Health Policy and Technology 9 (2020) 102–108

Contents lists available at ScienceDirect

Health Policy and Technology

journal homepage: www.elsevier.com/locate/hlpt

Viewpoint Paper

Validation of a self-implemented Walkway system for gait speed measurement in usual clinical care

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ARTICLE INFO

Article history:
Available online 19 November 2019

Keywords:
Gait speed
Walkway system
Validation
Functional assessment

ABSTRACT

Objectives: Validation of an infrared healthcare technology aimed at measuring gait speed in older adults.

Design: Validation study.

Setting: Geriatric Department

Participants: 90 patients from the Falls Unit of the Geriatrics Department for the validation assessment, and 5,328 patients of the Outpatient Clinic under usual care conditions for technology validation.

Measurements: Walking speed was measured manually with a stopwatch as part of the Short Physical Performance Battery (SPPB), using the GAITRite™ (first, second and mean of 5 walks) and with the Walkway system. Agreement was determined with the Bland-Altman method.

Results: Mean gait speed with the SPPB, GAITRite™ (first, second and mean of 5 walks) and Walkway were 0.68 m/s, 0.77 m/s, 0.81 m/s, 0.71 m/s, and 0.70 m/s respectively. Pearson correlations between the Walkway system and SPPB, GAITRite™ first walk, GAITRite™ second walk, and GAITRite™ mean of 5 walks were 0.822 ($p < 0.001$), 0.810 ($p < 0.001$), 0.824 ($p < 0.001$), and 0.811 ($p < 0.001$) respectively. The mean difference between the Walkway system and SPPB was 0.02 m/s and 95% of the values were between 0.29 and −0.26. Mean difference between Walkway system and GAITRite™ second walk gait speed was −0.11 and 95% values were between 0.17 and −0.38. Mean walking speed in 5382 outpatients was 0.65 m/s (range 0.13–1.43; 95%CI 0.6453–0.6568). No security problems or technical measurement errors were found using the Walkway system.

Conclusions: The Walkway system presented is a valid, easy-to-use, self-implemented device for walking speed measurement in usual clinical practice with older adults.

Introduction

Walking speed is currently one of the most important elements in health assessment of older adults; even some authors consider it a functional vital sign [1]. Walking speed is associated with adverse events in this population [2] like all-cause mortality [3–6], cognitive impairment [7–9], risk of institutionalization [10], disability [11,12], poor health status [13], and falls [14]. Slow walking speed is also one of the most important elements of the frailty phenotype [15], and some authors consider it a possible summary indicator of this geriatric syndrome [16–18]. Cut-off values for walking speed are used as a screening method to identify older adults at risk of some of the aforementioned health outcomes, and are being used for clinical decision-making [3,19]. Geriatricians, Family physicians and GPs are advised to measure gait speed in older adults for frailty screening [2,3,14,16,19].

Walking speed is an easy-to-measure physical function measurement that can be assessed in a short time in almost every clinical setting without large training [19]. It is a valid, sensitive,

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https://doi.org/10.1016/j.hlpt.2019.11.006
2211-8837/

and specific measure with high inter-rater and test-retest reliability [20,21]. It can be measured as an individual test [22], or as part of evaluation batteries for older adults such as the Short Physical Performance Battery (SPPB) [23]. Out of the three components of the SPPB (walking speed, balance and chair stands) gait speed has the greater association with disability, with similar diagnostic accuracy compared to the full battery (area under the curve for walking speed 0.67 and for total SPPB 0.69) [24]. Different methodologies for measuring walking speed have been described, and some authors have addressed that the variability in the methodology is believed to affect the implementation of the test and the clinical interpretation of the data [25,26], although others have not [27]. Gait speed analysis can be done at a normal or fast pace, with a dual-task methodology, across different distances, or from a stop or walking position.

Manual measurement using a stopwatch, or a timer are the most common methodologies, but their accuracy may be affected by intra and inter operator variability [28]. Some systems such as the GAITRite™[29], GaitMat II [30], Zeno walkway [31] or Microsoft Kinect for Windows v2 [32,33] include the walking speed as part of the gait assessment, offering more accurate results, although they are very expensive. Smartphones [18], radiofrequency or infrared technologies [34–36, 34] are also among the new technologies, but all of these systems were prototypes and they have not been used in real clinical settings. GAITRite™ offers more information in terms of assessment of complex gait characteristics, such as being able to capture foot patterns and stride variability, but important advantages of infrared lighting are that it does not require floor space, its sensors are be less susceptible to damage in busy clinical spaces such as hospitals, and the costs are much lower.

The hypotheses of our work was that a new electronic non-expensive, easy-to-use, self-implemented walking speed system based in infrared technology could be a valid method for measuring gait speed in older patients attending outpatient clinics, when compared to other usual healthcare assessment methods that are more expensive or with higher inter and intra-rater bias, with similar values and variability as described in previous literature in the domain. Self-implementation and automatic gait speed value incorporation to the electronic hospital database would be helpful in the routine assessment of this important frailty biomarker.

Methods

Design

Validation study of a healthcare technology, an electronic non-expensive, easy-to-use, self-implemented walking speed measurement system based in infrared technology, compared with the GAITRite™ platform and a stopwatch method.

Population study and setting

Participants for the clinical validation analysis were drawn from the Falls Unit of a Geriatrics Department, a specialized Unit for the evaluation, diagnose, management and follow-up of patients with falls and gait or balance disturbances, between June and September 2017, under usual clinical practice. All these patients were referred from the general outpatients clinic of our Geriatric Medicine Department. A total of 90 patients that completed the Falls Unit protocol were included in the validation study. This protocol included assessment of diseases and comorbidities with the Charlson index [37], medications, physical function with the SPPB [23], frailty with Frieds phenotype criteria [15], fear of falling with three validated questions [38], mental status with the Mini Mental State

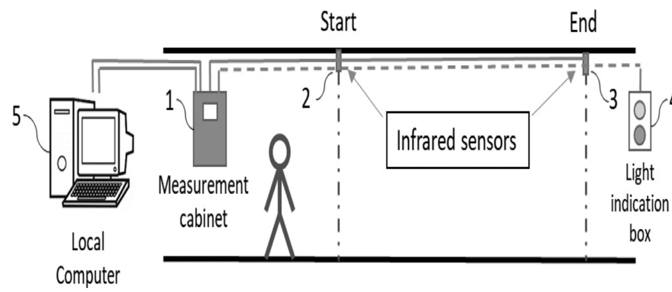

Fig. 1. Walkway operating scheme. It is composed of a measuring cabinet [1] with a computer board, an informative screen and a barcode scanner. Two proximity sensors [2,3] connected to the board, record the start and end of the walk. A specific computer program on the board deals with the signals from the sensors, and calculates the speed. A traffic light indicates the beginning of the test with a green light that switches-off when the test finishes, and displays a red light if the measurement has been inaccurate [4]. The result is communicated to a computer [5] connected to the hospital computer network.

Examination [39], handgrip muscle strength (JAMAR dynamometer), skeletal muscle mass index with bioimpedanciometry (BC-418 Segmental Body Composition Tanita instrument; Tanita, Tokyo, Japan), posturography (Neurocom Balance Master-L; NeuroCom® International, Inc., Clackamas, USA) and GAITRite™ (CIR Systems, Inc, Franklin, NJ, USA), and with this information the patient was given an etiologic diagnosis of falls and recommendations for preventing new ones. Patients were considered frail when meeting three or more frailty phenotype criteria, and having fear of falling when answering yes to at least one of the three questions.

We also present the measurements of the first 5328 patients able to walk attended to our outpatient clinic under usual care conditions between June 2017 and June 2018 that received a gait speed measurement with the Walkway system for frailty screening purposes. This second population, with similar clinical characteristics to the previous one, was used to detect technical problems in real life of the system, and to give information about usual gait speed of patients attending our clinic, but no clinical data were recorded.

Walkway system (video)

The walkway system is described in Fig. 1. The Walkway is 6 m long and 90 cm width. 1.5 m at the beginning is for positioning and walking initiation, 4 central meters for measurement and 1.5 m at the end for deceleration. It is composed of a measuring cabinet [1] with a computer board and an informative screen. Two proximity sensors placed in the ceiling [2 and 3] connected to the board record the start and end of the walk. Sensors are programmed to detect a signal above 1 m high from the ground in order to avoid detecting technical aids like canes or walkers. Moreover, it avoids detecting other persons walking near de walkway. A specific computer program on the board deals with the signals from the sensors, and calculates the speed. Sensors register the time of start and end of the walk in milliseconds. Gait speed (GS) is calculated by dividing the length of the Walkway (L) by the time difference in seconds between start (Tstart) and end (Tend) of the walk: $GS = L / (Tend - Tstart)$. The units of the speed calculation are in m/s.

A traffic light indicates the beginning of the test with a green light that switches-off when the test finishes, and displays a red light if the measurement has been inaccurate [4]. Although the traffic light is big enough, the Walkway has not been validated for patients with severe visual impairment. The result is communicated to a computer [5] connected to the hospital computer network, and is automatically incorporated to the clinical record. This is achieved through a call to the web services of the Healthcare

System that give support to the electronic clinical record. The appointment number is captured by means of a barcode scanner, allowing the person to be identified by consulting data from the central server. A specific computer program is loaded into the computer to receive the scanner data, communicate with the measurement system, and perform queries in the central server databases. The system is protected under the Spanish law By the Spanish Patents and Brands Office of the Spanish Ministry of Energetics, Tourism and Digital Agenda ("Oficina Española de Patentes y Marcas, O.A., Ministerio de Energía, Turismo y Agenda Digital") in the form of "utility model" ES 1216010 and U 201830673 (year CXXXII, Number 5284, Volume II, 22 October 2018, pages 30–31).

Walking speed measurements

For the validation study, participants walked first across the 4-meter walkway system at normal pace, second across the 4-meter GAITRite™ platform (CIR Systems, Inc, Franklin, NJ, USA), and last as part of the SPPB. The GAITRite™ protocol of the Falls Unit included five gait measurements, two at usual pace (the first one was considered training walk), one at fast pace, one at slow pace, and finally one with a dual-task (normal pace, verbal fluency with animals category). To reduce the acceleration and deceleration effect, the first and last steps were removed from the analysis. For validation purposes we considered the first and second usual pace measurement and the mean of the five measurements. Similar methodology has been used in recent studies in order to determine mean walking speed in real-life in older adults [40]. The SPPB walking speed was measured in 4 m following original instructions and was performed twice. Time was measured using a cellphone stopwatch and the fastest time was used for analysis.

Statistics

Continuous variables (gait speed values, Charlson index, number of drugs, weight, height, body mass index, hand grip strength, SPPB, skeletal muscle mass index and number of falls) were presented in the form of means and standard deviations, and categorical variables (sex, frailty, psychotropic use, fear of falling) were presented in percentages. To determine de relationship between walking speed methods, Pearsoń correlation analysis was performed. Agreement was evaluated with the Bland-Altman method. The limits of the normal distribution were defined as ± 2SD. Finally, *t*-test analysis were used to evaluate differences between walking speed measurements. All analyses were performed using IBM SPSS statistics software version 22.

Table 1
Basal characteristics of the sample (n =90).

	n (%)Mean (SD)
Age (years)	78.8 (5.3)
Sex	
Male	29 (32.2)
Female	61 (67.8)
Charlson index	4.2 (1.1)
Drugs number	7.7 (2.9)
Psychotropic drugs use	54 (60)
Weight (kg)	71.5 (12.8)
Height (cm)	155 (9.4)
BMI (Kg/m^2)	29.1 (4.7)
Hand grip strength (kg)	18.2 (9.4)
Frailty	28 (31.1)
Fear of falling	66 (73.3)
Falls number in the last year	1.9 (2.2)
Total SPPB	8.7 (2.4)
SMMI (kg/m^2)	7.2 (1.7)

BMI = Body Mass Index; SPPB = Short Physical Performance Battery; SMMI = Skeletal muscle mass index.

Results

A total of 90 patients were included in the validation study. Mean age was 78.8 years (SD 5.3) and 67.8% were women. The mean Charlson Index was 4.2 points (SD 1.1), the average number of drugs per patient was 7.7 (SD 2.9), 31.1% were frail, and 73.3% had fear of falling. The mean number of falls per patient in the last year was 1.9 (SD 2.2; range 0–12). In the patient's evaluation, the mean SPPB score was 8.7 points (SD 2.4) and the average skeletal muscle mass index measured by bioimpedanciometry was 7.2 kg/m^2 (SD 1.7). Table 1 presents the basal characteristics of the sample and Table 2 the walking parameters measured with the different methods. Although mean and median walking speed measures were higher with the GAITRite™ than with the other methods, variability both measured with the standard deviation or interquartile range were very similar, and skewness and kurtosis values were in the acceptable limits for normal distributions. In addition, Pearson correlations between the Walkway system and SPPB, GAITRite™ first walk, GAITRite™ second walk, and GAITRite™ mean of 5 walks were 0.822 ($p < 0.001$), 0.810 ($p < 0.001$), 0.824 ($p < 0.001$), and 0.811 ($p < 0.001$) respectively.

Agreement between the Walkway system and the other methods was determined with the Bland-Altman method. Taking into account that the Falls Unit protocol evaluated five GAITRite™ walks (two normal walks, one fast walk, one slow walk and one dual-task walk), we considered for this analysis only the second normal walk (the first was considered a training walk). Differences and standard deviations between the Walkway system measurements and the other methods (SPPB and GAITRite™ second walk) were calculated, and a scatter plot between differences against the average of the two measures was constructed. Results are presented in Fig. 2. The mean difference between the Walkway system and SPPB gait speed was 0.02 m/s and 95% of the values were between 0.29 m/s and −0.26 m/s. Mean difference between Walkway system and GAITRite™ second walk gait speed was −0.11 m/s and 95% values were between 0.17 m/s and −0.38 m/s. To determine the accuracy of estimated limits of agreement, a *t*-test analysis did not find differences between the Walkway system and SPPB, but we found a statistically significant difference with the first and second GAITRite™ walks (Table 3).

In Fig. 3 we present the first 5328 measurements that have been conducted at our Outpatients Clinic in real life under usual clinical practice conditions between June 2017 and June 2018. Gait speed measurements do not follow a normal distribution (Kolmogorov–Smirnof $p < 0.001$). Mean walking speed of the patients was 0.65 m/s (SD 0.22), range 0.13–1.43 m/s, 95% CI 0.6453–0.6568 m/s, quartiles 0.50, 0.64 and 0.80 m/s, skew 0.312, kurtosis −0.047. The walkway system did not present security problems in any of the patients, nor technical measurement errors.

Discussion

Our results show that the Walkway system is a valid, easy-to-use, non-expensive self-assessment method to determine walking speed in older patients in a clinical setting. The agreement between the Walkway system and the walking speed measured by SPPB and GAITRite™ was analyzed by the Bland-Altman method. We found differences with the first and second GAITRite™ walks, but not whit the walking speed measured by SPPB and the average of the five walks in the GAITRite™.

Previous studies have reported clinically meaningful differences in walking speed measurements using different methods in community-dwelling older adults, ranging from 0.05 to 0.12 m/s [22,41,42], and changes in gait speed of 0.10–0.20 m/s have

Table 2
Basal walking speed measurements (Validation n =90; Real life n =5328).

	Mean (SD)m/s	Median (IQR)	Min-Max	Skew/Kurtosis
Validation measures (n =90)				
Walkway	0.70 (0.23)	0.65 (0.31)	0.27–1.30	0.597/0.291
GAITRite™ - first walk	0.77 (0.23)	0.79 (0.34)	0.29–1.32	0.170/−0.439
GAITRite™ - second walk	0.81 (0.24)	0.84 (0.34)	0.31–1.34	0.042/−0.540
GAITRite™ - mean of 5 walks	0.72 (0.22)	0.74 (0.31)	0.26–1.24	−0.006/−0.455
SPPB	0.69 (0.23)	0.69 (0.28)	0.23–1.55	0.566/1.458
Real life (n =5328)	0.65 (0.22)	0.64 (0.30)	0.13–1.43	0.312/−0.047

SPPB = Short Physical Performance Battery. SD: Standard deviation. IQR: Interquartile range. Min: lower value. Max: higher value.

Table 3
Association between Walkway, SPPB and GAITRite™ (t-test analysis).

	Mean difference	95% Confidence Interval	p value
Walkway-SPPB	0.014	−0.013 to 0.043	0.30
Walkway-GAITRite™ first walk	−0.071	−0.101 to −0.04	0.00
Walkway-GAITRite™ second walk	−0.107	−0.136 to −0.078	0.00
Walkway-GAITRite™ total	−0.017	−0.045 to 0.011	0.24

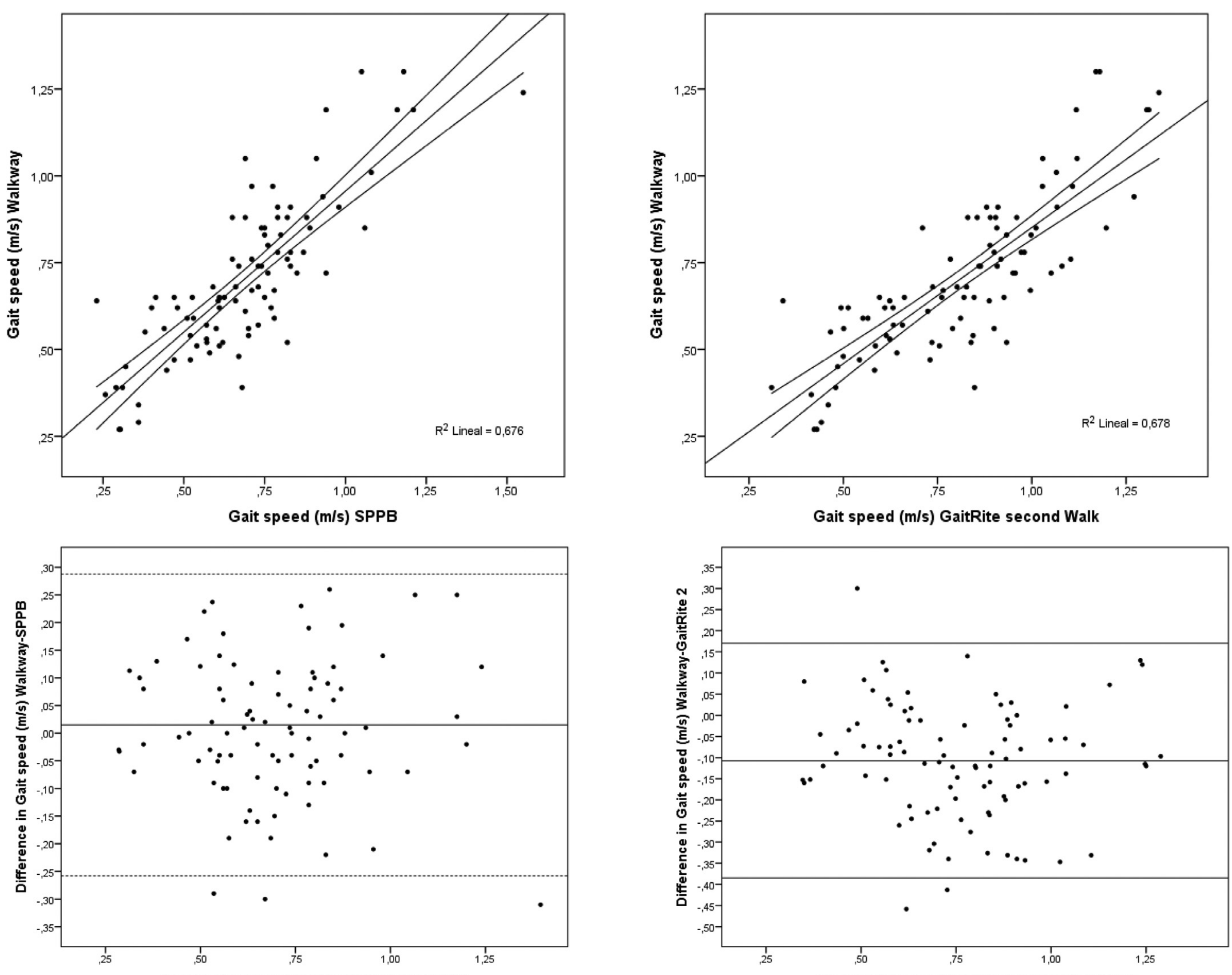

Fig. 2. Scatter plots (A,B) and Bland-Altman plots (C,D) between Walkway-SPPB (A,C) and Walkway-GAITRite second walk (B,D); SPPB: Short Physical Performance Battery.

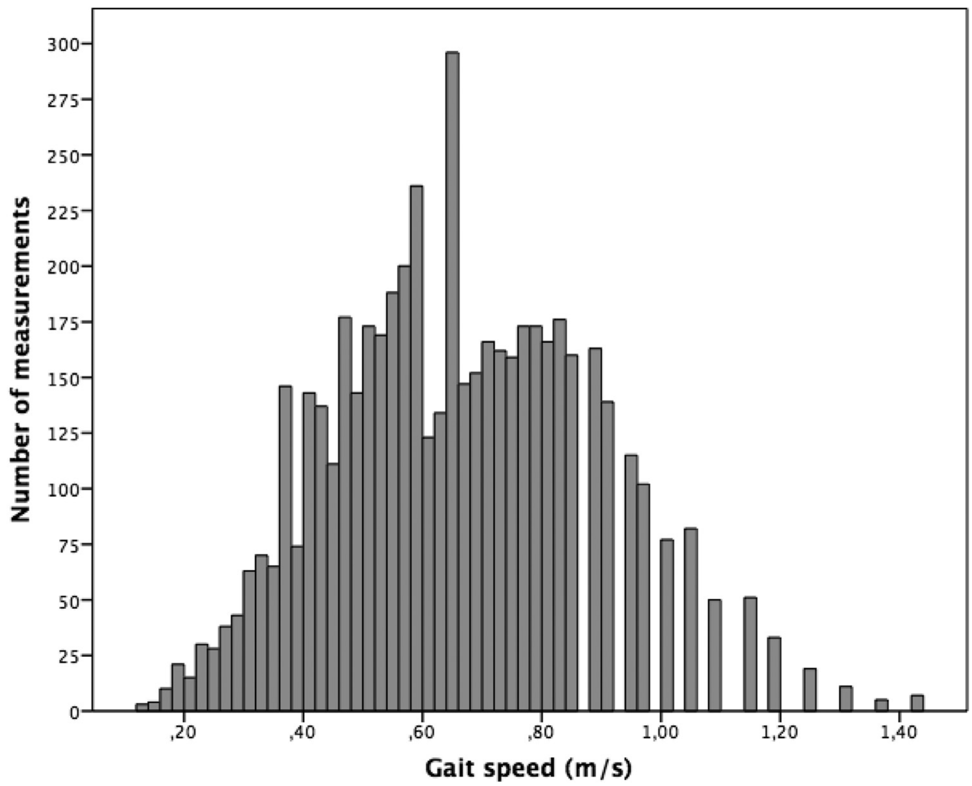

Fig. 3. Walkway measurements performed in consecutive outpatients (n =5328).

been proposed as important across multiple patient groups [42,43]. The differences in our study were very small between the Walkway and the stopwatch method of the SPPB and mean five walks GAITRite™ (0.01 and 0.02 m/s respectively), but moderate between the Walkway and the first and second GAITRite™ individual walks (0.07 and 0.11 m/s respectively). These differences may be explained by the GAITRite™ device protocol used in our Falls Unit. The first and last steps in the GAITRite™ walks are always removed from the analysis in order to avoid acceleration and deceleration bias in every measurement, thus increasing the final mean gait speed. In addition, in every consecutive GAITRite™ normal walk, the gait speed seemed to increase slightly, from 0.77 m/s in the first one to 0.81 m/s in the second, probably associated to a test-repetition bias. Although we have described the differences between methodologies, the purpose of our work was to analyze the agreement between the Walkway system and the other methods, and the hypothesis was that the Walkway could be a valid one was achieved.

When compared to other gait measurement methods, our system has some advantages and some limitations. The set-up time is very short because only depends on switching-on a computer and placing the patient in the front line of the walkway. The space needed is a 6-meter long and 0.90-meter wide corridor, similar to the space needed for the methodology with a stopwatch or the GAITRite™. Sensors, traffic light and scan are placed in the ceiling and walls respectively, without space consuming. The material cost of the system is between 100 and 150€, cheaper than the GAITRite™ with an approximate cost of 35,000–40,000€ (commercial price), but more expensive than a simple stopwatch. However, to our opinion, the avoidance of observer bias, the automatization of the measurements reducing the time employed by physicians or nurses for the measurement and the possibility of directly incorporating the data to the medical records make the costs very low. Our system is only capable of measuring gait speed, useful for frailty, physical function and sarcopenia screening, and the assessment of other gait parameters should have increased the complexity and the costs of the device. However, as patients can have several repeated measurements across the time with the Walkway, it can calculate speed differences between them in order to detect functional decline or improvement. Other infrared systems have been designed for unobtrusive measurement of gait velocity and its variability based on continuous monitoring of patients in their homes [36,34], showing high validity and reliability. However, they were not designed for clinical use in older adults.

A number of studies have identified gait speed as a sole marker of frailty and as a predictor for adverse health events [44]. However, gait speed is a nonspecific item, also linked to aging and other aging-related gait disorders, and should not be used as a frailty diagnosis item by itself. Furthermore, assessment of gait speed does not provide insight into the specific gait pattern that should also be assessed when a slow gait speed is measured. Dual task assessments, fast walking, reduced gait cadence, reduced step length, gait speed variability, step width variability are other gait variables that have been associated with frailty [45]. Gait speed should be used as an easy and non time-consuming screening tool for frailty, in order to detect older patients who should undergo a complete comprehensive geriatric assessment, as has been stated in international clinical guidelines [46–48]. Moreover, it could be useful for the follow-up of functional decline or early detection of clinical problems like cognitive impairment.

A modular approach to our technology, with increased costs but increased measures like assessment of complex gait characteristics that are actually missing (foot patterns and stride variability), could be of interest for future upgrades of our system.

We validated the walkway system in a hospital setting. However gait speed measurement may be useful in other settings like

Primary Care or long-term care in order to screen for frailty, assess the need for further evaluation, physical function monitoring, risk of adverse events or resources allocation [49]. It has been described that in ambulant older people in long-term care, gait speed is slow but remains functional. Since many residents are likely to be unable to walk, further studies are needed in this population in order to analyze the validity of this instrument [50].

Conclusions

The agreement analysis whit the GAITRite^{TM} Walking Analysis System and with the SPPB, demonstrated that a new electronic Walkway system, non-expensive, easy-to-use, self-implemented, infrared technology-based is a valid method to determine walking speed in older patients in a clinical setting.

This technology may be implemented in clinical settings like Hospitals, Primary care centers or Long-term care centers in order to determine frailty, need for further evaluation, physical function monitoring, risk of adverse events or resources allocation.

Summary

A new electronic Walkway system, non-expensive, easy-to-use, self-implemented, infrared technology-based is a valid method to determine walking speed in older adults in a clinical setting.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.hlpt.2019.11.006.

Author Statements

Funding

This work was supported by CIBERFES (CB16/10/00408), Instituto de Salud Carlos III, Ministerio de Economía y Competitividad, España. Ayuda cofinanciada por el Fondo Europeo de Desarrollo Regional FEDER Una Manera de hacer Europa.

Competing interests

None declared.

Ethical approval

The study was approved by the Ethics Review Committee of Albacete, that formally approved that consent was not necessary. Data were collected retrospectively and anonimyzed by the medical doctor of the Falls Unit before analysis. For this reason written consent was not obtained.

CRediT authorship contribution statement

Pedro Abizanda: Project administration. **Luis Carlos Venegas:** Formal analysis. **Gunnar M. Andersen:** Writing - original draft. **Héctor Caulín Roldán:** Writing - original draft. **Melisa López Utiel:** Data curation. **Mariano Esbrí Víctor:** Data curation.

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