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Title

6MWT on a new self-paced treadmill system compared with overground

Authors

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Highlights

- Participants walked a greater distance on treadmill compared with overground 6MWTs
- A low-cost LIDAR sensor was a reliable tool to self-pace a treadmill
- Similar gait parameters were found between the treadmill and overground 6MWTs
- The use of a LIDAR sensor was demonstrated for self-pacing a 6MWT on a treadmill

Abstract

The 6-minute walk test (6MWT) is a useful tool for clinicians and researchers to estimate gait performance and fatigue affecting functional mobility. A modified 6MWT administered on a treadmill (TM) can be an efficient, space-saving alternative to perform the 6MWT.

The aim of this study was to investigate if a 6MWT on a self-paced (SP) TM produced similar results compared to an overground (OG) 6MWT among healthy participants with the hypothesis that users would demonstrate similar gait parameters. The second aim was to assess the reliability of SP TM sessions with the hypothesis that gait parameters would be reliable.

Twelve healthy young adults performed one OG 6MWT and two SP TM 6MWTs, with the TM tests performed on two different testing days. The OG 6MWTs were conducted along a 20 m corridor with a portable optometric system. The SP TM 6MWTs were performed using a dual-belt instrumented TM with speed controlled by feedback from a LIDAR sensor.

In the OG condition, participants walked 664.8 m ± 48.9 m when the standard method was used to calculate distance and 721.3 m ± 56.2 m with an average-speed-based estimation of distance, which corrects for U-turns. For the SP TM 6MWT, they covered 729.4 m ± 45.8 m in the first session and 727.4 m ± 56.0 m in the second session. Gait parameters showed good to excellent within- and between-day reliability on the adaptive TM. Gait parameters were similar between modalities.

A significant difference in the 6MWT distance was found between modalities. This is attributable to the U-turns, because a comparison between TM 6MWT distance and the average-speed-based estimation of the distance for the OG modality showed no significant difference. However, this system produced similar spatiotemporal gait parameters among participants compared to OG.

Background

The growing number of ageing adults is associated with an increase in the incidence of chronic conditions that may affect functional capacity. Functional tests are now widely used by clinicians and other health professionals to measure exercise capacity. The results are an indicator of a patient's condition and mobility-related function. Analysis of spatiotemporal gait parameters (gait speed, distance, step time, step length, cadence) is becoming crucial in predicting fall risk or to quantify mobility in older adults, particularly after a stroke or to monitor the progression of Parkinson's diseases [1–3]. Exercise performance is, therefore, an important clinical feature to evaluate functional capacity.

The guidelines approved by the American Thoracic Society (ATS) in 2002 definitively recognized the 6-minute walk test (6MWT) as a useful tool and it has been used by clinicians and researchers to estimate gait performance and fatigue affecting functional mobility [4,5]. The 6MWT is performed in a long, straight and undisturbed 33-metre hallway. The 6MWT is a submaximal exercise test used to assess aerobic capacity and endurance. The distance covered in a time of six minutes is used as the outcome by which to compare changes in performance capacity. The patient has to walk as far as possible during the six minutes and is allowed to self-pace and rest as needed. The distance covered during the six minutes reflects the functional exercise level for daily physical activities because most of them are performed at a submaximal level of exertion[4–6]. However, in laboratories that have restricted space less than 33 m long, the patient will need to perform many U-turns, which will affect the total distance covered during a 6-minute walk because the patient will need to slow down for each U-turn. This underestimation will affects the clinical outcome compared to standard outcome metrics defined by the ATS [7]. Therefore, for a 6MWT, the walkway length is of great importance.

To better assess mobility-related functions from gait deviations, a portable optometric system can be coupled to the gait test to obtain additional data like walking speed, stride time, stride length, etc. [3]. Likewise, in-ground force plates provide more consistent measures of forces, moments and centres of pressure to obtain spatiotemporal and dynamic data, although force plates are limited in the number of strides they are able to capture. These additional results give more indicators for patient condition than just the distance walked [8–10].

To overcome these limitations a modified 6MWT, administered on instrumented treadmills (TMs), can be an efficient, space-saving alternative to performing the 6MWT [4]. These TMs can be monitored with an optoelectronic camera network and electromyography to obtain a complete set of gait parameters with no restrictions on the duration of the experiment or the number of gait cycles measured [8]. This enables a more reliable measurement of gait parameters such as gait variability, which requires at least 50 consecutive cycles to be measured reliably [11]. However, several studies have reported that walking performance is altered in TM walking compared with overground (OG) walking. Studies have reported shorter stride and increased cadence or higher stance time on a treadmill [12,13]. The most common reasons for these differences are the fixed walking speed of the TM, the optical flow, proprioceptive inputs and the treadmill paradox [8,14]. Indeed, patients tend to choose a lower walking speed on the fixed treadmill speed in comparison to overground walking [15].

To increase the similarity between TM and OG walking, having a self-selected walking speed rather than an imposed walking speed on the treadmill could be a solution. Different methods may be used to compute the self-selected speed. The most common method is to take the speed from a 10-meter walking test on the ground and then implement it on the treadmill [8,16]. Then, the operator determines the preferred walking speed by asking participants if they wants to speed up or slow down [1,4]. However, this manual selection process is timeconsuming and exhausting for participants who are not familiar with the treadmill [17]. An alternative is to use an interactive TM system with self-pacing controllers. These consist of two parts, the first estimates the participant's speed and position and the second controls the treadmill speed. The system keeps the subject within the desired area of the treadmill belt while allowing the participant to freely accelerate or decelerate [18–20]. Several approaches to estimate speed and position exist but the most commonly used method is based on reflective markers and an optical motion capture system using a commercially available virtual reality apparatus (GRAIL, Motek Medical BV, The Netherlands) [17,18,21]. Other approaches have been proposed using an ultrasonic sensor [22], a harness with force sensors [23], force plates on an instrumented treadmill [17] or marker-free infrared sensors [19]. Most of these approaches are costly (GRAIL, instrumented TM) or not ecological, with the patient wearing accessories (a harness for the force sensor or passive reflectors on the chest for the ultrasonic sensor), that cause inconvenience and contribute to an unnatural feeling while walking.

Cost and inconvenience are major limitations for clinicians to administer a self-paced (SP) TM 6MWT. The LIDAR sensor partly overcomes these limitations. It is a cost-effective, non-contact sensor that measures position in the same way as an ultrasonic sensor but without requiring a passive chest reflector and with more accurate detection of the patient's position than sonar systems because it does not suffer from absorption by clothing. The device projects a frequency-modulated light beam onto a target. The distance from the target is calculated using the time taken for the beam to travel to and from the target by measuring the phase difference between transmission and reception.

The first aim of this study was to investigate if a 6MWT on an SP TM produced similar results compared with an OG 6MWT among healthy participants. We hypothesised that users would demonstrate similar gait parameters during an OG 6MWT and an SP TM 6MWT with a low-cost LIDAR sensor for self-pacing control. The second aim was to assess the within- and between-day reliability of the SP TM sessions. We hypothesised that gait parameters would be reliable within SP TM sessions and between sessions on different days.

Methods

1. Subjects

Twelve healthy young adults (8 women, 4 men; age: 23.5 ± 3.4 years; height: 173.2 cm ± 10 cm ; weight : 68.2 kg ± 11.4 kg) volunteered to participate in the study after providing informed written consent and GDPR consent. One participant enrolled in the first session only. They were free of any known neurological, musculoskeletal, or other systemic disorders that would affect gait or functional mobility. The study was approved by the local ethics committee and conduced in accordance with the declaration of Helsinki.

2. Protocol

Each participant first performed one OG 6MWT then one SP TM 6MWT on the same day. A second SP TM 6MWT on a different day was conducted to assess the reliability of the TM between days. All tests were performed in barefoot conditions to avoid footwear effects on spatiotemporal parameters and to enable future data processing of the SP TM 6MWT data with inverse dynamics [24]. A seated rest was provided between the OG and SP TM 6MWTs for at least 30 minutes [25]. Standardised instructions were provided before each trial with a reminder every 2 minutes: “walk as far as possible in 6 minutes without running or jogging” [5]. A warmup of two minutes with a five-minute rest was imposed for the OG 6MWT. The test was performed in accordance with the 2002 guideline of the ATS, using a 20 m corridor [5,26]. Regarding the SP TM 6MWT, all participants completed a familiarisation session of at least 5 minutes on the TM with a five-minute rest prior to the test. This session included an explanation of the system and the use of the treadmill’s SP function. During the familiarisation session, participants were encouraged to interact with the system until they felt confident to try fast speed walking for one minute. Participants were not allowed to hold the handrails during the evaluation unless there was a loss of balance.

3. Materials

A 10 m long OptoGAIT portable optometric system (Microgate, Bolzono, Italy) was placed in the middle of the course to measure spatial and temporal gait parameters. Participants walked through the OptoGAIT on each pass of the 20 m course and made a U-turn at each end marker [26] [Figure 1]. SP TM 6MWT sessions were conducted on a Bertec dual-belt instrumented TM (Bertec Corp., Columbus, OH, USA) sampled at 1000 Hz with a network of 8 Optitrack Prime 13 optoelectronic cameras (NaturalPoint, Inc. Oregon, USA) sampled at 100 Hz.

The feedback-controlled speed was assessed with a purpose-built controller made of a Garmin LIDAR (Garmin Ltd, Lenexa, Kansas, USA) and an Arduino Uno REV3 microcontroller board (Arduino SRL, Torino, Italy) [Figure 2]. The position of the subject was filtered with a first-order discrete-time low-pass filter with I for input and O for output [Equation 1] [23] with a sampling at 20 Hz to reduce trunk oscillations. Then, a Matlab algorithm aimed to keep users in the centre of the treadmill via a speed correction [20], sent directly to the TM system with incremental position and speed defined as x and $\dot{x}$ respectively [Equation 2].

$$Equation\ 1: O_t = 0.6065 * O_{t-1} + 0.2131 * I_t + 0.1804 * I_{t-1}$$

$$Equation\ 2: \dot{x}_t = \dot{x}_{t-1} + 0.009 * x_t * |x_t|$$

Ground reaction force (GRF) data were low-pass filtered at 20 Hz. Strides with foot placement on both belts were excluded from the data analysis. The distance of the SP TM 6MWT was calculated from the integral of the walking speed over the 6 minutes. Gait parameters were calculated using the initial contact and toe off from the ground reaction force as well as the walking speed to derive step length, step time, stance phase, double support, cadence, and average walking speed.

The first and last step of the OptoGAIT acquisitions in each direction were excluded to remove partial steps. Gait parameters were calculated taking the initial contact and the toe off from when the foot crossed the infrared beam light between the two bars. A filter of 2 LEDs was used to eliminate a potential systematic bias due to the position of the LEDs in the OptoGAIT system, 3 mm above the ground [27]. The distance of the OG 6MWT was computed with the standard method from the number of turns and the remaining distance covered (the number of metres in the final partial lap) using the markers on the floor as distance guides. In order to compare SP TM and OG distances calculated by similar methods, another OG 6MWT distance was estimated by multiplying the average walking speed measured by the OptoGAIT system during the test by 6 minutes (average-speed-based estimation method).

To compare the two modalities, the 6MWT was split into three 1-minute intervals, T1 (initial):0 – 1 min; T2 (middle): 2 min 30 s – 3 min 30 s; T3 (end): 5 min – 6 min. These intervals were chosen to better compare the different strategical periods of adaptation and tolerance involved in performing a 6MWT [28].

4. Statistical Analysis

The assumption of normality was checked with the Shapiro-Wilk test. Given the very definition of the p-value, it cannot provide evidence in favour of an equivalence. However, an alternative to the traditional H_0 significance testing approach is possible by treating H_0 and H_1 differently with the two one-sided test (TOST) [29]. For the primary outcome, the equivalence between OG and SP TM Day 1 distance was checked by TOST. The equivalence interval was fixed at ±45m (~7% of the mean distance) and alpha levelat 5% for a clinical difference [30,31].The Bland-Altman method was used to assess agreement between the two modalities, to compare the OG distance defined by the standard method and the OG distance estimated from the average speed, without U-turns and therefore more similar to the SP TM distance. For the secondary outcome, to assess the validity of gait parameters of the SP TM 6MWT compared to the OG 6MWT, Bland-Altman plots were used to test the agreement of cadence, step length, stance phase, double support, and gait speed. Then, cadence, stance phase, double support and step length were analysed using a mixed-model multivariate analysis of variance (MANOVA) with one factor (OG compared to SP TM). The assumption of partial correlation between variables was checked with Pearson's partial correlation of the MANOVA variables. Box's M Test was significant with p-value = 0.066 > 0.001 indicating that potential distortion of the alpha level is not significant. Pillai's trace was chosen due to the small population of fewer than 30 participants.

The reliability of the feedback-controlled speed algorithm for the SP TM 6MWT was assessed through within-day and between-day reliability. The within-day reliability was determined by the intraclass correlation (ICC) type (2,1) between participants and gait cycles based on the first 20 strides of each of the three 1-minute periods in the day 1 SP TM 6MWT [11]. ICC values were considered poor (<0.50), moderate (0.50 – 0.75), good (0.75 – 0.90), or excellent (>0.90) [32]. To examine the test-retest reliability of the gait parameters obtained from the SP TM 6MWT between days, 20 strides of each of the three 1-minute periods were combined between the day 1 and day 2 sessions to construct each trial. Reliability was determined by the ICC type (3,1) [33].

Results

A comparison between the SP TM and OG modalities for the 6MWT is shown in [Figure 3] with two computed distances for OG: the standard method and the average-speed-based estimation. In the OG condition, participants walked 664.8 m ± 48.9 m with the standard method using floor markers and 721.3 m ± 56.2 m with the walking speed method. For the SP TM 6MWT, they covered 729.4 m ± 40.8 m in the first session and 727.4 m ± 49.9 m in the second session. A comparison between the SP TM day one and day two sessions showed significant equivalence with an average of -2.0 m difference (95% CI -27.8 – 23.8, p-value< 0.05). Participants walked, on average, -64.6 m (95% CI 45.3 – 83.9 m, p-value >0.05) between the OG 6MWT and the day 1 SP TM 6MWT, i.e., 9% less in the OG test with the standard distance method than the TM distance. The difference was 8.1 m (95% CI -17.1 – 33.4 m, p-value < 0.05) with the average-speed-based estimation.

Bland-Altman plots showed a significant difference in the distance between the adaptive treadmill and the OG 6MWT with the distance calculated by the usual method but not with the average-speed based estimation [Figure 3]. The cadence, step time, step length, stance phase, double support and gait speed were similar between both systems with no significant difference shown on the Bland-Altman plots [Figure 4].

There was no significant main effect between SP TM and OG walking (p-value = 0.847) using Pillai's test for cadence, step length, stance phase and double support.

The ICC values for gait parameters showed good to excellent reliability for the SP TM algorithm during the three parts of the 6MWT on the adaptive TM [Table 1]. For test-retest reliability, ICC values between both 6MWT sessions on the adaptive TM showed moderate to excellent between-day reliability [Table 2].

Discussion

The main purpose of this study was to examine if the results of a 6MWT on an SP TM were similar to an OG 6MWT. Our results showed a significant difference for the distance between modalities with a 9% greater distance on the SP TM 6MWT compared to the OG 6MWT. However, neither the spatiotemporal parameters nor the average-speed-based distance estimation demonstrated a significant difference to their counterparts between 6MWT modalities. Moreover, the SP TM algorithm showed high reliability of the spatiotemporal parameters within and between days.

Our findings support that SP TMs are a reliable tool to evaluate gait speed with no significant difference in gait speed between the two modalities at points T1, T2 and T3 during a 6MWT after a 5-minute accommodation period. Plotnik et al. and Song et al. found similar results in their studies, with no significant difference in gait speed between SP TM and OG after an adaptation period [8,17]. This accommodation time is an essential step in TM gait tests due to the treadmill paradox. Paradoxically, any chosen fixed gait speed on a TM, including a manually self-selected walking speed, does not reflect OG walking accurately and therefore underestimates distance. Through an analysis of speed convergence, Plotnik et al. suggested a longer speed-adaptation period for SP TM than for OG, with at least 2 m needed to reach self-selected gait speed for OG, compared with 30 m or more for SP TM walking [8]. Additional studies confirm the effect of the familiarisation period, suggesting a small learning effect. Sloot et al. found a small difference between the two modalities, with a 3 min accommodation period and recommend, like the Zeni et al. study, at least 5 min to become accustomed to SP walking to avoid the TM paradox [18,34]. These findings bring to light the importance of feedback-controlled, self-paced walking speed on a treadmill after an accommodation period to limit the TM paradox, which will underestimate walking speed.

In contrast to the gait speed comparison, the mixed results of the distance comparison led to a better understanding of the impact of U-turns on the 6MWT. Indeed, the OG distance with the standard method underestimated the distance by 72.7 m when compared with the distance predicted using the average walking speed taken in the middle of the hallway. This difference could be clinically meaningful for measuring a patient's condition [30]. The distance estimated from the average walking speed showed no significant difference with SP TM 6MWT. This significant difference observed with the standard method may be due to the U-turns required during the OG 6MWT. In the present study, the distance with the usual method was underestimated because the use of a 20 m hallway introduced a large number of turns. Elazzazi et al. found no significant difference between the OG, using the usual calculation method to obtain the distance, and the SP TM conditions. They attributed this result to the use of a 33 m hallway. The authors suggested that increasing the walkway length to reduce the number of turns would possibly increase the distance covered by participants during the 6MWT. Unfortunately, gait speeds were not recorded during the OG 6MWT so it was not possible to compare possible effects of the U-turns on the distance. The authors highlighted the problem of the lack of standardisation of hallway length, which may lead to underestimated distances for OG compared with SP TM 6MWTs [4]. The effect of different walkway length for a 6MWT was studied by Shamay S. Ng et al. with 10 m, 20 m, and 30 m. Their findings support the significant effect of the walkway length on the distance covered in the 6MWT in patients with stroke and among the elderly [7,35]. This effect highlights the importance for clinicians to use the norm value of the 6MWT with much more care, depending on walkway length. It is possible that new norm values may be needed to effectively compare OG distances with those on SP TM, because distances estimated from the average speed walking back and forth several times may be different from walking in a straight line. This difference, of slowing down and turning, may allow participants to walk at a higher speed in the walkway [36]. Finally, the difference in distance between the SP TM and the OG 6MWT distances means that the reader should be cautious in applying the previously established norms.

Regarding the spatiotemporal parameters, the study showed similar step length, cadence, gait speed, stance phase, and double support between the two modalities. For comparison, Cronin et al. measured comparable outcomes for gait speed, stance time, step time and stance phase, between TM and OG in barefoot conditions [37]. In running tests, García-Pérez et al. reported no significant difference in cadence at 3.33 m/s between TM and OG [38]. Hollman et al. similarly measured no differences for stride time, stride length, cadence, and stance phase between SP TM walking and OG walking [16]. In contrast, some studies have highlighted differences in spatiotemporal parameters between SP TM and OG. In particular, Van Der Krogt et al. found similar gait speed but with shorter and wider strides on the TM, possibly due to the dual-belt treadmill. These results were in line with the findings of Schellenbach et al. in adult participants with, in addition, an increase in cadence and time in double support compared with OG walking. After a familiarisation period, these participants reached a stable pattern with small differences compared to overground walking but did not fully abandon a careful walking style. However, these differences between modalities, do not necessarily mean that TM walking is less suitable for clinical analysis [39,40]. These findings are in agreement with our results that no significant difference between SP TM and OG gait parameters is observed after a 5-minute accommodation period.

Our results suggest that the feedback-controlled speed algorithm for the SP TM 6MWT provides excellent reliability for step time and cadence and good reliability for gait speed, step length, stance phase and double support during the three parts of the 6MWT on the adaptive TM. Matsas et al. found similar results for the ICC of the stride time, step length and cadence after 6 min of treadmill walking, with ICC values higher than 0.94, 0.93 and 0.94, respectively, from six consecutive gait cycles [41]. For test-retest reliability, our data suggest moderate to excellent between-day reliability, depending on the spatiotemporal parameter. Analogous test-retest reliability was found for a comfortable speed with an ICC of 0.982 (0.956 – 0.992) for stride time and 0.960 (0.904 – 0.983) for stride length [3]. Choi et al. confirm this hypothesis with a series of 6 trials on a 10 min gait test spread over 2 days with ICC> 0.90 for speed, stride time and stride length [42]. Another study found high between- and within-day reliability for most of the spatiotemporal gait parameters, including stride frequency, stride length and stride time [43]. However, stance phase and double support were less reliable on the treadmill compared to the other spatiotemporal gait parameters, in agreement with our results. Faude et al. found a similar result with a lower reliability for double support, with an ICC of 0.86, comparable to the 0.80-0.88 measured in our study [43]. To conclude, the reliability of gait parameters on an SP TM allows clinicians to use the 6MWT to better analyse mobility-related function using gait deviation.

This study has some limitations which need to be considered. The test-retest reliability was based on only 2 sessions which was not very consistent with ICC interpretation [33,42]. Also, to get more consistent data in order to perform inverse dynamics on the 6MWT, participants were in a barefoot condition. This limits the generalisability, as the OG 6MWT is usually performed in a shod condition. Further, all participants included in the study were healthy young adults. This population is not representative of patients with fatigue and gait variability performing 6MWTs. This lack of variability is the main limitation of this study to fully highlight the capabilities of the SP algorithm. Only the stability of the system was assessed in the study, as participants experienced no fatigue during the three parts of the 6MWT. In addition, young people typically require less familiarisation time compared with the patient group. This parameter can be a serious limitation for patients with endurance issues. Another limitation is the possible learning effect, as the OG 6MWT was performed before the SP TM 6MWT. Further investigation of SP TM including individuals with gait limitation is needed to show the feasibility of the SP algorithm to reveal fatigue and gait variability. Related to this, another investigation with longer gait tests on healthy participants will show the potential use of an endurance test and will focus on natural low-frequency variability between OG and SP TM tests [16]. Finally, the SP TM system used was based on different studies, but its performance is not representative of all SP TM, which will depend on the algorithm and the user-driven treadmill control.

Conclusion

In conclusion, the distance walked on an SP TM presents a significant difference compared with that measured in an OG 6MWT. This difference highlights that the norm values cannot be compared with measurements in this modality and establishes the necessity of new norm values for SP TM 6MWT. However, a comparison of spatiotemporal parameters highlighted no significant difference between modalities. These results indicate that, after a familiarisation period, SP TM walking does not notably affect gait parameters for clinical analysis. Moreover, the SP TM 6MWT allows the use of optoelectronic camera networks, force platforms and other tools to perform more accurate gait analysis while observing walking speed, gait variability and endurance.

Conflict of interest statement

The authors have no professional relationship with companies of manufacturers who might benefit from the results of the study.

Tables

Table 1

Intraclass reliability of the 6MWT on the adaptive treadmill for Step Length (SL), Step Time (ST), Cadence (Cad), Walking Speed (WS), Stance Phase (SPh) and Double Support (DS):

Gait parameters:	ICC (CI 95%)		
	T1	T2	T3
SL	0.87 (0.76 – 0.95)	0.96 (0.92 – 0.99)	0.90 (0.83 – 0.97)
ST	0.96 (0.92 – 0.99)	0.96 (0.92 – 0.99)	0.97 (0.94 – 0.99)
Cad	0.97 (0.93 – 0.99)	0.96 (0.92 – 0.99)	0.97 (0.94 – 0.99)
WS	0.81 (0.68 – 0.93)	0.95 (0.91 – 0.98)	0.91 (0.83 – 0.97)
SPh	0.82 (0.68 – 0.93)	0.85 (0.74 – 0.94)	0.85 (0.73 – 0.94)
DS	0.80 (0.65 – 0.92)	0.88 (0.79 – 0.96)	0.88 (0.77 – 0.95)

Table 2

Test-retest reliability of the 6MWT on the adaptive treadmill for Step Length (SL), Step Time (ST), Cadence (Cad), Walking Speed (WS), Stance Phase (SPh) and Double Support (DS):

Gait parameters:	ICC (CI 95%)		
	T1	T2	T3
SL	0.90 (0.84 – 0.95)	0.97 (0.95 – 0.99)	0.89 (0.83 – 0.95)
ST	0.95 (0.90 – 0.97)	0.96 (0.94 – 0.98)	0.87 (0.79 – 0.93)
Cad	0.96 (0.93 – 0.98)	0.96 (0.93 – 0.98)	0.89 (0.82 – 0.94)
WS	0.93 (0.89 – 0.97)	0.98 (0.96 – 0.99)	0.98 (0.96 – 0.99)
SPh	0.80 (0.68 – 0.89)	0.87 (0.79 – 0.93)	0.74 (0.61 – 0.86)
DS	0.80 (0.69 – 0.90)	0.88 (0.81 – 0.94)	0.86 (0.78 – 0.93)

Figures

Figures

Figure 1: OG 6MWT setup.

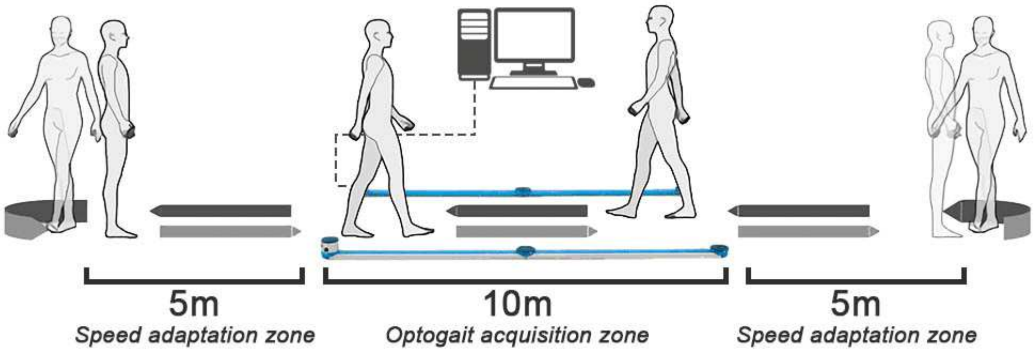


Figure 2: Speed adaptation treadmill setup: Position *x* computed by the LIDAR sensor sends the trunk position to the computer and with a Matlab algorithm, sends a speed command to the treadmill to place the participant in the centre.

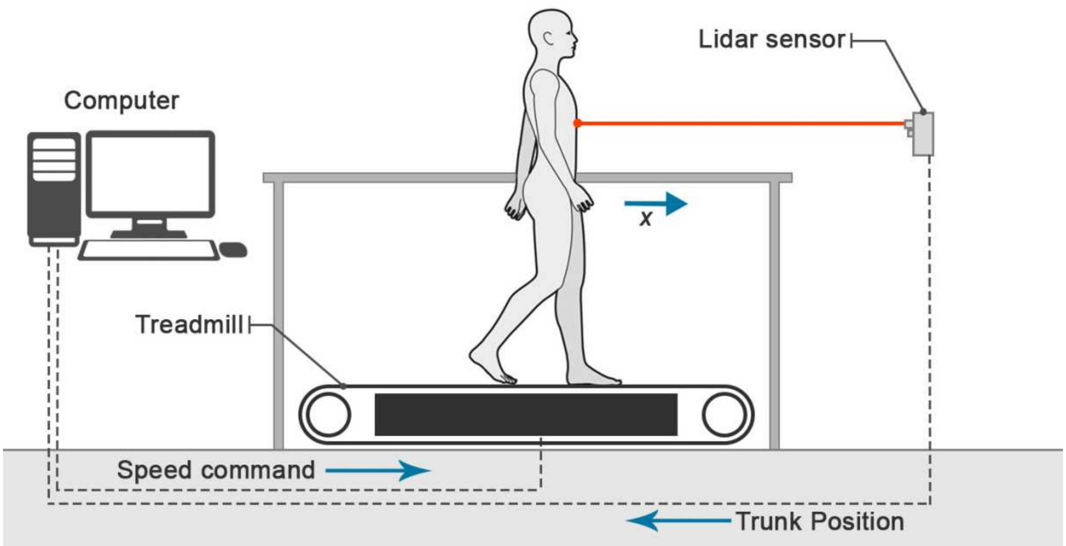


Figure 3: Bland-Altman plots of the difference in distance between the SP TM and OG 6MWTs with the standard method (a) and the average-speed-based estimation (b)

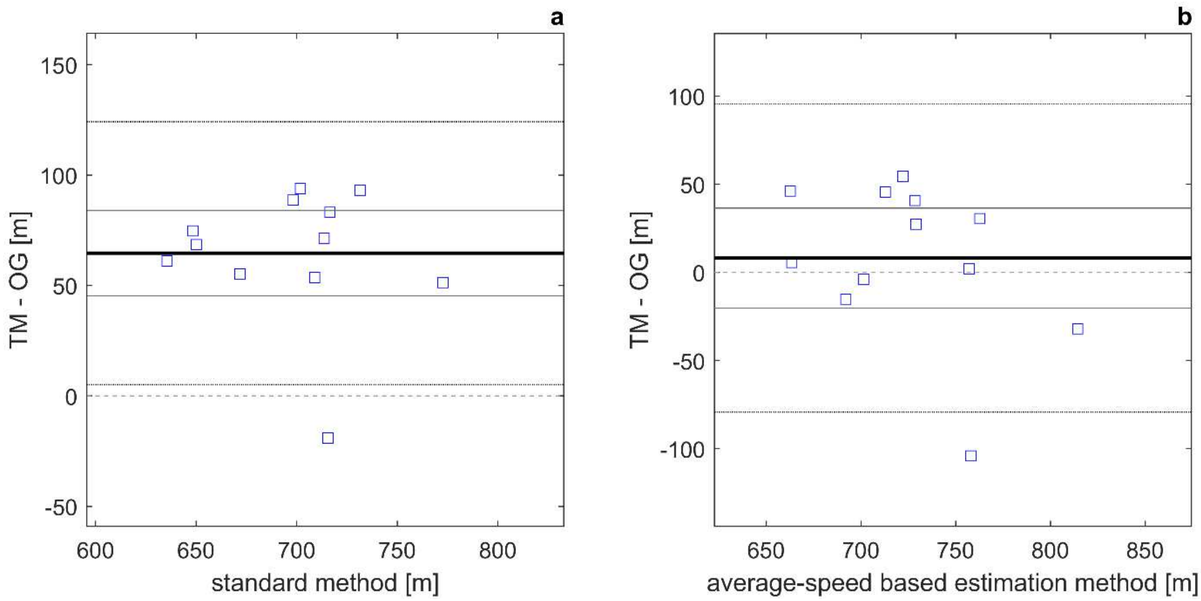
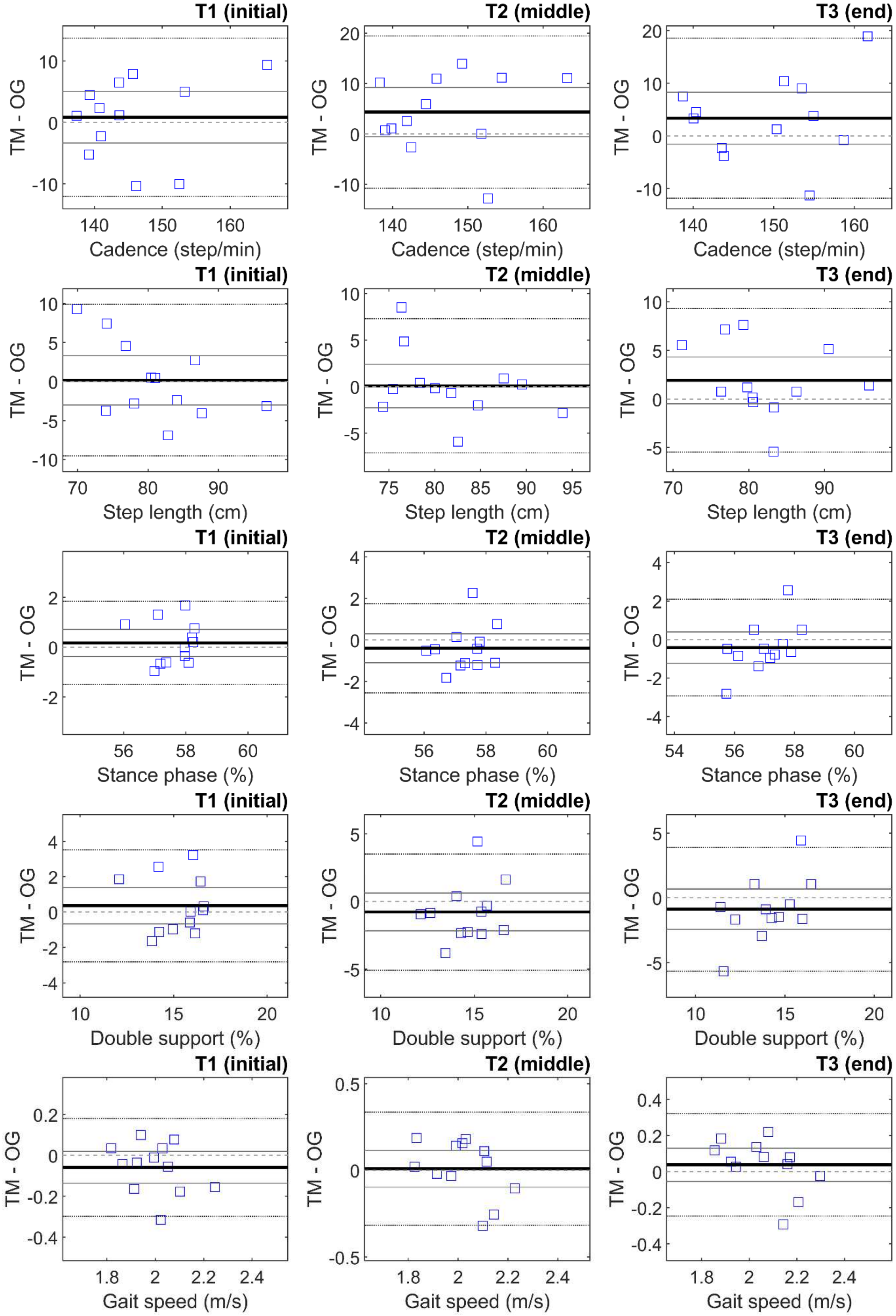


Figure 4: Bland-Altman plots of cadence, step length, stance phase, double support and gait speed at T1 (initial), T2 (middle), and T3 (end) of the 6MWT between SP TM day 1 and OG.



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