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WALKINSENSE VALIDATION: PRELIMINARY TESTS OF MOBILITY PARAMETERS

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The purpose of this study was to perform a preliminary validation of a new electronic instrument for human movement and performance assessment in sports. Measurements of distance, walking speed, step length and frequency were acquired, for a small sample of 15 subjects in a track of 10 m length, and compared to reference data. Results show good repeatability and data agreement across several trials at three different self-selected walking speeds.

KEY WORDS: gait parameters, repeatability, measurement agreement.

INTRODUCTION: In the field of physical activity and sports monitoring, we are currently witnessing a shift in the paradigm for the assessment of human movement and performance. Empowered by the fast paced development of portable and wearable technology, research in this field can now take place in real life scenarios, under everyday and long term conditions, as opposed to short term, laboratory or otherwise controlled experiments.
This trend towards the use of wearable monitoring and recording equipment, seamlessly attached to the human body, allows effortless data capturing without disturbance or discomfort to the subject under observation (Pantelopoulos and Bourbakis, 2010). However, for these equipments to be widely accepted as research or clinical tools, they have to be validated against well known and established methods and instruments (Bland and Altman, 1986).
WalkinSense® is one such type of equipment designed for activity monitoring, combined with foot pressure evaluation and analysis of gait parameters. While many systems are available for each one of those assessments individually, the former combines all three capabilities in a single fully autonomous portable lightweight unit with accompanying analysis software. Amidst several other parameters, it provides effective measures of traveled distance, average speed, step length and frequency, together with foot pressure trends during gait cycles for extended periods of time, which can span several days of activity. Finding usefulness in the field of lower limb prophylaxis and rehabilitation, its suitability for performance assessment in sports such as athletics, football or golf, among others, is the main concern of this work.
The main purpose of this study was to perform a preliminary validation of the WalkinSense® equipment, under controlled conditions and evaluate its repeatability on several gait parameters, as well as on the accuracy of the distance measure with respect to ground truth data. Related studies evaluating similar gait parameters can be found in the literature. Al-Obaidi et al. (2003) compare the basic gait parameters of normal subjects from Kuwait with a similar group of subjects from Sweden, following a previous study reported by Öberg et al. (1993).

METHODS: This study was approved by the local ethical committee.
Participants: The sample of convenience included fifteen participants, eleven male and 4 female, all of them students enrolled at the University that hosted the study. All participants were healthy and physically active and did not have any gait impairments. The participants were on average 20.1 (±5.5) years old, with height and body mass of 1.70 (±0.083) m and 67.8 (±11.2) kg, respectively.

Instruments: WalkinSense® (Tomorrow Options SA, Porto, Portugal) is a CE Mark class I electronic medical device designed to dynamically monitor human lower limbs activity. It gathers and processes quantitative and qualitative information and sends it to a computer, laptop or palmtop computer via wireless Bluetooth® connection or wired USB cable to be analyzed with the WalkinSense® software (Tomorrow Options SA, Porto, Portugal). The device contains MEMS triaxial accelerometer and gyroscope and an array of eight force sensing resistors for foot pressure measurements. The device can operate in two modes, the offline recording mode that allows data capturing for several days, and the real-time mode that can acquire data at 100 Hz and send it directly to a computer with the WalkinSense® software using the Bluetooth connection. For this validation study, we chose the real-time mode to have the detailed data, in order to perform a more complete statistical analysis.
Experimental protocol: Firstly, the procedures were explained to each participant, then anthropometrics data were obtained, followed by a familiarization period. The tests were carried out in a gym where the beginning and end of a track was marked on the floor over a ten meter distance. Each participant performed six tests: in the first two, subjects were asked to walk at a normal self-selected speed, in the third and fourth tests at a slow self-selected walking speed and the last two tests were performed with a fast self-selected speed.
The participants began the test one step before the start mark, since the device excludes the first step, and stopped over the end mark. During the test, the participants were asked to look forward and to walk as naturally as possible.
Data analysis: For data acquisition and recording, we used the WalkinSense® software. A data set with a total of 90 trials was recorded (six tests of fifteen participants). Four temporal gait parameters were analyzed: gait distance, average speed, step frequency and step length. The last three parameters were calculated considering only the three central steps at mid distance in the track.
Statistical analysis: To verify intra-individual repeatability for all variables the intra-class correlation coefficient (ICC) was calculated for all tests (n = 90). The results are presented as mean, standard deviation and confidence interval; these statistical procedures were conducted using SPSS (v.17; SPSS Inc, Chicago, IL, USA).
Aiming to compare the distance data provided by the WalkinSense® equipment with the track length (10 m), we used the method proposed by Bland and Altman (1986), where the difference between every test and the track distance was analyzed.
For the calculation of sample size to a future definitive validation study we used the SYSTAT (v.12; Cranes Software International, Chicago, IL, USA) software.

RESULTS: Table 1 shows the mean, standard deviation, confidence interval and ICC for all studied mobility variables and the values found by Al-Obaidi et al. (2003) for average speed, step length and frequency. It is noteworthy the high ICC values obtained for all the studied variables. Regarding the distance, we notice that a value much closer to the target value is recorded for faster walking. Figure 1 presents the comparison between gait distance data measured by WalkinSense® and the track length. Using a limit of two standard deviations, 96.3% of the measured gait distance data are in the “limits of agreement”, indicating a good capability of the device to perform gait distance measurements.
Additionally, we used the standard deviation of the gait distance data of this preliminary study to calculate the sample size required for a future extended validation study. For that future purpose, the number of 50 participants was obtained in order to provide a statistical power of 95% with an alpha error level of 5%.

DISCUSSION: According to the values of ICC for all variables, it appears the data provided by the device are consistent and display good repeatability. With regard to the distance data, accuracy seems to improve for higher speeds, showing a relative error of -6.8% at the lower speed against only -1.6% for the higher speed in the 10 m track. This underestimation of the mean distance may be due to the subjects' inaccuracy to step on the beginning and ending marks of the 10 m track. These relative errors would have much less significance for longer tracks.

Table 1
Mean, standard deviation (SD), lower and upper confidence interval, intra-class coefficient correlation (ICC) of the variables and larger and lower values found by Al-Obaide et al. (2003)

			Confidence Interval			Al-Obaidi et al. (2003)	
Variables		**Mean (SD)**	**Lower**	**Upper**	**ICC**	**Larger mean**	**Lower mean**
	Slow	0.82 (0.20)	0.74	0.90		0.80 (0.16)	0.84 (0.20)
Average Speed	*Normal*	1.20 (0.18)	1.13	1.26	0.98	1.08 (0.15)	1.24 (0.17)
(m/s)	*Fast*	1.67 (0.16)	1.61	1.73		1.56 (0.14)	1.81 (0.22)
	Slow	1.40 (0.16)	1.34	1.46		1.42 (0.19)	1.59 (0.20)
Step frequency	*Normal*	1.75 (0.15)	1.70	1.80	0.99	1.73 (0.15)	2.08 (0.15)
(Steps/s)	*Fast*	2.04 (0.17)	1.97	2.10		2.18 (0.27)	2.56 (0.25)
	Slow	0.59 (0.19)	0.56	0.62		0.52 (0.07)	0.57 (0.06)
Step length	*Normal*	0.68 (0.07)	0.66	0.70	0.96	0.59 (0.06)	0.70 (0.07)
(m)	*Fast*	0.84 (0.07)	0.81	0.86		0.67 (0.06)	0.83 (0.07)
	Slow	9.32 (1.47)	8.71	9.93		—	—
Gait Distance	*Normal*	9.53 (0.60)	9.31	9.75	0.88	—	—
(m)	*Fast*	9.84 (0.58)	9.61	10.01		—	—

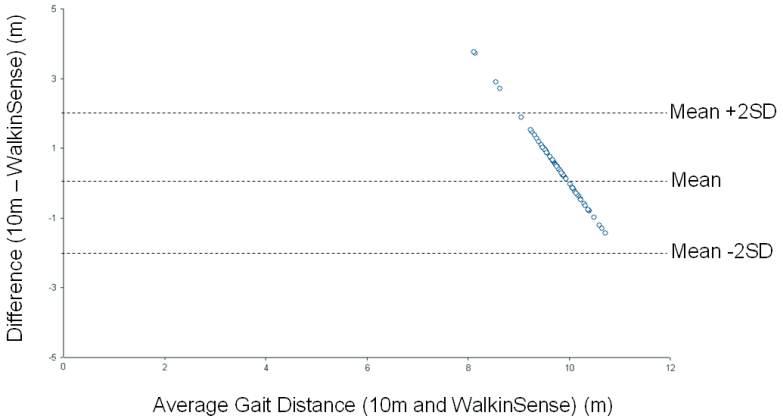

Figure 1: Comparison between gait distances measured by WalkinSense® and the track length using method proposed by Bland and Altman (1986).

For the walking speeds, step lengths and frequencies presented in Table 1 no ground truth data was available for this preliminary study. However, when comparing with reference data obtained by Al-Obaidi et al. (2003) for the same gait parameters of men and women aged between 20 and 29 years of Kuwait and Scandinavia, one can observe that our results fall well within the same limits, considering data for the average walking speed, step length and frequency (see Table 1). The results of the present study could only be more similar if there was a better match between the subjects age and separated by gender.
The limitations and issues identified on this preliminary study will be properly addressed and resolved on a follow up and more extended validation work.

CONCLUSION: This preliminary study, for the validation of WalkinSense® as an instrument for human movement and performance assessment in sports, allowed us to obtain consistent data with good repeatability across all the mobility parameters analyzed. The distance measurements, in particular, showed good accuracy and agreement with ground truth data for the ten meter track. Notwithstanding, several limitations were identified, such as the sample size and the reduced number of trials, as well as the lack of ground truth for the other parameters (average walking speed, step length and frequency). This study will be followed for a more extended validation work with a larger sample of subjects. Also, it will include a comparison of WalkinSense® measurements with other gold standard or well established methods following the guidelines that were set with this preliminary validation.

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