Comparison of the lower limb kinematics obtained using an optoelectronic system and a markerless system

Cédric Schwartz *

ULiège, LAM – Motion Lab, Liège, Belgium

Jean-Louis Croisier

ULiège, LAM – Motion Lab, Liège, Belgium

Jean-François Kaux

CHU of Liège, Department of Physical and Rehabilitation Medicine, Liège, Belgium

Kevin Gramage Medina

ULiège, LAM – Motion Lab, Liège, Belgium

***Corresponding author.** Email: cedric.schwartz@uliege.be

Keywords*:* running; cutting; jump; opencap

1. Introduction

The evaluation of sport kinematics (and kinetics) could contribute to detect individuals at greater risk to sustain an injury (Pedley et al., 2020) and therefore be integrated in primary and secondary injury risk prevention programs. Kinematic evaluation usually requires costly equipment (such as optoelectronic systems) that is usually found in dedicated infrastructures such as hospitals and research laboratories. This situation limits the possibility for healthcare practitioners and physical trainers implied in prevention and/or rehabilitation programs to perform kinematic follow-ups. Looking for advanced and cost-effective solutions is therefore desirable but imply satisfying several requirements including: 1) being affordable to substantially increase the scope of potential users, 2) providing biomechanical analysis as similar as lab ones, 3) providing sufficient accuracy.

Recent developments (Uhlrich et al, 2023) now offer the possibility to perform markerless measurements using low cost equipment in comparison to traditional optoelectronic systems. However, these systems still lacks validation for a number of gestures. The aim of the present work is to compare results from the markerless system Opencap and from a traditional optoelectronic system for several sport gestures.

2. Methods

2.1 Population

Fourty volunteers (half male, half female) between 18 and 25 years old and performing at least two hours of sport per week where recruited. At the moment of the test, they should not present pain and have had a recent (less than one year) surgery.

2.2 Tasks

After familiarization trials, the volunteers were ask to perform the following movements: running 15m, performing a cutting manoeuvrer at 45°, a counter movement jump (CMJ), a drop jump (DJ) from a box of 30 cm and a single hop test.

The volunteers' movements were recorded simultaneously using an optoelectronic system (Qualisys, Arqus 9) at 200 Hz and the Opencap system (using two iPads and the default settings – OpenPose algorithm) at 60 Hz (Uhlrich et al, 2023). The volunteers were equipped with fourty-one markers, which were placed following the musculoskeletal model from (Lai et al., 2017) used by the Opencap. The two-iPads were placed at 30-45° of the line facing forward from the volunteer as recommended by the Opencap procedure.

2.3 Data processing

The same model than the one used by Opencap (Lai et al., 2017) was used in Opensim to process the data acquired by the optoelectronic system. Before performing the inverse kinematics calculation, the model was scaled accordingly to the leg length of the volunteers (distance between the anterior superior iliac spine and the lateral malleolus). The scaling was performed separately for each approach.

The movements were limited to the following periods: one right stride for running and cutting movements, from the initiation of the movement to takeoff for the CMJ, from the first landing to takeoff for the DJ and from landing to maximal knee flexion for the single hop jump. Each movement was resampled as one cycle (100 frames) to allow inter-volunteers and between systems comparisons. The root-mean square error between the motion estimations of both systems was computed for each motion as well as a SPM1d statistic.

3. Results and discussion

From a qualitative point of view, the waveforms identified by the markerless system (Opencap) reflect the same pattern as the ones identified by the optoelectronic systems but significant differences were identified (Figures 1 & 2). Amplitude (i.e. hip rotation for the single hop jump) and temporal (i.e. knee flexion for the CMJ) offsets may exist. These differences may be explained by the landmarks localization errors of the Opencap system but also by the different scalings of the models (due to different landmark position estimations).

From a quantitative perspective, the amplitude of the errors depends on the movement and the degree of freedom considered (Table 1). Large errors (over 15°) were identified in the sagittal plane for the hip, knee, ankle and lumbar joints for most tasks. Errors are more limited for the other degrees of freedom but these better results should be put in perspective with the reduce amplitudes in these other degrees of freedom. The errors obtained for the DJ are only a few degrees higher than the results reported by the paper from (Uhlrich et al, 2023) and therefore confirm these previous results.

Previous researches have also underlined other limitations of using the Opencap system (but not evaluated in this study) including the influence of the direction of the movement on accuracy (Martiš et al., et al, 2024) and an increased inter-trial variability (Horsak et al., 2024).

Table 1. *Root mean square difference between the lower limb kinematics estimated using an optoeletronic system and a markerless system*

(°)	Run	Cut	CMJ	DJ	Single hop
Hip flex	21±10	18±10	16±7	15±7	11±6
Hip add	8±2	6±3	3±2	3±2	6±4
Hip rot	7±4	8±5	5±2	5±3	7±4
Knee flex	14±6	13±11	8±7	8±8	9±6
Ankle flex	19±7	15±7	8±6	12±6	9±7
Lumbar ext	13±6	12±6	12±5	14±8	11±6
Lumbar bending	8±3	6±3	4±3	3±2	5±3

4. Conclusions

The comparison of the kinematics obtained with an optoelectronic system and the Opencap markerless system show promising results. However, despite a non-arguable ease of use, the amplitude of the errors, the temporal and amplitude offsets that may be present does not allow, at the present time, the use of such system for injury prevention in sports. Errors over 5° are indeed usually considered with cautious for clinical interpretations (McGinley et al., 2009).

Conflict of Interest

The authors have no conflict of interest to report.

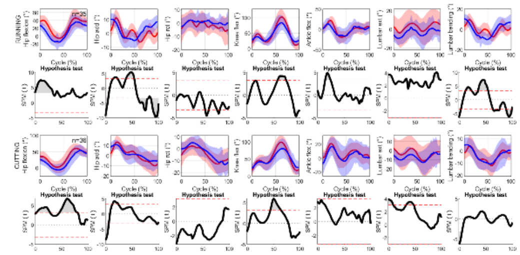

Figure 1. *Lower limb kinematics for running tasks estimated using an optoeletronic system (red) and a markerless system – Opencap system (blue)*

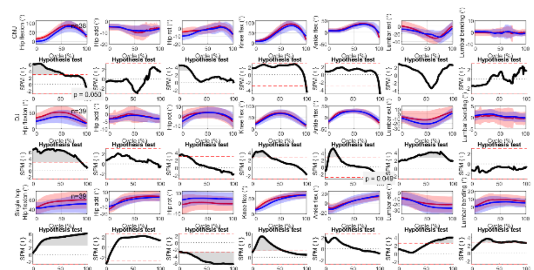

Figure 2. *Lower limb kinematics for jumping tasks estimated using an optoeletronic system (red) and a markerless system – Opencap system (blue)*

References

Horsak B, Prock K, Krondorfer P, Siragy T, Simonlehner M, Dumphart B, Inter-trial variability is higher in 3D markerless compared to marker-based motion capture: Implications for data post-processing and analysis, *Journal of Biomechanics*, 2024; 166.

Lai AKM, Arnold AS, Wakeling JM. Why are Antagonist Muscles Co-activated in My Simulation? A Musculoskeletal Model for Analysing Human Locomotor Tasks. Ann Biomed Eng. 2017; 45: 2762–2774.

Martiš P, Košutzká Z, Kranzl A. A Step Forward Understanding Directional Limitations in Markerless Smartphone-Based Gait Analysis, *www.preprints.org*, 2024.

McGinley JL, Baker R, Wolfe R, Morris ME. The reliability of three-dimensional kinematic gait measurements: a systematic review. *Gait and Posture*, 2009; 29:360-369

Pedly JS, Lloyd RS, Read PJ, Moore IS, De Ste Croix M, Myer GD, Oliver JL. Utility of Kinetic and Kinematic Jumping and Landing Variables as Predictors of Injury Risk: A Systematic Review. *Journal of Science in Sport and Exercise*, 2020; 2:287–304

Uhlrich SD, Falisse A, Kidziński Ł, Muccini J, Ko M, OpenCap: Human movement dynamics from smartphone videos. *PLOS Computational Biology*. 2023 19(10): e1011462.

Received date: leave blank
Accepted date: leave blank
Published date: leave blank
Volume: leave blank
Publication year: leave blank