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PRELIMINARY RESULTS: A COMPARISON OF SPECIFIC IMU-BASED CALIBRATIONS FOR CYCLING VS. CONVENTIONAL METHODS.

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Introduction

Recent technological advances in MEMS allow considering the biomechanical evaluation of cyclists outside the laboratory (road, track cycling, etc). Indeed, optoelectronical motion capture in cycling is commonely used in laboratory to provide relevant biomechanical parameters associated to performance optimization and/or injury prevention. However, it does not allow evaluation in ecological and outdoor conditions, which can be counteracted using inertial measurement units (IMU). These sensors give the opportunity to estimate 3D segmental rotations, from which body-to-sensor rotations can be obtained. However, IMUs usually suffer from signal drift and require calibration procedure when accurate 3D joint angles are calculated. This latter calibration procedure is of major interest and is generally based on static or dynamic tasks. However, specific calibration procedures applied to cycling are missing and should be developed for outdoor applications. The aim of this study is to develop specific IMU-based methods for analyzing cycling motion, using calibration tasks based on pedaling motion. This method is compared to conventional methods applied in IMUbased gait analysis.

Methods

Six participants were equipped with IMU sensors on thigh and shank at a sampling rate of 75 Hz. Each sensor was placed on lower limb segments as depicted in Figure 1. Each subject achieved calibration tasks prior to cycling exercise: two conventional method following methodology adapted from (Palermo et al., 2014, Favre et al., 2009). Then, a third static calibration was realized on the bike and was based on leg extension associated with crank at bottom dead center. Finally, a dynamic calibration based on cycling motion consisting of a 2 minutes pedaling motion at 90rpm at 60% MAP allowed to estimate flexion/extension axis using an optimization procedure (Seel et al. 2012). We evaluated the influence of the four methods on the estimation of knee flexion/extension axis in IMU frame. Differences are presented along each axis with a significant level set at $p<0.05$. **Results**

Differences between methods are presented in table 1 for thigh and table 2 for shank. Significant difference (p<0.05) was found between conventional methods for X and Z-axis for thigh. Significant difference (p<0.05) was also found for thigh Y-axis between static calibration on bike and dynamic method versus static conventional methods. Concerning thigh X- axis, the only difference was quantified between statics methods (p<0.05). The largest difference was obtained between conventional vs. on bike, dynamic method for thigh Z axis. Lastly, concerning shank, significant difference was observed only between conventional dynamic method and on bike static method.

Discussion

An objective of this study was to show the interest of a dynamic calibration directly on the bike instead of conventional procedures before cycling. This study showed significant differences between tasks and seems to be relevant for cyclist in order to avoid preliminary calibrations using IMU when cycling. Such a method may therefore be used during the warming session. The next step will be to evaluate error between IMU and optoelectronical motion capture when calculating 3D anatomical joint axis (ISB norm). Further step in this work will require more subjects and will evaluate the effects of various conditions such as power output, cadence, etc.

Reference

Palermo E, Rossi S, Larini F, Patanè F, Cappa P. (2014). Measurement, 52, 145-155.

Seel T, Schauer T, Raisch J. (2012). IEEE International Conference on Control Applications

Favre J, Aissaoui R, de Guise JA, Aminian. (2009). Journal of Biomechanics, 42, 2330-2335

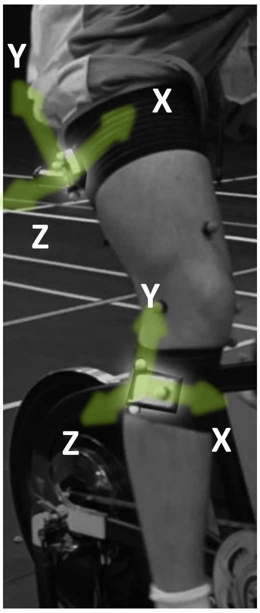

Figure 1 Sensor positioning on thigh and shank and local axis

*Tableau 1 Friedman multiple comparison between methods, of flexion axis in thigh frame along X, Y and Z axis. The four methods are conventional static (CS), conventional dynamic (CD), on Bike static (BS) and on Bike dynamic (BD). (No statistical difference: NS; *: p<0.05; **: p<0.01)*

1.	CS			CD			BS			BD		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z

CS												
CD	**	NS	NS									
BS	*	NS	NS	NS	NS	NS						
BD	NS	*	NS	NS	*	**	NS	*	NS			

Tableau 2 Friedman multiple comparison between methods, of flexion axis in shank frame along X, Y and Z axis.

2.	CS			CD			BS			BD		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
CS												
CD	NS	NS	NS									
BS	NS	NS	NS	*	*	NS						
BD	NS	NS	NS	NS	NS	NS	NS	NS	NS			