Investigating the Impact of Frugal Inertial Sensors on Ankle Biomechanics during a Badminton Lunge

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Summary

Commercial inertial sensors ensure acceptable kinematic accuracy but pose major challenges owing to their premium and non-transparent processing algorithms. To assess whether the application of a frugal custom inertial sensor altered the kinematics and kinetics during a badminton lunge motion, this study employed an optical motion capture system to compare ankle biomechanics with and without the custom sensor. Negligible differences in ankle angles and no significant changes in muscle activation were observed, supporting the use of custom sensors in tracking on-field joint biomechanics.

Introduction

Wearable inertial sensors are a popular alternative to optical motion capture in characterizing movement biomechanics in natural environments [1]. Given the expensive and discreet nature of commercial sensors, a custom, frugal, modular inertial measurement unit (IMU)-based motion capture system was developed in-house to analyse the dynamic motion of a badminton lunge. Although 50 times cheaper, the form factor and weight of the custom system were two to three times higher than that of the commercial equivalent. Therefore, the aim of the study was to assess the impact of using the custom IMU-based system on the kinematics and kinetics of the ankle during the critical injury-prone phase of the badminton lunge motion.

Methods

Following institute ethics approval, 12 recreational badminton players (seven male, age=29±7 years), with optical markers attached on their lower limb segments [2] and electromyography (EMG) sensors (Delsys, USA) attached to the tibialis anterior and triceps surae, performed forward lunges on a force plate (Kistler, Switzerland) with and without custom IMUs affixed to their shank and foot segments. Ankle kinematics and muscle activations were analysed for the intermediate, foot planted closed-chain phase of the lunge motion, due to its injury proneness. An eight-camera optical motion capture system (Qualisys, Sweden) was used to process ankle kinematics following ISB recommendations [3]. EMG data were processed using a bandpass filter (25–250Hz), normalized using maximum voluntary contractions of each muscle, and analysed at three critical events - heel strike, foot flat and foot off. Absolute differences in ankle kinematics throughout the motion were analysed for the conditions of with and without the IMUs. Wilcoxon signed-rank test was performed to determine differences in peak muscle activation at aforementioned critical events.

Results and Discussion

The maximum absolute difference in ankle kinematics for the two cases of with and without the custom IMUs was 3.69±2.69° for plantar-dorsiflexion, 2.18±2.39° for inversion-eversion, and 1.47±1.28° for internal-external rotation (Figure 1). The peak true difference in PDF, Inv-Ev and IErot across the motion was 0.49±4.06°, 1.22±3.11° and 0.87±1.71° respectively, showing no overestimation or underestimation of joint kinematics. No differences in muscle activations were observed due to the use of the IMUs ($p>0.05$) (Figure 2).

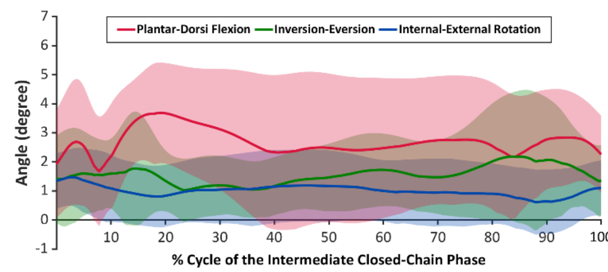

Figure 1: Absolute differences in ankle kinematics during the forward lunge motion for cases with and without custom IMUs

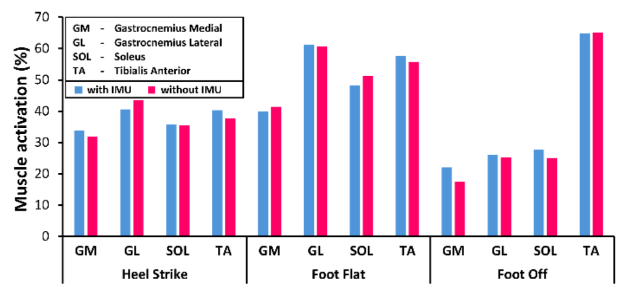

Figure 2: Peak muscle activation at critical events during the forward lunge motion for cases with and without custom IMUs

Conclusions

Ankle kinematics and EMG suggested minimal differences in joint biomechanics due to the custom IMU-based system, indicating its potential for acquiring more accessible on-field biomechanical measurements frugally.

Acknowledgments

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