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COMPARISON OF AN INNOVATIVE INERTIAL SYSTEM AT HIGH SAMPLE RATE WITH THE GOLD STANDARD OPTOELECTRONIC SYSTEM IN GAIT ANALYSIS TEST

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INTRODUCTION

Gait analysis can be performed by means of optoelectronic system. Because of the top-accuracy they represent the gold standard. However, cameras need a pre-arranged environment, a long set-up procedure and can be very expensive. In order to overcome some of those drawbacks, wearable devices based on inertial measurement units (IMUs) have been taking hold. IMUs are poorly invasive, adoptable in any environment, have a fast set-up procedure [1] and are relatively cheap. We present a novel IMU technology Movit System G1 (by Captiks Srl, Rome, Italy), and its validation in terms of accuracy, with respect to a gold-standard camera based system for gait analysis purposes.

METHODS

Four healthy subjects, two males and two females, with different anthropometric characteristics were enrolled in this study, at the "Movement and Posture Analysis" laboratory, Santo Stefano Institute (Porto Potenza Picena, Italy). The gold-standard system was made of six infrared cameras with refresh rate of 100 Hz. The under-test system was made of 7 IMUs (Movit G1) with sample rate at 200 Hz, 3D accelerometers and 3D gyroscope full-scale range of ±2g and ±2000 dps, respectively. They were positioned on pelvis, thighs, shanks and feet. The passive markers were positioned on specific body landmarks according to the Davis protocol. The subjects, wearing both the systems and starting from standing position, performed a bilateral knee flexion (useful to set a motor triggering for synchronization purpose) and then walked for 6 meters at a subject-comfortable speed. They repeated this test 10 times. Our measurements aimed at considering the temporal parameters of Stride time, Step time and Cadence and the range of motion (ROM) of the pelvis along the three plane, of the hip, knee and ankle on the sagittal plane. ROM was calculated after offset removal measured during the standing position.

RESULTS

In order to assess the accuracy of the system, for each test repetition we calculated the root mean square error (RMSE) and the Pearson correlation coefficient, of the joints' ROM (Table 1).

Table 1. Mean and Standard Deviation of RMSE and Pearson correlation coefficient of ROMs

ROM	RMSE(°)	PEARSON COEFF
PELVIS TILT	1.75 ± 0.66	0.75 ± 0.23
PELVIS LATERAL BENDING	1.15 ± 0.23	0.93 ± 0.03
PELVIS ROTATION	1.28 ± 0.37	0.94 ± 0.03
HIP FLEXION-EXTENSION	3.14 ± 0.59	0.99 ± 0.00
KNEE FLEXION-EXTENSION	3.06 ± 0.58	0.99 ± 0.00
ANKLE FLEXION-EXTENSION	2.86 ± 1.08	0.95 ± 0.04

The absolute error (ε) and the absolute percentage error ($\varepsilon_{\%}$) have been calculated for Stride Time, Step Time and Cadence for each test, reporting mean and standard deviation values of ε= 0.01±0.01(s), 0.01±0.01(s), 0.91±0.81(step/min) and $\varepsilon_{\%}$ = 0.99±0.88, 1.62±1.59%, 0.98±0.86%, respectively.

DISCUSSION

As a conclusion, the Movit system G1 highly performed in terms of measurement accuracy. In fact, according to our results, comparing this IMU-based system to the Vicon gold-standard camera-based system, the ROM error was found always smaller than 5°, which is considered as an excellent result according to [2]. In addition, the Pearson coefficient was higher than 0.9 for all ROMs, that is, an excellent result, except for pelvis tilt, that is, a good acceptability [2]. All the percentage errors, $\varepsilon_{\%}$, are less than 5%, which demonstrate an excellent accuracy [3]. Further work will be devoted to examining ROMs in the frontal and transversal planes.

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