Revealing the knee joint loading during directional badminton lunges via subject-specific modelling

Qichang Mei*, Yaodong Gu, Justin Fernandez

Email: qmei907@aucklanduni.ac.nz
Background

• Knee joint - one of the most injured sites among badminton players;
  - patellar tendinopathy & patellofemoral pain;
  - up to 42.7%.
  (Jérgensen et al, 1987; Shariff et al, 2009; Yung et al, 2007)

• Knee brace & knee tape – commonly observed;

• Conservative & compensatory movements - reduced performance & other injury risks.
  (Huang et al, 2014; Lin et al, 2015)

• Mechanism: Chronic injury – Repetitive sub-maximal lunges;
  Acute injury – Maximal lunges + inciting factors.
Objectives

- Current approaches of musculoskeletal (MSK) modelling and Finite Element (FE) simulations provide feasible and reliable solutions;

- Aiming to reveal the 1) knee joint kinematics (angles in degree);
  2) knee joint moment (torque in Nm/kg);
  3) quadriceps muscle forces (in Body Weight, BW);
  4) knee joint contact forces (BW);
  5) patellar and femoral cartilage stress (MPa).
Methods

- 20 badminton athletes (national level) (right hand & right leg dominant)
  - 12 males  (age: 20.5±3.1yrs, height: 176±4.9m, mass: 68.6±5.6kg);
  - 8 females (age: 19.3±4.1yrs, height: 165±3.8m, mass: 57.6±3.5kg);

Protocol - MSK

- Subject-specific model Scaling
  - Static markers
  - Body mass (kg)
  - Imaging data (Knee CT)

- Inverse kinematics
  - Joint angles

- Inverse dynamics
  - Joint moments

- Static optimization
  - Muscle activation & force

- Joint Reaction
  - Joint contact force
Protocol - MSK-FE

1. MoCap (trc & mot)
2. IK (angle) & ID (moment)
3. SO (muscle force) & JR (contact force)
4. FE simulation (cartilage loading)
Protocol – FE simulation

Segmentation + Mesh

Assign material properties +
Apply Load +
Boundary conditions

Patellar tendon

Quadriceps force
Results (Angle & Moment)
Results (Knee contact force)
Results (PatFem contact force)

Boundary condition + Load:

- Knee joint angle (positions);
- Quadriceps (vastus lateralis, vastus medialis, vastus intermedius and rectus femoris) muscle force (Load).
Results (PatFem Cartilage Stress)

S_\text{mises} (Avg: 75%)

- +6.500e+00
- +5.958e+00
- +5.417e+00
- +4.875e+00
- +4.333e+00
- +3.792e+00
- +3.250e+00
- +2.708e+00
- +2.167e+00
- +1.625e+00
- +1.083e+00
- +5.417e-01
- +0.000e+00

Patellar_Cartilage Stress (MPa)

Femur_Cartilage Stress (MPa)
Sub- vs Max- Lunges

- Significantly increased peak knee flexion moment were observed from sub-lunge (2.24Nm/kg) to maximal lunge (4.1Nm/kg);

- Tibiofemoral axial contact force and patellofemoral compressive force increased significantly during maximal-lunge (8.4BW and 8.1BW) comparing to sub-lunge (7.2BW and 7.3BW).

- Forces of vastus lateralis, vastus medialis, vastus intermedius and rectus femoris muscles increased from 0.31BW, 1.62BW, 1.21BW and 3.1BW (sub-lunge) to 0.68BW, 1.8BW, 1.56BW and 3.6BW (maximal-lunge), respectively.
Conclusions

- Left-Backward and Left-Forward lunges presented higher knee contact force and cartilage stress loadings.

- 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.
From Lab to Court

- Synchronize IMU with MoCap
- Pattern recognition (Machine learning algorithm)
- Real-time on-court monitor & Feedback
Thanks for your attention!

Acknowledgment