Accuracy of a multi-sensor system in stride parameters estimation: comparison of straight and curvilinear portions

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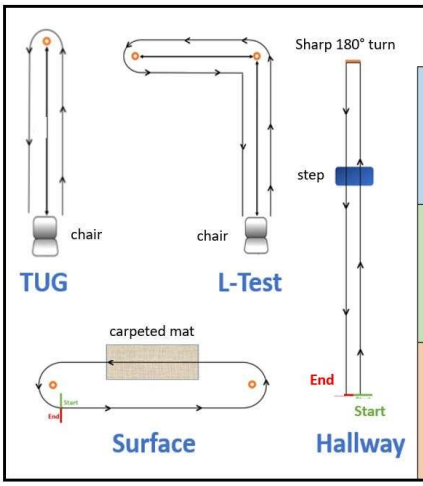
INTRODUCTION

The evaluation of gait performances in free-living conditions requires the adoption of wearable devices to step out of the laboratory. With this aim, researchers are focusing their attention on the development of technologies and algorithms to estimate the relevant digital mobility outcomes with the same level of accuracy and robustness reached in standardized environments. When analyzing real world walking, it is fundamental to discriminate between straight and curvilinear portions. This because specific analysis of curvilinear walking can be informative of turning impairments in pathological populations [1]. This work deals with the evaluation of performances of a wearable multi-sensor system (INDIP) against the stereophotogrammetric (SP) system in the estimation of stride-related variables for both straight and curvilinear portions.

METHODS

The INDIP system includes three inertial measurement units (IMUs, fs=100 Hz, lower back and feet), two plantar pressure insoles (PI, 16 sensing elements, fs=100 Hz) and two time-of-flight distance sensors (fs=50 Hz) [2]. Experiments were carried out on 20 healthy participants (12 males, age 29.4±9.4 years) while performing four motor tests (Fig. 1). Data were processed according to the following steps: (i) static/dynamic activity periods recognition; (ii) PI-based gait events detection; (iii) spatial variables computation from feet-IMUs; (iv) stride identification and selection; (v) walking bouts identification; (vi) turning portions recognition from lower back IMU [2] and distinction between straight and curvilinear strides; (vii) parameters estimation including stride duration, stride length. For each parameter, accuracy was evaluated for each test in terms of Bias and standard deviation (STD) and mean absolute percentage error (MAE%).



DMO	Tests	MAE %		Bias (STD)	
		Straight	Curves	Straight	Curves
Stride duration (ms)	TUG	3.2	2.6	-17 (30)	1 (31)
	L-Test	1.3	1.3	-8 (16)	1 (21)
	Surface	1.3	1.2	-10 (18)	0 (19)
	Hallway	1.8	3.1	-5 (30)	4 (35)
Stride length (mm)	TUG	3.6	9.4	-6 (60)	5 (114)
	L-Test	3.4	5.3	4 (52)	17 (73)
	Surface	3.7	4.3	11 (60)	24 (60)
	Hallway	4.3	15.8	10 (71)	12 (154)
Stride speed (mm/s)	TUG	5.7	8.8	17 (50)	7 (114)
	L-Test	3.7	5.2	12 (49)	15 (61)
	Surface	3.9	4.3	20 (50)	20 (51)
	Hallway	4.5	16.8	11 (61)	-2 (135)

Figure 1. Overview of the tests and results obtained from the INDIP system.

RESULTS

Results averaged over subjects are presented in Fig.1.

DISCUSSION

Results showed that, for stride duration, the errors are very limited and similar for both straight and curvilinear strides (MAE%: 1.3%-3.2%). For both stride length and speed, errors are always higher in case of curvilinear strides. Smaller errors were observed for those tests such as L-Test and Surface test show which include more progressive and smooth turns. Larger errors observed for the TUG and the Hallway tests can be ascribed to the limited length of the walking portions and the presence of 180° sharp turn. Future developments include the extension of this analysis to free-living conditions, including both healthy participants and patients affected by different mobility impairments.

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REFERENCES

[1] M. Bertoli, et al. *Gait & Posture* 2019; 74: 187-193.
[2] F. Salis, et al., *GNB Conference*, 2020.
[3] M. El Gohary, et al., *Sensors* 2014; 14(1): 356-369.