Biological Sex Differences in Table Tennis Biomechanics – Implications on Injury Mechanisms

Xiaoyi Yang[1,2], Qichang Mei[1,2], Vickie Shim[1], Justin Fernandez[1,2,3]
[1]Auckland Bioengineering Institute, The University of Auckland, Auckland, New Zealand
[2] Faculty of Sports Science, Ningbo University,Ningbo, China
[3]Department of Engineering Science and Biomedical Engineering, University of Auckland, Auckland, New Zealand
Email: xyan725@aucklanduni.ac.nz

Summary

Table tennis athletes are required to use proper footwork to perform and machine learning has been used to assist table tennis coaching, classification, and outcome prediction. Sexual dimorphism in lower limb anatomy, particularly in the hip and femur regions, has been extensively studied using advanced imaging and statistical techniques. This study aims to evaluate differences in anatomical shape on accumulative bone and tissue damage between professional male and female table tennis athletes using both rigid body and finite element approaches.

Introduction

Sex-based differences are consistently observed, with variations in femoral head sphericity and acetabular depth between males and females. The chasse step is equally used by both males and females and is also associated with a variety of injury mechanisms [1]. It has been reported that female collegiate table tennis athletes were more likely to be injured at the hip joint and this could be attributed to anatomical differences and muscle strength differences [2]. However, there are no studies that integrate and quantify anatomical shape and sex differences in kinetics with muscle forces into advanced computational models to analyze potential injury mechanisms.

Methods

Statistical shape analysis was performed using the GIAS 3 toolbox (Geometry Image-Analysis Statistics) [3]. Using principal component analysis (PCA) 32 female and 35 male intraperitoneal segmented geometries were registered and aligned prior to shape analysis. The age range for the males and females was from 20 to 29 years old and consistent with the age range of the professional table tennis players whose footwork data will be used in the finite element models.

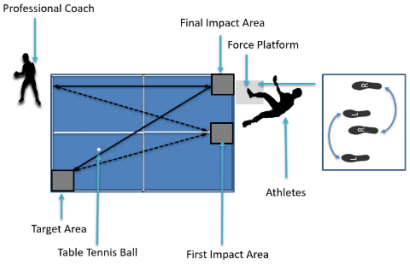

Figure 1: Chasse-step footwork movement.

A female and male hip model was created from the mean shapes generated from the STL geometries (pelvis and femur) in the principal component analysis in GIAS3. These were then imported into Hypermesh [4] for finite element meshing. Abaqus was used to simulate the side movement during the Chasse-step (Figure 1), which is associated with the largest transverse ground reaction forces and is most associated with ligament and soft tissue injuries [2].

Results and Discussion

15 principal components were sufficient to describe ~90% of the entire variation in shape across the population (Figure 2-I). Blue represents regions where the male was ~12 mm and ~8 mm smaller than the female in femur and pelvis shape, whereas red represents regions where the male was ~20 mm and ~5 mm larger than females. Most regions were within ~ 4 mm in femur and ~ 1 mm in pelvis.

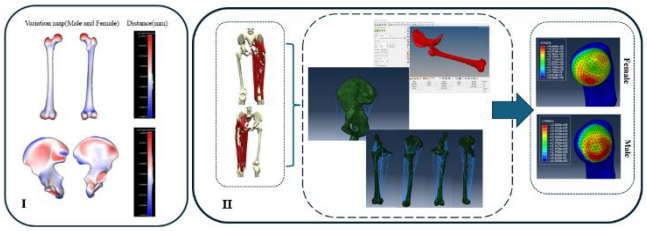

Figure 2: I. Mapped spatial differences between the mean male and female femur (Top) and Pelvis (Bottom); II. Abaqus model and hip contact pressure of chasse-step movement.

During peak lateral hip force movement both male and female models exhibited a pattern of high contact pressure towards the distal femoral contact region (Figure 2-II). The male showed one distinct contact zone, whereas the female showed two contact zones, a large region, and a smaller region. The female peak contact pressure was lower with 4.6MPa, contrasted with the higher 5.8MPa shown in the male model.

Conclusions

Male hip contact was more medial-lateral, whereas females tended to be superior-inferior in direction. Given differences in shape, kinetics, kinematics, and joint pressure, male and female athletes may have different injury mechanisms.

Acknowledgments

This study was supported by the China Scholarship Council (202408250056).

References

[1] Malagoli Lanzoni et al. (2020). *Int. J. Racket Sport Sci*,**1,** 44–48.
[2] Yang et al. (2022). *Bioengineering*, **9**, 1–10.
[3] Yu et al. (2023). *Gait & posture*, **106**, 11–17.
[4] Zhang et al. (2008). (2008). CSSE, **2**, 622–6.