ASSESSMENT OF THE SENSITIVITY OF AN EMBEDDED SENSOR-BASED METHOD FOR JOINT MOMENT CALCULATION IN CYCLING

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Summary

This study evaluates the sensitivity of a sensor-based method for calculating joint moments during cycling. The results reveal measurement discrepancies, particularly in hip moments. Improvements in kinematic measurement are needed to optimize joint moment estimates in cycling.

Introduction

Studying mechanical actions, such as joint specific moments or power during cycling, highlights muscle coordination and adaptations to conditions such as cadence [1], or fatigue [2]. These data have been studied in the laboratory but not directly on the field. The aim of this study is to assess the sensitivity of a method based on embedded sensors for calculating joint moments during cycling.

Methods

The three-dimensional kinematic and dynamic data of two healthy participants (mean sd taille poids age) was measured during cycling. Each participant underwent three analysis sessions (sess), all conducted by the same therapist. During each session, five cycling trials of 60 secondes were recorded at a self-paced velocity on an ergocycle.

Joint angles were measured using Noraxon (Scottsdale, USA) inertial measurement unit (IMU) and a Qualisys (Göteborg, Sweden) optoelectronic (opto) system associated with the conventional gait model [3] to allow comparison between the two sources. Three-dimensional pedal reaction forces were measured thanks to PI3D designed by Phyling (Orsay, France). Inverse dynamic was performed over 10 cycles for each trial by OpenSim ID tool.

The sensitivity of the method was evaluated using the Standard Error of Measurement (SEM), which quantifies the degree of measurement variability that is not due to true changes in joint moments, but rather to measurement error.

Results and Discussion

The results for all participants and each degree of freedom, as defined by the chosen model, are presented (Table 1). The SEM ranges from a minimum of 0.9 N·m for the ankle flexion moment to a maximum of 8.1 N·m for the hip adduction moment, highlighting variability in measurement accuracy across different joint angles.

Table 1: Results for all participants. SEM and ICC are presented for Flexion (F), Adduction (A), Rotation (R). SEM is given in N.m

	Hip F	Hip A	Hip R	Knee F	Ankle F
SEM	6.5	8.1	2.7	5.1	0.9
$ICC_{3,1}$	0.97	0.86	0.93	0.87	0.96

The observed variability in the SEM can be attributed to the inherent errors in estimating joint angles during the kinematic measurements. Even if the SEM for each angle is below 2 degrees which corresponds to errors previously reported for IMU-based kinematic estimation [4].

We observed a notable offset, particularly in the pelvis forward orientation and ankle flexion angle. This led to an overestimation of hip flexion moment (Figure 1).

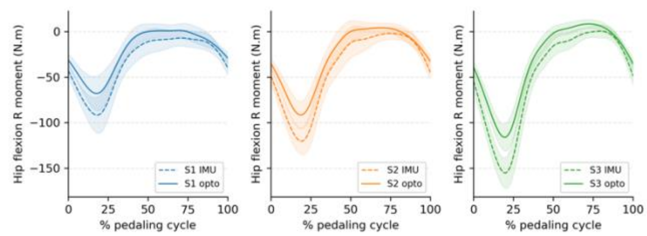

Figure 1: Right hip flexion moment (N·m) for each session and both participants.

These offsets are attributed to sensor to segment calibration and segment reference frame definition. Interestingly, the smallest SEM was observed for the ankle flexion, which is the joint most affected by fatigue-induced modifications [5]. Further research will aim to correct these offsets to improve the estimation of joint moments from embedded sensors.

Conclusions

This method demonstrates significant potential for accurate joint moment estimation. It provides a reliable, practical tool for future on-field cycling studies

References

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