Evaluation of kinematics in tennis forehand drives using OpenCap and marker-based motion capture

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Introduction

Biomechanical metrics derived from the analysis of 3D joint angles can provide relevant insights on tennis performance. Such methods have been extensively used to investigate tennis serve [1], but only a few studies focused on tennis forehand drives and the effect of stances [2]. One of the obstacles is that 3D biomechanical studies mostly rely on marker-based motion capture systems, that are difficult to use in ecological situations. The development of markerless tools like OpenCap [3] looks promising for democratizing 3D kinematic analysis directly on the court.

The objective of our study was then to evaluate the accuracy of the OpenCap system for the assessment of kinematics during tennis forehand drives.

Materials and Methods

Six tennis players (1 woman and 5 men), at the regional to national level, were recruited for this study. In lab conditions, they performed series of tennis forehand strokes, with open or square stances, aiming at a target integrated into the projection of a tennis court image. They also performed series of squats to have a baseline evaluation for a movement involving only flexion.

Trajectories of anatomical landmarks were collected with 3 iOS devices (OpenCap, Stanford University, USA) concurrently with a marker-based optoelectronic system (41 markers, 14 cameras, Qualisys, Sweden). Joint angles were computed with the OpenCap pipeline, and compared with the same angles inferred from 3D marker trajectories, using scaling and multi-body kinematics optimization tools from OpenSim (Fig. 1).
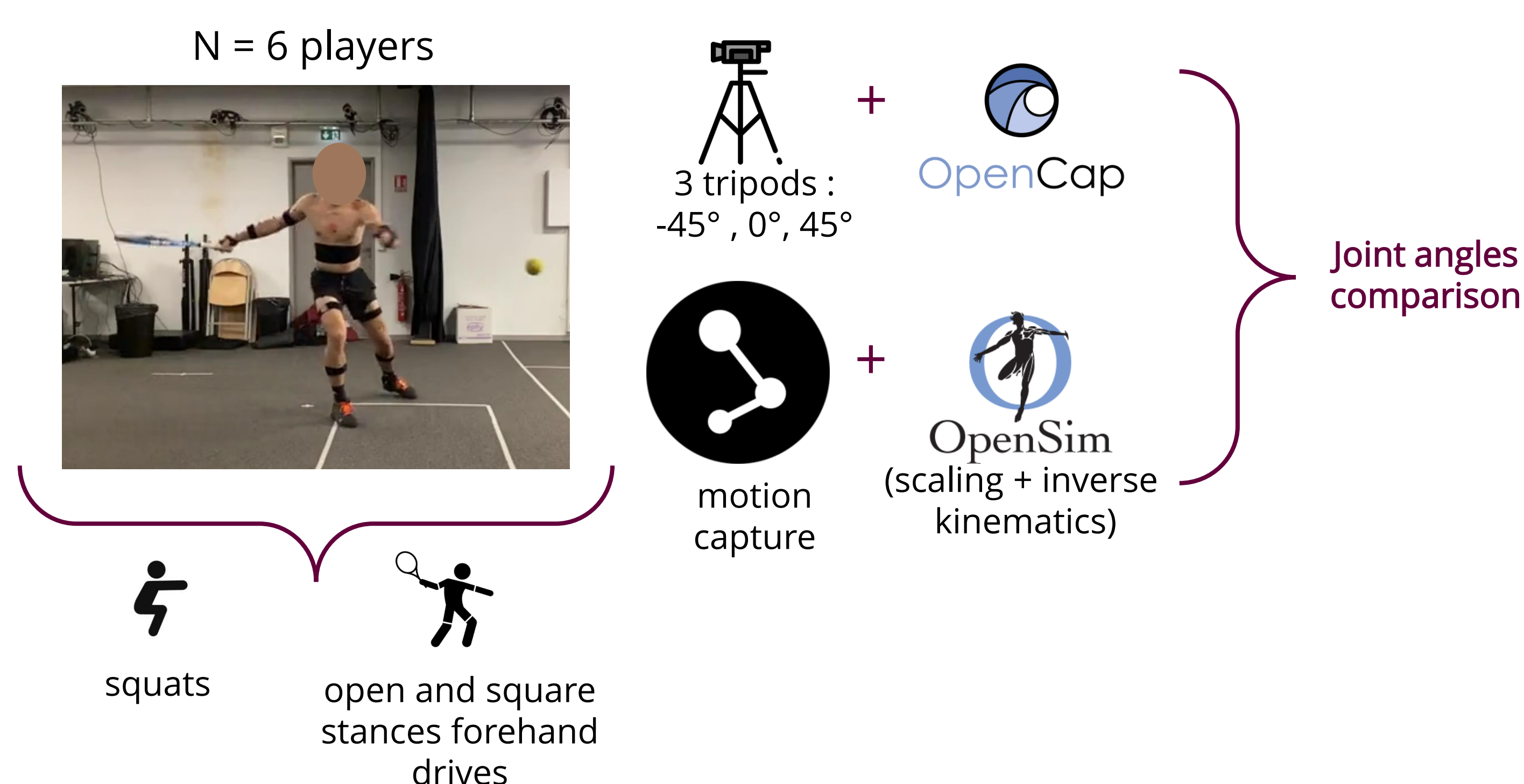

Fig. 1 Scheme of the experimental protocol

Results

For squat motions, differences in peak flexion angles between the two systems reached 12.3°± 6.1° for the hip and 6.8°± 3.9° for the knee. As expected, our preliminary analyses showed that differences between the two systems (Fig. 2) were higher for tennis strokes (24.5° ± 15.3° for arm flexion), with large errors occurring for rotations around the longitudinal axis (31.1° ± 23.7° for arm internal rotation).
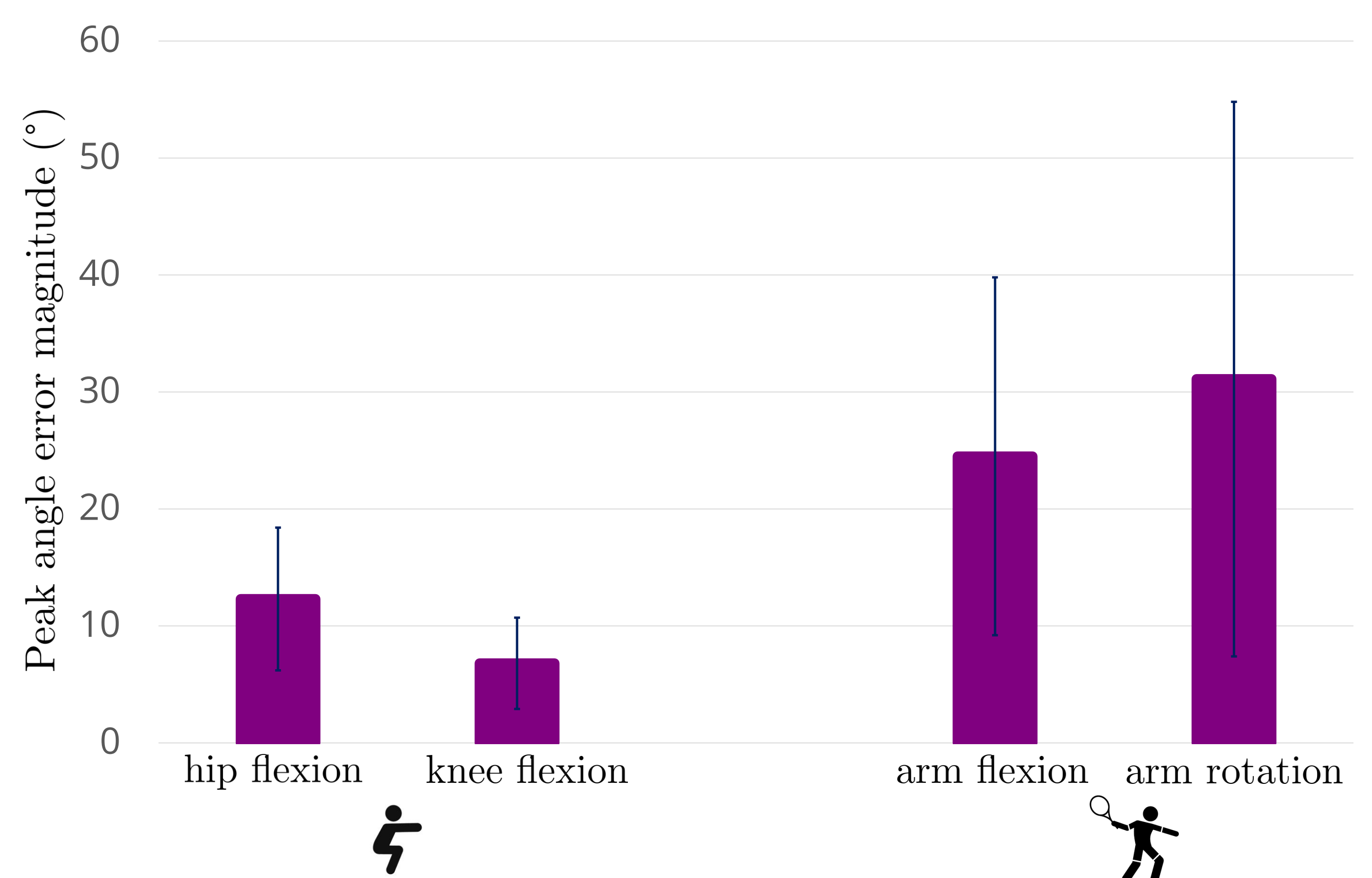

Fig.2 Error between OpenCap and marker-based motion capture for the estimation of peak angles

Discussion

Markerless motion capture tools like OpenCap allow to measure 3D kinematics on the tennis court, with the advantage of providing hands-on results. However, as reported in the literature [4], users should be aware that depending on the task and joint angles investigated, the magnitude of errors in comparison with marker-based motion capture can be high.

In our case, the errors for squat movement were consistent with values reported in the literature [4] and drastically increased when investigating tennis strokes. This may be due to the specific movement of the tennis forehand, inducing upper and lower body dissociation and combinations of flexion, internal rotation, and adduction. Further investigations are required to compare this system to other embedded measurement tools like IMUs and OpenSense, to find the most suitable tool for 3D kinematics evaluation on the tennis court.

References
[1] Lambrich J, Muehlbauer T. Biomechanical analyses of different serve and groundstroke techniques in tennis: A systematic scoping review. PLoS One. 2023 Aug 17;18(8):e0290320.
[2] Martin C, Sorel A, Touzard P, Bideau B, Gaborit R, DeGroot H, Kulpa R. Can the Open Stance Forehand Increase the Risk of Hip Injuries in Tennis Players? Orthop J Sports Med. 2020 Dec 11;8(12):2325967120966297.
[3] Uhlrich SD, Falisse A, Kidziński Ł, Muccini J, Ko M, Chaudhari AS, Hicks JL, Delp SL. OpenCap: Human movement dynamics from smartphone videos. PLoS Comput Biol. 2023 Oct 19;19(10):e1011462
[4] Lima YL, Collings T, Hall M, Bourne MN, Diamond LE. Validity and reliability of trunk and lower-limb kinematics during squatting, hopping, jumping and side-stepping using OpenCap markerless motion capture application. J Sports Sci. 2024 Oct;42(19):1847-1858