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Reliability and accuracy of spatial–temporal gait parameters measured by the WalkinSense®

Ana Querido[1], Marcelo P Castro[1], João Paulo Vilas-Boas[1,2], Rui Corredeira[3], Daniel Daly[4] and Ricardo J Fernandes[1,2]

Abstract

The WalkinSense® is a relatively new device designed to monitor walking exercise. The purpose here was to assess its reliability and accuracy when analysing spatial–temporal gait parameters. Forty-two young adults performed 3 × 400 m walking at moderate intensity on a 400-m standard track, using both the WalkinSense and a pedometer. The between-trial reliability was excellent for all variables, with intraclass correlation coefficient values ranging from 0.90 to 0.98. The absolute and percentage differences between the WalkinSense and the track length were (mean ± standard deviation) −36.7 ± 45.0 m (95% confidence interval: −44.6, 28.6) and 9.2 ± 11.3% (95% confidence interval: −11.2, 7.2), respectively. The absolute and percentage differences between the WalkinSense and the pedometer for number of strides were 0.7 ± 10.5 strides (95% confidence interval: −1.2, 2.6) and 0.1 ± 4.0% (95% confidence interval: −0.7, 0.8), respectively. The WalkinSense system showed excellent reliability for assessing spatial–temporal gait parameters. Considering accuracy, users should be aware of the limitations of the device, which in this study ranged between −0.7% and 0.8% and between −11.2% and 7.2%, for number of strides and travelled distance, respectively.

Keywords

WalkinSense®, gait analysis, pedometer, physical activity, sports medicine

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Introduction

The WalkinSense® (Tomorrow Options SA, Sheffield, UK) assesses physical activity and plantar pressures during walking and running. This device provides information on travelled distance, average speed, stride length and frequency and duration of the activity and plantar pressures on eight foot regions for periods up to several days.[1,2] It is useful in the field of sports medicine as it monitors the levels of physical activity and provides information to aid prevention and rehabilitation of lower limb–related injuries.

Before a device is used in clinical or research contexts, it should demonstrate acceptable reliability (difference between two or more measurements using the same instrument under the same testing conditions) and accuracy (difference between the values of a known quantity – reference standard – and that measured by the new device).[3] Although classification criteria for determining reliability are straightforward,[4] the level of accuracy usually depends on the application of the device.

The plantar pressure parameters recorded by the WalkinSense showed acceptable reliability and accuracy,[2,5] but only one preliminary study addressed the reliability of spatial–temporal gait parameters.[1] Castro et al.[1] obtained consistent data with good reliability across all spatial–temporal gait parameters analysed.

The purpose of this study was to assess the reliability and accuracy of the spatial–temporal gait parameters acquired by the WalkinSense. We hypothesized that (1) the WalkinSense would show good to excellent

[1]Centre of Research, Education, Innovation and Intervention in Sport, Faculty of Sport, University of Porto, Porto, Portugal
[2]Porto Biomechanics Laboratory, University of Porto, Porto, Portugal.
[3]Research Centre in Physical Activity, Health and Leisure, University of Porto, Porto, Portugal
[4]Department of Kinesiology, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Leuven, Belgium

Corresponding author:
Ricardo J Fernandes, Faculty of Sport, University of Porto, Rua Dr. Plácido Costa, 100, 4200.450 Porto, Portugal.
Email: ricfer@fade.up.pt

between-trial reliability for the measured parameters, and (2) the WalkinSense would show values of accuracy (with 95% confidence interval ($CI_{95\%}$)) better than 10% in measuring distance travelled and number of strides.

Research methods

Participants

Based on the mean and standard deviation (SD) of travelled distance from a previous study,[1] a minimum of 39 participants were needed for comparisons between WalkinSense and a reference standard accepting an alpha error level of 1% and a beta error level of 20%. Forty-two young adults (21 from each gender), age (mean ± standard deviation) 23.9 ± 3.9 years, height 1.70 ± 0.09 m and body mass of 66.3 ± 9.7 kg, were recruited. Anthropometric parameters were recorded for participants' characterization and have not impacted on the results. Exclusion criteria were any traumatic-orthopaedic impairment, pain or difficulty with independent gait. This study was approved by the local ethical committee, and all participants gave their written consent.

Equipment

The WalkinSense (weight, 68 g; length, 78 mm; width, 48 mm; and depth, 18 mm) is a CE Mark class I electronic medical device designed to dynamically monitor human lower limb activity. It gathers and processes quantitative information, sending it to a fixed laptop or palmtop computer, via wireless Bluetooth connection or wired USB cable, to be analysed with the WalkinSense software (Tomorrow Options SA). The device contains a microelectromechanical system triaxial accelerometer and one gyroscope and an array of eight force sensing resistors for foot pressure measurements. Distance is calculated from the triaxial accelerometer and gyroscope, by a sensor fusion algorithm based on an extended Kalman filter with a velocity zero update at each cycle. Simultaneously, a commercially available electronic pedometer, the Omron Walking-Style II (HJ-113-E; Omron Healthcare Co., Kyoto, Japan), previously shown to be an accurate and reliable device,[6–10] was used for comparison.

Protocol

All participants performed three trials on a 400-m running track in a single session. The WalkinSense was attached over the anterior-inferior surface of the right tibia, and the pedometer was attached at the lateral (right) surface of the coxal region, between the greater trochanter of femur and iliac crest. After measuring body mass and height, participants familiarized themselves with the WalkinSense and pedometer by walking a short distance (30 m). Afterwards, each participant walked 3 × 400 m at a self-selected gait speed.

Data analysis and statistics

Six spatial–temporal gait parameters were analysed: duration, number of strides, travelled distance, mean speed, stride length and stride frequency (see Table 1).

All statistical analyses were performed using the SPSS v.17 software (SPSS Inc, Chicago, IL, USA), and descriptive statistics were presented.

Reliability. For assessing the reliability of the WalkinSense, the two-way mixed model (type: consistency) intraclass correlation coefficient (ICC) was used and the between-trial reliability (three trials) for each spatial–temporal gait parameter was calculated. An ICC of $\leqslant 0.69$ was poor; 0.70–0.79, fair; 0.80–0.89, good; and $\geqslant 0.90$, excellent.[4]

Accuracy. The accuracy of the WalkinSense in measuring two parameters was assessed: travelled distance and number of strides. Track length (400 m) was the reference for distance, while the pedometer was the reference for stride count. The absolute and percentage differences, and $CI_{95\%}$ between the travelled distance recorded by the WalkinSense and the track length, as well as for stride count of the WalkinSense and the pedometer, were calculated. For the travelled distance, 5% difference intervals around the 400 m were also assessed. Bland–Altman plots were also constructed using GraphPad Prism 6.

Results

Reliability

The between-trial reliability was excellent for all parameters with ICC values ranging from 0.90 to 0.98 (Table 2).

Table 1. Definition of the six spatial–temporal gait parameters analysed by the WalkinSense®.

	Description
Duration (s)	Time to complete one trial
Strides (strides/trial)	Number of strides, that is, two successive placements of the same foot, for each trial
Travelled distance (m)	Distance recorded during each trial
Average speed (m/s)	Speed recorded during each trial
Stride length (m)	Average length of all strides from each trial
Stride frequency (stride/min)	Number of strides per minute

Table 2. Mean, SD, ICCs and $CI_{95\%}$ for all variables recorded by the WalkinSense® and for the comparative instrument.

Variables	Mean	SD	ICC	$CI_{95\%}$
Duration (s)	268.0	27.0	0.96	0.93–0.98
Strides (strides/trial)	264.4	18.9	0.90	0.84–0.94
Strides pedometer (strides/trial)	265.1	20.3	0.95	0.91–0.97
Distance (m)	363.3	45.0	0.96	0.94–0.98
Average speed (m/s)	1.4	0.2	0.97	0.94–0.98
Stride length (m)	0.8	0.1	1.00	0.99–1.00
Stride frequency (stride/min)	59.1	3.4	0.98	0.96–0.99

SD: standard deviation; ICC: intraclass correlation coefficient; $CI_{95\%}$: 95% confidence interval.

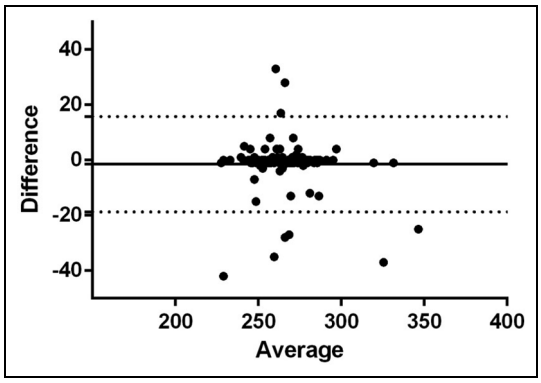

Figure 1. Bland–Altman plot of comparison between the WalkinSense® and the pedometer. Average difference line (solid line) and 95% CI (dashed lines) are indicated.

Accuracy

The absolute and percentage differences between the travelled distance obtained by WalkinSense and the true distance of the track were -36.7 ± 45.0 m ($CI_{95\%}$: −44.6, 28.6) and $-9.2 \pm 11.3\%$ ($CI_{95\%}$: −11.2, 7.2), respectively. For stride count, the absolute and percentage differences between the WalkinSense and pedometer were 0.7 ± 10.5 strides ($CI_{95\%}$: −1.2, 2.6) and $0.1 \pm 4.0\%$ ($CI_{95\%}$: −0.7, 0.8), respectively.

The Bland–Altman plot of the difference between the WalkinSense and the pedometer are reported in Figure 1. The average difference for stride count was -1.4 ± 8.8 with limits of agreement (95%) from −18.7 to 15.8 (Figure 1). In all, 92% of the tests are inside the limits of agreement.

The interval with the highest frequency of measured travelled distances was 360–379 m (Figure 2). Almost 50% of the measurements (48%) were within the 360–379 m and 380–399 m intervals.

Discussion

This study assessed the reliability and the accuracy of the WalkinSense, and a field experiment was conducted with the participants using the WalkinSense and a pedometer simultaneously. The WalkinSense showed excellent between-trial reliability, supporting our hypothesis. Our hypothesis was also confirmed for accuracy of stride count. A small $CI_{95\%}$ (−1.2%, 2.6%) was found. The hypothesis was not confirmed for travelled distance and the $CI_{95\%}$ (−7.2%, 11.2%) was larger. Users need to analyse findings and decide whether or not this level of accuracy is acceptable for their applications.

The WalkinSense device previously demonstrated excellent reliability and accuracy for plantar pressure parameters similar to other widely used devices (Pedar and FScan).[2,5] Spatial–temporal parameters have received much less attention in the literature.[1] The authors[1] assessed 15 participants using two WalkinSense devices in a 10-m track and good to excellent reliability was found (ICC of 0.88 for travelled distance, 0.98 for gait speed, 0.96 for step length and 0.99 for step frequency). It is important to note that the WalkinSense device presents only stride parameters (i.e. stride length and stride frequency). In the mentioned study,[1] the authors integrated data from two devices to calculate step parameters. In this study, the participants used one WalkinSense device and stride parameters were analysed. It is very likely that reliability values for step and stride parameters are similar. Thus, the results from both studies are in agreement and suggest WalkinSense with good to excellent reliability for spatial–temporal parameters.

With regard to accuracy, this study found a difference of 0.7 ± 10.5 strides between the WalkinSense and the pedometer, considered an accurate device to measure walking strides.[10] A source of error often mentioned is slow walking speeds.[8,11,12] Several studies reported the accuracy of pedometers[9,10,13] at similar self-selected speeds to this study (1.4 m/s). Crouter et al.[6] observed the mean values for stride count that were within 1% of the real number of strides which is similar to our result.

The accuracy of the WalkinSense for measuring travelled distance is less good. This is in agreement with observations for other devices, such as pedometers, that are more accurate in counting strides and less accurate in calculating travelled distance.[7] The body attachment position may have contributed to the underestimation of travelled distance.[14] According to Fujiki et al.,[15] the ankle is affected by complex rotational components, along with the impact from the ground, probably influencing the final findings. The stride length values were also smaller than expected, but it was not the aim of this study to assess the accuracy of this parameter.

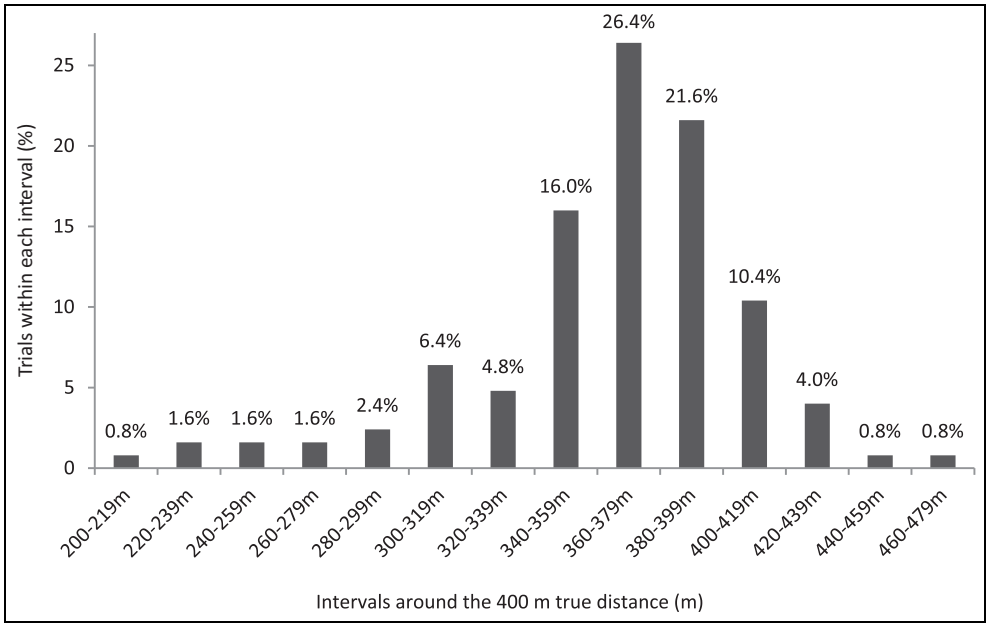

Figure 2. Percentage of trials for each 5% intervals of the true distance (400 m) with the WalkinSense®.

There are several study limitations to consider: (1) only between-trial within-session reliability was analysed, (2) only the accuracy of two spatial–temporal gait parameters was explored and (3) the test could have been video recorded to confirm stride count afterwards. However, this limitation is minimized as previous studies found good reliability and accuracy for pedometers.[6–13] We suggest future studies using WalkinSense: (1) the between-session reliability of spatial–temporal and plantar pressure parameters; (2) the accuracy for duration, average speed, stride length and frequency; and (3) the influence of walking and running speed on the reliability and accuracy of the device.

Conclusion

The WalkinSense system showed excellent within-session reliability for spatial–temporal gait parameters and accurate values for stride count. However, as substantial differences between the travelled distance recorded by this apparatus and the true distance were observed, users should be aware of errors with $CI_{95\%}$ between −11.2% and 7.2%.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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