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CAPTIKS - SANTO STEFANO INSTITUTE - TOR VERGATA UNIVERSITY

Comparison of an Innovative Inertial System at high sample rate with the gold standard optoelectronic system in Gait Analysis test

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1 Introduction

Gait analysis can be performed by means of systems based on image acquisition via one or more cameras. Because of the top-accuracy they can offer, the camera-based systems currently represent the gold standard. However, cameras need a clean light-of-sight, a pre-arranged environment, a time demanding set-up procedure performed by a skilled operator and, relevantly, such systems 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.

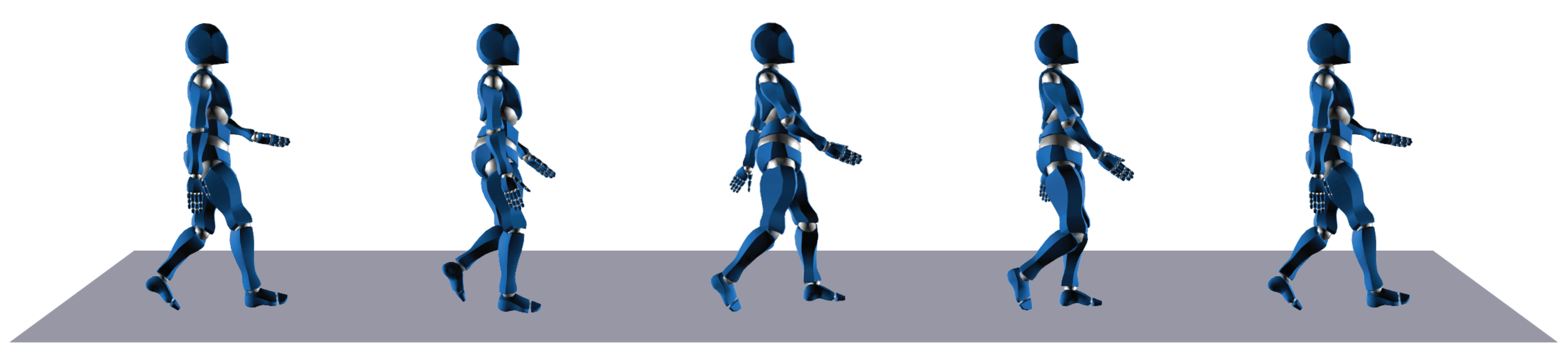

Figure 1. Gait Analysis Test

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 (Vicon) during Gait Analysis Test. We want to validate:

- Range of Motion (ROM) of Pelvis angles in the three planes, of Hip, Knee and Ankle angles in the sagittal plane
- Temporal Parameters of Stride time, Step time and Cadence

2 Methods and Materials

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 6 meters walking at a subject-comfortable speed. The standing position has been useful to remove the angular offset between the two systems. This offset is due to the different calibration procedures applied by both systems. They repeated this test 10 times.

MOVIT® TECHNOLOGY

Figure 2. IMUs technolgy Movit System G1 (by Captiks Srl, Rome, Italy)

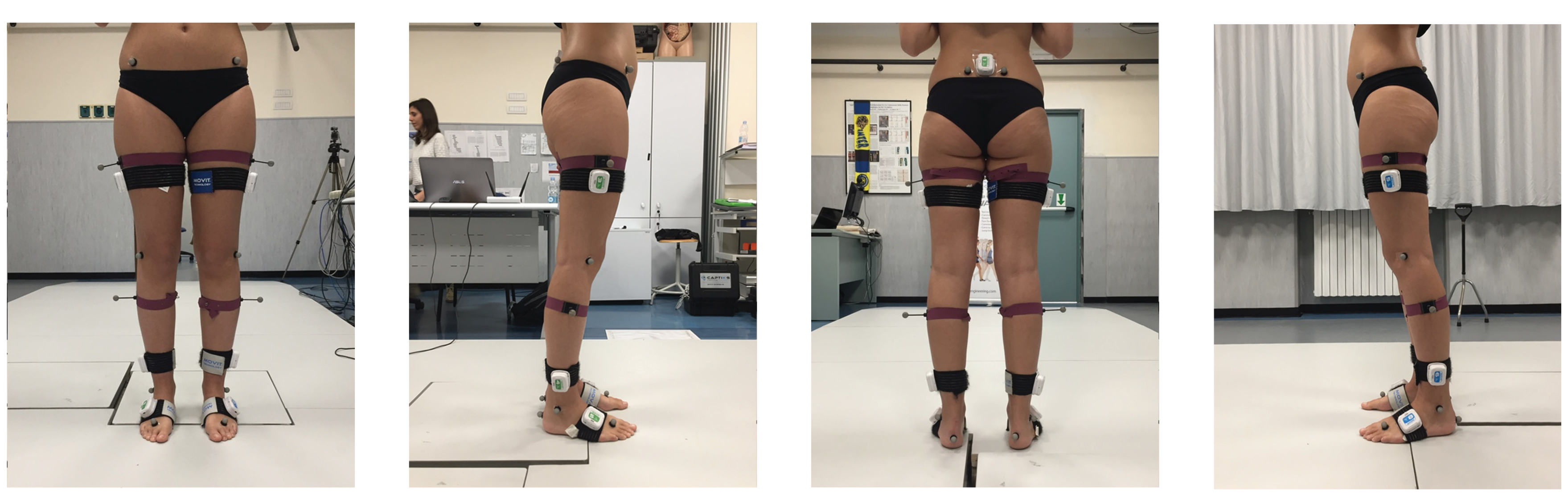

Figure 3. Typical subject setup with Movit sensors and markers in frontal, lateral and back positions

3 Results and Conclusions

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) and the absolute error (ε) and the absolute percentage error (ε%) of Stride Time, Step Time and Cadence (Table 2) .

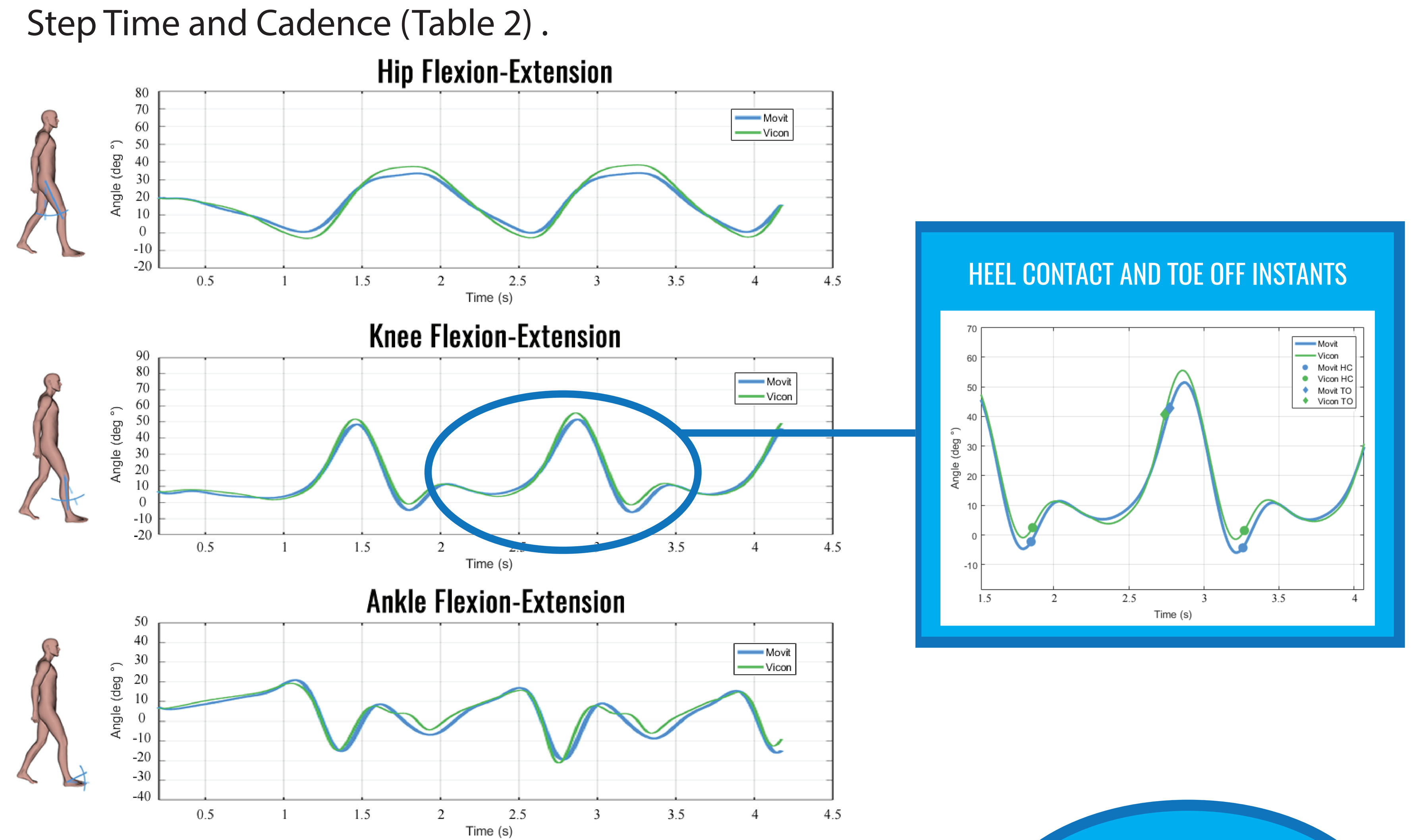

Figure 4. Comparison of Movit and Vicon ROMs for Hip, Knee, Ankle Flexion Extension angles

Range of Motion	RMSE(°)	Pearson Coefficient
PELVIS TILT	1.75 ± 0.66	0.752 ± 0.231
PELVIS LATERAL BENDING	1.15 ± 0.23	0.934 ± 0.030
PELVIS ROTATION	1.28 ± 0.37	0.941 ± 0.033
HIP FLEXION-EXTENSION	3.14 ± 0.59	0.993 ± 0.004
KNEE FLEXION-EXTENSION	3.06 ± 0.58	0.990 ± 0.004
ANKLE FLEXION-EXTENSION	2.86 ± 1.08	0.948 ± 0.045

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

< 3.1°
EXCELLENT RMSE

0.99
EXCELLENT PEARSON COEFFICIENT

Temporal Parameters	Absolute Error (ε)	Absolute Percentage Error (ε%)
STRIDE TIME (s)	0.01 ± 0,01	0.99 % ± 0.88 %
STEP TIME (s)	0.01 ± 0,01	1.62 % ± 1.59 %
CADENCE (Steps/Min)	0.91 ± 0.81	0.98 % ± 0.86 %

Table 2. Mean and Standard Deviation of Absolute Error (ε) and Absolute Percentage Error (ε%) of Temporal Parameters

< 2 %
EXCELLENT PERCENTAGE ERROR

As a conclusion, the Movit system G1 highly performed in terms of measurement accuracy. The ROMs error was found always smaller than 3.1°, which is considered as an excellent result according to [2]. In addition, the Pearson coefficient was higher than 0.93 for all ROMs, that is, an excellent result, except for pelvis tilt, that is, a good acceptability [2]. Regarding the temporal parameters all the percentage errors, ε%, are less than 5%, which demonstrate an excellent accuracy [3].

4 References

[1] Cuesta-Vargas AI, et al. Physical Therapy Reviews 2010;15 (6):462-473.
[2] Poitras I, et al. Sensors 2019;19(7): 1555.
[3] Fusca M, et al, Appl. Sci. 2018; 8(7): 1167.

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