Validating a method for the estimate of gait spatio-temporal parameters with IMUs data on healthy and impaired people from two clinical centers

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INTRODUCTION

Instrumented gait analysis offers objective clinical outcome assessment [1]. To this purpose, inertial measurement units (IMUs) represent nowadays a very effective solution due to their limited cost, ease of use and improved wearability. The aim of this study was to apply a well-documented IMU-based method to measure gait spatio-temporal parameters in a large number of healthy and gait-impaired subjects, and evaluate its robustness and validity across two clinical centers.

METHODS

Ninety-two participants (34 healthy elderly and 58 with either Parkinson's disease or mild cognitive impairment) were recruited within the EU-funded V-TIME project by two clinical centers (University of Genova-UNIGE, 50 participants, and the Katholieke Universiteit Leuven-KULEU, 42 participants). Each subject performed two gait trials of one minute each, at comfortable (C) and fast (F) speed. Subjects walked on an instrumented mat (GAITRite) used as gold standard (GS) while wearing two IMUs (Opal, APDM, 128Hz) above the ankles. The method proposed in [2] was used to identify the gait events (GE) and to estimate relevant spatio-temporal parameters. For each left and right gait cycle, the difference between IMUs estimates and GS values was computed (error). Error mean value and its standard deviation (sd), as well as the mean absolute error (MAE), were computed over the entire gait trial.

RESULTS

8648 gait cycles were analyzed, and no extra or missing GE were found. The errors in determining the GE and the selected spatio-temporal parameters are reported in Table 1. Errors were similar between the two clinical centers. IC MAEs were in general half the size of the FC MAEs. Temporal parameter MAEs were always below 30 ms. In particular, stride and step duration MAEs were well below 15 ms, with a mean error close to 0. Stride length MAEs were below 30 mm and showed a limited underestimation (mean error<0).

Table 1. Errors in determining the GE (Initial Contact, IC, and Final Contact, FC) and the gait spatio-temporal parameters.

			IC [ms]		FC [ms]		Stride Duration [ms]		Stance Duration [ms]		Swing Duration [ms]		Step Duration [ms]		Stride Length [mm]	
			UNIGE	KULEU	UNIGE	KULEU	UNIGE	KULEU	UNIGE	KULEU	UNIGE	KULEU	UNIGE	KULEU	UNIGE	KULEU
mean error (sd)	C	healthy	3 (9)	1 (8)	-9 (11)	-7 (13)	0 (12)	0 (11)	-12 (15)	-8 (16)	12 (15)	8 (16)	0 (13)	0 (12)	0 (21)	-7 (20)
		impaired	11 (11)	6 (9)	-10 (14)	-12 (14)	0 (16)	0 (13)	-21 (19)	-18 (19)	21 (19)	18 (18)	0 (17)	0 (14)	-2 (21)	-5 (18)
	F	healthy	6 (9)	3 (8)	-9 (10)	-8 (10)	-1 (12)	0 (10)	-16 (15)	-11 (14)	15 (15)	11 (14)	0 (13)	0 (12)	-6 (20)	-6 (21)
		impaired	10 (10)	6 (10)	-8 (14)	-9 (14)	0 (14)	0 (13)	-18 (18)	-14 (17)	18 (19)	15 (18)	0 (15)	0 (15)	-4 (31)	-4 (21)
MAE	C	healthy	10	8	22	24	10	9	26	26	26	26	10	10	21	24
		impaired	15	12	20	20	12	10	29	26	29	26	14	11	23	20
	F	healthy	11	9	21	21	10	8	25	24	25	24	11	9	18	28
		impaired	14	11	19	18	11	10	27	21	27	22	12	12	24	20

DISCUSSION

All the parameters showed similar or lower errors compared to previous results for both centers [2]. Mean error and MAE values were very consistent between centers, and similar for C and F trials. Stride and step durations MAE values resulted of the same order of magnitude as the IMU system nominal accuracy. Stance and swing durations were respectively underestimated and overestimated due to a late IC identification and an early FC identification. When averaged, stride length estimation was extremely accurate, however showing some residual inaccuracies in individual cycle estimation (sd values not negligible). Overall, the results of this work represent a robust and reliable foundation for the clinical use of the proposed IMU based method for gait parameters estimation.

REFERENCES

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