-Backward: 2.37BW, 1.14BW, 1.33BW and 1.25BW, and Left-Forward: 2.07BW, 0.98BW, 1.04BW and 1.18BW) contributions were revealed that could assist the training program for developing these muscles, so as to prevent potential knee pain and injuries and help improve lunging performance.

Conclusion: This project revealed the knee joint angles, moments, contact forces and cartilages stress during badminton lunges to the Right-Forward, Right-Backward, Left-Backward, and Left-Forward directions in Chinese athletes. Key findings were found in the Left-Backward and Left-Forward lunges with higher knee contact force and cartilage stress loading, which may link to knee pain. The larger flexion and adduction moments in the Right-Forward and Right-Backward should also be noted as potential factors contributing to overuse injury risks. Quadriceps muscle force contributions were revealed that could assist the training program for developing these muscles, so as to prevent potential knee pain and injuries and help improve lunging performance.

References:

Besier, et al. (2005). Medicine and Science in Sports and Exercise;

Delp, et al. (2007). IEEE Transactions on Biomedical Engineering;

Huang, et al. (2014). Journal of Sports Sciences;

Jérgensen, et al. (1987). International Journal of Sports Medicine;

Lin, et al. (2015). Journal of Sports Sciences;

Shariff, et al. (2009). Singapore Medical Journal;

Yung, et al. (2007). Research in Sports Medicine: An International Journal.