Proof-of-Concept for Quantifying Foot Kinematics and Movement Demands During Softball Fielding

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Summary

The purpose of this study was to provide a proof-of-concept for quantifying foot kinematics for non-symmetrical and non-cyclical sport movements using wearable instrumentation. We used the fielding movements of an elite softball infield player (shortstop) as our use case for proof-of-concept.

Introduction

The application of wearable sensors to capture on-field movements has largely focused on the estimation of total workload by approximating the whole-body center of mass, via trunk or pelvis sensors, or on movement phases description using foot/shank sensors [1]. However, to describe localized movement demands for improving performance or reducing injury risk, a segment-specific analysis may be more beneficial. This proof-of-concept study details a protocol based on the use of foot- and pelvis- mounted inertial sensors to quantify on-field individual foot kinematics and movement demands of an elite softball player.

Methods

Inertial measurement unit (IMU) (Opal, APDM, Inc. Portland, OR, USA; 250 Hz) and video (GoPro Hero9 SPBL1, GoPro, San Mateo, CA, USA; 30 Hz) data were collected during a single 47-min practice session with semi-prescribed fielding movements. IMUs were affixed to the pelvis (S1) and to the instep of each foot of a single right-handed elite softball player prior to the start of warm-up to allow for a seamless transition to practice. Inertial and video data were synchronized by using a 360° spin movement performed by subjects while in view of the camera and segmented in discrete fielding events.

Anatomical frames of both feet and pelvis were identified by manual position of the IMUs on the relevant segments [2]. Gyroscope biases were removed. Gravity contribution was removed from the recorded accelerations of each IMU using OPAL quaternion values. Inertial data were then low pass filtered using a cutoff frequency of 30 Hz. For each segmented fielding event, the following biomechanical parameters were computed: segments linear accelerations and angular velocities along anatomical axes; foot-ground angle in sagittal (pitch) and frontal (roll) plane; segments angular energy.

Results and Discussion

Forty-three fielding events were analyzed. For the sake of brevity, only the peak values of feet and pelvis linear accelerations are reported (Figure 1). The most prominent motion of feet and pelvis occurred along anteroposterior (AP) and mediolateral (ML) directions, respectively. Foot-ground pitch angles were larger for the right foot (29.2±6.7 deg) relative to the left foot (20.4±6.5 deg). Differences in linear accelerations and foot-ground angles between the right and left foot are mainly due to the right-handed throwing of the enrolled player, which led to greater movement demands on the right foot.

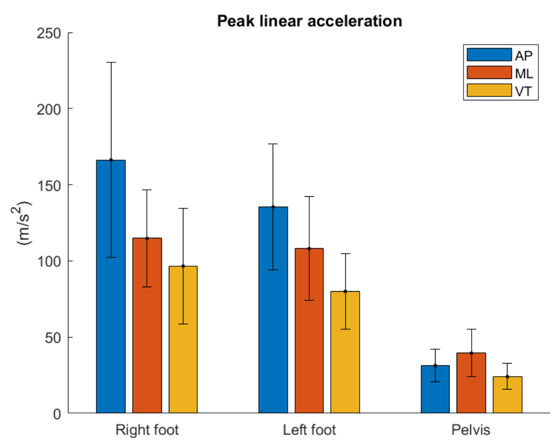

Figure 1: Peak linear acceleration of foot and pelvis segments. The right foot demonstrated the largest accelerations in all directions: AP (right=166.3±63.8, left=135.4±41.3, pelvis=31.4±10.8 m/s^2); ML (right=114.8±31.9, left=108.1±34.1, pelvis=39.5±15.6 m/s^2); VT (right=96.6±37.9, left=80.0±24.8, pelvis=24.1±8.5 m/s^2).

Conclusions

Inertial-based parameters can provide valuable insights into player infield movements demands by quantifying the kinematics and the prominent motion direction of each segment of interest. During shortstop play, right and left foot exhibited different kinematics, with the right foot of the right-handed player showing greater demands. Larger datasets are needed to generalize these findings.

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References

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