IMU vs. markerless motion capture:
Which direction to take for investigating joint kinematics during on-field change-of-direction movements?

Maurice Mohr[1], Mareike Kühne[1], Katharina Schiel[1], Peter Federolf[1]
[1]Department of Sport Science, University of Innsbruck, Innsbruck, Austria
Email: maurice.mohr@uibk.ac.at

Summary

In this study we investigated the concurrent validity of commercial solutions for IMU-based and markerless motion capture (MoCap) in estimating knee and hip joint kinematics during change-of-direction (COD) maneuvers compared to state-of-the-art marker-based optical MoCap (OMC). Both the IMU-based and markerless approaches showed good agreement with OMC for knee flexion and hip flexion/abduction but poor agreement for knee abduction/rotation and hip rotation.

Introduction

Within sports biomechanics, there are increasing efforts to investigate athletic movements, such as COD, in natural environments in order to better understand mechanisms of injury prevention and performance optimization [1]. Both IMU-based and markerless MoCap offer potential solutions for on-field movement analysis but it is currently unknown whether one solution may show superior agreement with movement reconstructions from state-of-the-art OMC.

The aim of this study was to compare COD knee and hip kinematics estimated from popular commercial solutions for IMU-based and markerless MoCap with OMC-based estimates in terms of their absolute (random errors) and relative agreement (rank-order correlation).

Methods

Twenty-five healthy and physically active participants (60% female) were equipped with a full-body reflective marker set and eight inertial measurement units (Ultium Motion, Noraxon Inc.) applied to torso, pelvis, thighs, shanks, and feet. Individuals completed five maximal-speed 180° COD movements. All movements were captured by synchronized infrared cameras (OMC, 10-camera Vicon system, Vicon Motion Systems Ltd.), RGB cameras (markerless, 8-camera Flir Blackfly S system, Teledyne FLIR LLC), and the 8 IMUs at an equal sampling rate of 200 Hz. Three-dimensional hip and knee joint angles were estimated using OpenSim inverse kinematics (OMC), Theia3D software (Theia Markerless Inc.), and Noraxon MR3 software (IMU).

The statistical analysis was carried out with respect to the average joint angles at the initial contact of the 180° COD. Bland-Altman limits of agreement and Spearman's rank correlation coefficients were estimated for the comparisons OMC vs. markerless and OMC vs. IMU. The random errors (upper – lower limit of agreement) were expressed relative to the maximum ROM in the OpenSim model (Figure 1).

Results and Discussion

Both markerless and IMU-based approaches showed the lowest random errors (9-17% of ROM, Figure 1a) and strongest rank correlations (0.65-0.92, Figure 1b) for knee flexion and hip flexion/abduction and thus provide viable alternatives to OMC for tracking these joint angles during COD. Markerless compared to IMU-based MoCap showed slightly lower random errors and higher correlations for knee and hip flexion suggesting superior performance of markerless MoCap in the sagittal plane. For knee abduction/rotation and hip rotation, markerless and IMU-based estimates showed high random errors of 27-69% of ROM and generally lower and partially non-significant rank correlations (0.37-0.64). For these joint rotations, neither markerless nor IMU-based MoCap should be used in place of OMC when investigating COD maneuvers.

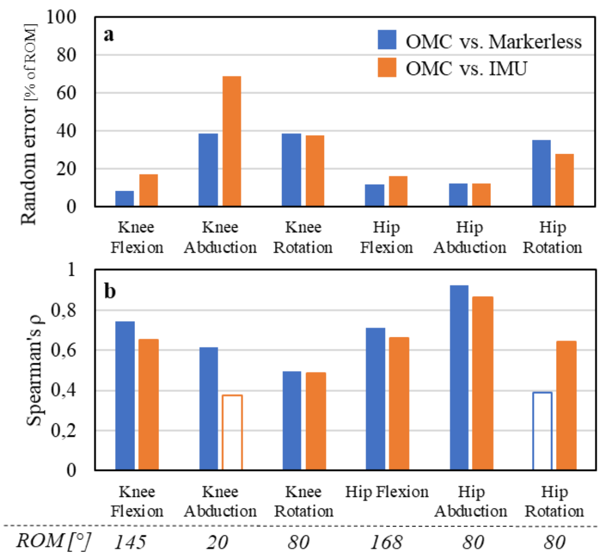

Figure 1: Relative random error (a) and rank correlation coefficients (b) for OMC-based vs. markerless or IMU-based joint angle estimates. Unfilled bars show non-significant correlations.

Conclusions

When focusing on knee/hip flexion and hip abduction, both markerless (Theia3D) and IMU-based (Noraxon Ultium) MoCap seem viable alternatives to OMC for investigating COD kinematics with slightly superior agreement of markerless estimates in the sagittal plane. However, both approaches failed to provide valid estimates of knee abduction /rotation and hip rotation compared to OMC warranting new solutions for the on-field analysis of these movements.

References

[1] Mohr M et al. (2023). *Front. Bioeng. Biotechnol.*, **11:**1210173