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On using an inertial motion capture system in cycling

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1. Introduction

Cycling is a highly competitive sport with many biomechanics research projects carried out to improve the performance of athletes. To analyze the rider's technique, optoelectronic motion capture system method is mainly used in laboratory. Marker motion capture system has, however, a restricted acquisition area due to the limitation of the number of cameras. Therefore, marker or marker-less motion capture system are not suitable for studying the body's kinematic in ecological condition for cycling tasks.

To overcome this critical lock, inertial motion capture systems are more and more used nowadays (Roetenberg et al. 2013). Most of the IMU system validation studies have been done during contact floor sports (walking, running...) for lower limb analysis. Promising results were obtained so far. As example, lower limb kinematic in sagittal plane is estimated within 2.4° to 8.27° RMSE in squatting (Teufl et al. 2019).

Some validation studies are focusing on full body kinematic. The upper limb seems to have a higher RMSE than the lower limb (Robert-Lachaine et al. 2017).

However, few validation studies have been done in non-contact sports such as cycling (Marin-Perianu et al. 2013) and they are focusing on lower limb in sitting position.

In this paper, our aim is to estimate the validity of the IMU's motion capture system by comparing it with

optoelectronic system for full-body kinematics (except the trunk motion) in sagittal plane in different cycling positions.

Our first hypothesis was that the upper body kinematic will be captured with less validity than the lower limb motion. A second hypothesis was that the riding position will affect the validity of the result.

2. Methods

2.1 Participants

One participant (age: 25 years, height: 168cm, and mass: 62kg) volunteered to participate and gave informed consent to the protocole.

2.2 Instrumentation

Full body motion was recorded with 60 markers tracked by a twelve-camera Vicon system at 200Hz and on the other hand, with 15 wire-less Xsens IMU at 60Hz. Both systems were synchronized using a trigger signal sent by the Xsens MVN system in the Vicon system.

2.3 Experimental protocol

The IMUs system was calibrated with a static calibration N-pose used to estimate an approximative position and orientation of the IMU and the segment in the global frame thanks to the anthropometric data. Then a walking calibration is performed to optimize the relationship between the sensor and the body segment position.

After the calibration, the subject performed a warm-up of 5min on a professional track cycling bike fixed on rollers. He was pedaling wearing a pair of cleats shoes. The experiment is composed of 6 trails of 15s in total with 3 sets of 3 different riding positions: sitting, standing, and start. The start position is a mimic of the start riding technique in track cycling with a pelvis oscillation between the saddle and the stem. The rider has no specific cadence or power instruction during the experiment. To limit the fatigue effect, the participant had 30 seconds rest period between trials. One trail was divided into two phases: 3s staying in the N-pose position and 10s on the bike pedaling.

2.4 Data analysis

The Vicon tracking data have been labeled using Nexus software. Then kinematic have been computed by using a biomechanical model as close as possible to the one used by Xsens (MVN model). The parameters of the chain model were set using a static anatomical position (N-pose) similar to the one used for the Xsens system. Finally, the Vicon's kinematic has been filtered by a Butterworth filter at 5Hz. Xsens data have been directly interpolated at 200Hz to be compared with the Vicon data.

The RMSE during a crank cycle has been computed for the different joints and riding positions using the crank angle captured by the Vicon system. The statistical results have been obtained on a sample of 33 crank cycles for the saddle and the stand position. The start position had a sample of 16 crank cycles.

3. Results and discussion

The results of the experiment were presented for the right side of the body.

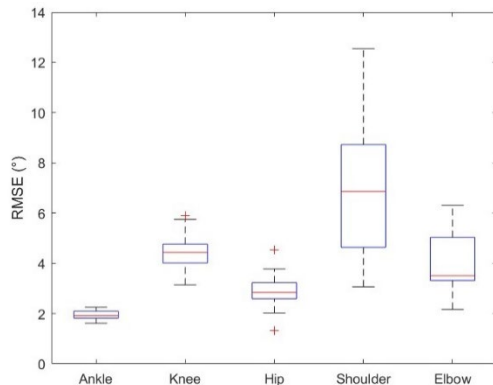


Figure 1. Right joints RMSE in the start position.
Credit: LABAT Paul

Figure 1 shows that the lower-limb joints have a lower RMSE than the upper-limb joints (4.4° vs 7° max). In addition, the shoulder has the highest RMSE of the joints with 7° in average in the start position (see Table 1). This can be explained by the large scapula motion during the start pedaling technique. The main difference between the lower and upper limbs is the calibration procedure of the Xsens system. Hence, the dynamic calibration is a walking motion during which small movement of the upper limb are observed.

Table 1. Mean RMSE in degrees for the different joints in the different position
credit: LABAT Paul

RMSE (°)	Sitting	Standing	Start
Ankle	2.1	1.6	1.9
Knee	6.7	5.7	4.4
Hip	2.3	1.7	2.9
Shoulder	2.9	5.8	7
Elbow	4.4	1.5	3.9
Global*	18.4	16.3	20.1

* sum for the 5 joints mean RMSE

Compare to the literature, (Marin-Perianu et al., 2013) found in the sitting position respectively 4.8° RMSE and 2.3° RMSE for the ankle and the knee. In our study, we found a RMSE of 2.1° and 6.7° for the ankle and knee respectively. Both studies results are in the same range. However, the differences can be

explicated by the calibration procedure and the number of participants.

Regarding the global RMSE in the Table 1, the standing position had the best global validity. However, it was not true for all the joints. Some specific joints like the shoulder are less precise in the standing position than the sitting position.

The difference between the Vicon system and the Xsens system are mainly due to the difference of the estimation of the centre of rotation used in the biomechanical model.

4. Conclusions

The difference between optoelectronic system and Xsens system were higher on the upper limb joints confirming our first hypothesis. Regarding the riding position, the results obtained cannot confirm our second hypothesis due to variability of the evolution of the joints RMSE between riding positions.

To conclude, joints RMSE were lower than 10° in average for the 5 joints studied. Therefore, the Xsens system show a potential tool to track cyclist in ecological condition.

Conflict of Interest Statement

The authors declare no conflict of interest during this study.

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