Combinations of gait speed testing protocols (automatic vs manual timer, dynamic vs static start) can significantly influence the prevalence of slowness: Results from the Korean Frailty and Aging Cohort Study

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ABSTRACT

Aim: This study aimed to compare 4-m usual gait speed obtained with different protocols and to determine the prevalence of slowness using different diagnostic criteria in a large cohort of community-dwelling older adults.
Methods: A total of 1177 non-disabled community-dwelling older adults aged 70–84 years were assessed for 4-m usual gait speed using four different testing protocols: (1) automatic timer (ultrasonic sensor), dynamic start; (2) manual timer (stopwatch), dynamic start; (3) automatic timer, static start; and (4) manual timer, static start. To assess agreement between usual gait speed and the testing protocols, linear regression and Bland-Altman analyses were performed.
Results: There was systematic bias (i.e., difference between automatic timer and manual timer methods), with underestimation of usual gait speed (bias 0.0695 m/s for dynamic start; bias 0.0702 m/s for static start) by the manual timer. There was systematic bias in start conditions, with underestimation of usual gait speed with a static start using both timer methods, compared with that in dynamic start assessment (P < 0.001). The prevalence of slowness ranged from 2.3 to 4.7% in men and 5.9–11.1% in women for < 0.80 m/s, and from 17.1 to 30.5% in men and 26.3–45.9% in women for < 1.00 m/s.
Conclusions: The findings of this study indicated that 4-m usual gait speed measured under different testing protocols was able to determine different prevalence rates of slowness among non-disabled community-dwelling older adults. An automatic timer may be useful for measuring gait speed changes in individuals likely to have faster gait speed in community-based research settings.

1. Introduction

The capacity to walk underlies basic and community functions necessary for independence (Studenski, 2009). Gait speed is an important measure in comprehensive geriatric assessment (Peel, Kuys, & Klein, 2013). It is a potentially useful clinical indicator of well-being among older adults (Hall, 2006). Given its objectivity as a simple, quick, reproducible, inexpensive, and feasible test, slow gait speed (or slowness) may be as important as vital signs in screening of older adults in clinical settings (Cummings, Studenski, & Ferrucci, 2014; Studenski et al., 2003, 2011). Gait speed has also been used to predict geriatric health outcomes for multiple diagnoses (Abellan van Kan et al., 2009; Middleton, Fritz, & Lusardi, 2015). Moreover, slowness is a key component of diagnostic criteria for sarcopenia and frailty phenotypes (Alley et al., 2014; Chen et al., 2014; Cruz-Jentoft et al., 2010; Fried et al., 2001; Provencher et al., 2017).

Literature reviews have compared various testing protocols to determine the differences between studies. A systematic review reported widely varied walking test methodologies, such as pace, starting or timing protocols, and distance covered in clinical research (Graham, Ostir, Fisher, & Ottenbacher, 2008). This review recommended the 10-m straight line walk, while walking distances of 10, 6, and 4 m was the most commonly used and that a static start was slightly more common than a dynamic start (30 vs. 26 studies). Middleton et al. (2015) reported that instrumented walkways ranging in length from 5 to 10 m were used that required acceleration phases of approximately 2.5 m for self-selected speeds, and hand held stopwatches can be used for timing. Graham, Ostir, Kuo, Fisher, and Ottenbacher (2008) recommended gait speed tests at a practical distance of 4 or 6 m using a static start. Consensus concerning the optimal testing protocol is limited. Walking

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performance and prevalence of slowness are difficult to compare among studies with dissimilar or unspecified test procedures. The methodologic factors of walking test evaluation may influence the clinical meaningfulness of group and/or individual performance based on select published standards (Graham, Ostir, Kuo et al., 2008). Therefore, the diagnosis of slow gait speed requires a standardized protocol in clinical and community settings.

Distances stratified based on group of participants and limited settings space have demonstrated specific patterns. However, gait speed measured with a timed 4-m walk at a usual pace has been widely used in clinical and epidemiological research (Rydwik, Bergland, Forsen, & Frandin, 2012). Gait speed is commonly tested using a manual timer (i.e., a handheld stopwatch) with the criterion standard method. Maggio et al. (2016) reported that although the concordance of gait speed assessed manually or instrumentally is not optimal, stopwatch measurement might lead to misclassification diagnostic of dismobility syndrome in non-disabled community-dwelling older adults. Furthermore, although various walking test protocols have shown excellent interrater and test-retest reliability (Barry et al., 2018; Bisca et al., 2018; Karpman, Lebrasseur, Depew, Novotny, & Benzo, 2014; Kim, Park, Lee, & Lee, 2016; Peters, Fritz, & Krotish, 2013), there are small clinically meaningful differences in recorded gait speeds in community-dwelling older adults (Sustakoski, Perera, VanSwearingen, Studenski, & Brach, 2015).

Therefore, the aim of the present study was to compare 4-m usual gait speeds obtained with four different testing protocols (starting protocol and timing instrument) in a large group of community-dwelling older adults, the nationwide Korean Frailty and Aging Cohort Study (KFACS). The second aim was to use the four different testing protocols to determine the prevalence rate of slowness based on different diagnostic criteria (usual gait speed < 0.8 m/s and < 1.0 m/s).

2. Materials and methods

2.1. Subjects

The KFACS aims to identify risk factors for adverse outcomes associated with frailty in community-dwelling older adults, as well as means of prevention. The study participants consisted of community-dwelling individuals aged 70 years or older who participated in the KFACS. The KFACS is a nationwide cohort study that began in 2016 for the purpose of identifying and preventing factors contributing to aging in community-dwelling older adults. KFACS is a multicenter, longitudinal study, with the baseline survey conducted in 2016-2017. Sex- and age-stratified community residents aged 70 to 84 years from urban and rural regions nationwide were eligible for participation in the study (Won et al., 2016). A total of 3014 subjects participated in the baseline survey. Of the 1455 subjects who participated in the baseline survey in 2017, 16 were excluded for not being independent in any of the five basic activities (dressing, bathing, toileting, transferring, and feeding) using the Katz Index for activity of daily living (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963), while another 19 potential participants who used walking aids in their daily lives were also excluded. The automated timing system used ultrasonic sensor beams because the system cannot differentiate whether the participant's foot or the walking aid triggered activation at the start and end of the measurement. Further, we excluded an additional 243 participants who could not complete the measurement of the usual 4-m gait speed with the four different protocols. Thus, the final analytical sample included 1177 participants.

KFACS protocol was approved by the Institutional Review Board (IRB) of the Clinical Research Ethics Committee of the Kyung Hee University Medical Center, and all subjects provided written informed consent (IRB number: 2015-12-103). This study was exempt from IRB review by the Institutional Review Boards of the Clinical Research Ethics Committee of the Kyung Hee University Medical Center (IRB number: 2018-04-013).

2.2. Measures

Assessments included demographic information, weight, height, and body mass index. Weight and height were measured in light clothing without shoes. Body mass index was calculated as body weight in kilograms divided by height in meters squared. Functional status was measured using the 10 domains of the Instrumental Activities of Daily Living (IADL) (decorating, housework, preparing meals, laundry, short outings, using transportation, shopping, handling money, using the telephone, and taking medicine). We defined disability as answering at least one domain with dependence on the IADL. Mobility disability was assessed with two consecutive self-reports of having "a lot of difficulty/ inability" to walk one-quarter of a mile or climbing up 10 steps without resting. Cognitive function was assessed based on the mini-mental state examination (MMSE) scores that range from 0 to 30, with higher scores indicating better cognitive function. Physical frailty was defined using a modified operational definition of the Fried frailty index using data collected in the Cardiovascular Health Study (Fried et al., 2001). The five different components of frailty indicators were evaluated as: 1) Weight loss: answering "yes" to "In the last year, have you lost more than 4.5 kg unintentionally?"; 2) Weakness: maximal grip strength < 26 kg for men and < 18 kg for women measured using a digital hand grip strength measuring instrument (Takei TKK 5401; Takei Scientific Instruments, Tokyo, Japan) twice for each hand; 3) Slowness: 4-m usual gait speed < 1.0 m/s with an acceleration and deceleration phase of 1.5 m each measured by automatic timer; 4) Exhaustion: answering "yes" to either one of the following statements from the Center for Epidemiological Studies-Depression scale "I felt that everything I did was an effort" or "I could not get going" for 3 or more days a week; and 5) Low physical activity: kilocalorie per week (kcal/week) expenditures were calculated for each activity using its metabolic equivalent score using the International Physical Activity Questionnaire, with low physical activity defined as values < 494.65 kcal for men and < 283.50 kcal for women, which was the lowest value for 20% of the sex-specific total energy consumed from a general Korea population-based survey of older adults (Son et al., 2015). Subjects with three or more components were considered to have physical frailty.

2.3. Procedures for measuring 4-m usual gait speed

2.3.1. Dynamic start, automatic timer (ultrasonic sensor), and manual timer (stopwatch)

Our study used ultrasonic sensors for automatic timing (Gaitspeedometer Ver.2, Dynamicphysiology, Daejeon, Korea). A technical note described a low-cost ultrasonic motion analysis system capable of measuring temporal and spatial parameters while subjects walk on the floor (Huitema, Hof, & Postema, 2002). Knowing the speed at which sound travels through the air, ultrasonic sensors measure the time it takes to send and receive the wave produced as it is reflected on an object. The walking time is the time required for the signal to travel and return, and the speed is calculated for the distance between the two points (Muro-de-la-Herran, Garcia-Zapirain, & Mendez-Zorrilla, 2014). The quantitative evaluation of gait velocity, such as gait speed, cadence, step length, and step time, was validated with an ultrasound sensor (Weir & Childress, 1997). A flat 7-m walking path was marked with tape at 0-, 1.5-, 5.5-, and 7-m points, and an automated timing system using ultrasonic sensor beams (15-cm * 10-cm * 9-cm) was set up at 1.5-m and 5.5-m points. This provided a 1.5-m acceleration zone, a 4-m timing area, and a 1.5-m deceleration zone. Gait speed was measured over a 4-m distance with acceleration and deceleration phases of 1.5 m each by an automated timing system that triggered activation. The time is automatically triggered when the participant's foot (toe) crosses the ultrasonic sensor. Participants were asked to perform the test by walking at a normal pace. The participant stood with both feet touching the starting line. When the researcher said "ready, begin," the participant walked the 7-m length twice and was

given a 1-min rest period between measurements. The time to walk 4 m was manually measured during the automated timing protocol trials; a researcher walked beside the participant while simultaneously measuring the gait speed using a manual stopwatch. A stopwatch was used to measure the time taken to walk 4 m: from when the foot (toe) first crossed the ground after the 1.5-m line to when the foot (toe) crossed the round after the 5.5-m line.

2.3.2. Static start, automatic timer (ultrasonic sensor), and manual timer (stopwatch)

A flat 4-m walking path was marked with tape at 0- and 4-m points, and an automated timing system using ultrasonic sensor beams was set up at 0-m (starting line) and 4-m (stopping line) points. Gait speed was measured over a 4-m distance by an automated timing system that triggered activation. Participants were asked to walk at their normal pace. The participant stood with both feet touching at 10 cm before the starting line. When the researcher said "ready, begin," the participant walked the 4-m length twice and was given a 1-min rest period between measurements. The time to walk 4 m was manually measured during automated timing protocol trials; a researcher walked beside the participant while simultaneously measuring gait speed using a manual stopwatch. A stopwatch was used to measure the time taken to walk 4 m: from when the foot (toe) first crossed the ground after the 0-m line to when the foot (toe) crossed the ground after the 4-m line.

We calculated gait speed as distance divided by walking time (m/s). Participants performed two trials with results averaged to the nearest 0.01 m/s. A minimum of 5 min was provided between tests comparing the two protocol trials in a random sequence (see Supplementary material). Measurements of usual 4-m gait speed with each testing protocol were obtained by trained clinical research coordinators.

2.4. Statistical analysis

Study population characteristics were analyzed using descriptive statistics, including mean ± standard deviation (SD). Differences in age, anthropomorphic parameters, and gait speed characteristics between male and female participants were assessed with an unpaired t-test. Intraclass correlation coefficients (ICCs) with 95% confidence intervals (CIs) and coefficients of variation were calculated to evaluate test-retest reliability of the two trials for gait speed as assessed using the four different testing protocols. ICC values less than 0.5 indicate poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability (Fleiss, 1986). To assess agreement between 4-m usual gait speed measurements using automatic and manual timers (dynamic start and static start), linear regression and Bland-Altman analyses were performed. Simple linear regression models were used to create equations to estimate conversions for gait speeds obtained from different testing protocols. In the Bland-Altman plots, systematic bias was calculated as the mean difference between methods, and the 95% limits of agreement were calculated as the bias ± 2 SD for the differences between methods. Because there was evidence of proportional bias for the four different testing protocols, Pearson's correlation was used to quantify the bias observed in the Bland-Altman plots. Prevalence rates of slowness based on different diagnostic criteria were determined by using the four different testing protocols and were analyzed with the χ^2-test. Slowness was determined using two different diagnostic criteria (usual gait speed < 0.8 m/s and < 1.0 m/s) for cut-off points of usual gait speed. (Studenski et al., 2011) Statistical analyses were performed using IBM SPSS software version 23 (SPSS Inc., Chicago, IL, USA) and SigmaPlot software version 12.0 (Systat Software Inc., Chicago, IL, USA). For all tests, statistical significance was set at P < 0.05.

Table 1
Characteristics of the sample.

	Total (n = 1,177)	Male (n = 554)	Female (n = 623)
Age, years	75.7 (3.8)	76.1 (3.8)	75.3 (3.7) [*]
Body weight, kg	60.8 (9.2)	65.0 (8.9)	57.1 (7.7) [*]
Height, cm	157.9 (8.5)	164.9 (5.4)	151.7 (5.5) [*]
Body mass index, kg/m^2	24.4 (3.0)	23.9 (2.9)	24.8 (3.0) [*]
IADL disability, n (%)	159 (13.5)	84 (15.2)	75 (12.0)
Mobility disability, n (%)	153 (13.0)	25 (4.5)	128 (20.5) [*]
Physical frailty, n (%)	74 (6.4)[a]	28 (5.2)	46 (7.6)
MMSE score, mean (SD)	25.7 (3.2)	26.2 (3.0)	25.3 (3.3) [*]
4-m usual gait speed measures			
Automatic timer (ultrasonic sensor), dynamic start, m/s	1.19 (0.25)	1.23 (0.24)	1.16 (0.25) [*]
Manual timer (stopwatch), dynamic start, m/s	1.12 (0.22)	1.17 (0.21)	1.08 (0.21) [*]
Automatic timer (ultrasonic sensor), static start, m/s	1.13 (0.24)	1.17 (0.24)	1.10 (0.24) [*]
Manual timer (stopwatch), static start, m/s	1.06 (0.20)	1.11 (0.20)	1.02 (0.20) [*]

Values are presented as mean (standard deviation) or number (%). ADL, activities of daily living; IADL, instrumental activities of daily living; MMSE, Mini-Mental State Examination. *Significantly different between men and women (P < 0.05).
[a] n = 1,150.

3. Results

Table 1 presents characteristics of the study population according to sex. The age range was 70–84 years and the mean age was 75.7 (SD = 3.8) years. The female participants were slightly younger than the male participants (75.3 ± 3.7 years vs. 76.1 ± 3.8 years). Body mass index was significantly greater in women than in men. The participants had IADL disability (13.5%), mobility disability (13.0%), and physical frailty (6.4%). The average 4-m usual gait speed measured in two trials with four different testing protocols was significantly faster in men than in women (all, P < 0.05).

Table 2 presents usual gait speed for trials 1 and 2, determined using the four different testing protocols. The reliability of the four different testing protocols was excellent, with ICC ≥ 0.90 and coefficient of variation > 0.05. With a dynamic start, usual gait speed in the second trial was faster than that in the first trial (P < 0.001). The usual gait speed recorded with a static start and an automatic timer was statistically slightly faster than that in the first trial (P = 0.013). In a static start with a manual timer, there was no statistically significant difference between trials 1 and 2 (P = 0.660).

Fig. 1A, B shows the results of simple linear regression analyses for usual gait speed determined with automatic and manual timers. The correlations between the two timers for usual gait speed in a dynamic start (r = 0.90) and static start (r = 0.88) were strong (all P < 0.001). In a comparison of testing protocols with the two timers, significant coefficients of determination (R^2) were obtained for usual gait speed ($R^2 = 0.81$, standard error of estimate [SEE] 0.11 m/s kg in dynamic start and $R^2 = 0.78$, SEE = 0.12 m/s in static start). The discrepancy between automatic and manual timers was assessed using Bland-Altman plots at the individual level using two protocols (Fig. 1C, D). There was systematic (constant) bias (i.e., difference between automatic and manual timer methods), with underestimation of usual gait speed (bias 0.0695 m/s, 95% CI 0.063 to 0.076 for dynamic start; bias 0.0702 m/s, 95% CI 0.063 to 0.077 for static start) by the manual timer in both start positions. In both start positions, proportional bias between automatic timer and manual timer was noted for measurement of usual gait speed (r = 0.333, P < 0.001 for dynamic start; r = 0.378, P < 0.001 for static start). Fig. 2A, B shows the results of simple linear regression analyses for usual gait speed determined by dynamic start

Table 2
Reliability of gait speed testing with different protocols.

	Mean (SD)		ICC (3,1)	95% CI	CV %
	First test	Second test			
4-m usual gait speed measures					
Automatic timer (ultrasonic sensor), dynamic start, m/s	1.17 (0.25)	1.21 (0.25) **	0.90	0.89-0.91	0.05
Manual timer (stopwatch), dynamic start, m/s	1.10 (0.22)	1.14 (0.22) **	0.92	0.91-0.93	0.04
Automatic timer (ultrasonic sensor), static start, m/s	1.13 (0.25)	1.14 (0.25) *	0.92	0.90-0.92	0.05
Manual timer (stopwatch), static start, m/s	1.06 (0.21)	1.06 (0.21)	0.92	0.92-0.93	0.04

Note: CI = confidence interval; ICC = intraclass correlation coefficient; CV = coefficient of variation.
Significantly different between first test and second test ($^*P < 0.05$, $^{**}P < 0.001$).

and static start methods. The correlations between devices for usual gait speed with automatic (r = 0.85) and manual timers (r = 0.87) and two start positions were high (all, P < 0.001). In a comparison of testing protocols using two start positions, moderate to substantial coefficients of determination (R^2) were obtained for usual gait speed ($R^2 = 0.73$, SEE = 0.13 m/s kg with the automatic timer and $R^2 = 0.76$, SEE = 0.11 m/s with the manual timer). The discrepancy between dynamic start and static start was assessed using Bland-Altman plots at the individual level using two timer protocols (Fig. 2C, D). There was systematic bias (i.e., difference between dynamic and static start methods), with underestimation of usual gait speed during a static start using both timer methods. Bland-Altman plots indicated no significant proportional bias between dynamic start and static start with an automatic timer (r = 0.031, P = 0.285). In contrast, proportional bias was noted for the difference between dynamic start and static start with a manual timer, with underestimation of the usual gait speed (static start with

manual timer) increasing with increasing usual gait speed (r = 0.113, P < 0.001).

Fig. 3A, B compares the prevalence rates of slowness by sex, based on different diagnostic criteria according to usual gait speed using the four different testing protocols. By applying these different cut-off points to our study population, the prevalence of slowness ranged from 2.3 to 5.9% in men and 5.9 to 11.1% in women for < 0.80 m/s, and from 17.1 to 30.5% in men and 26.3 to 45.9% in women for < 1.00 m/s.

4. Discussion

On the basis of the findings, different testing protocols determine different prevalence rates of slowness in a large cohort of community-dwelling older adults. Furthermore, the manual timer with static start method showed a higher prevalence of slowness for men and women
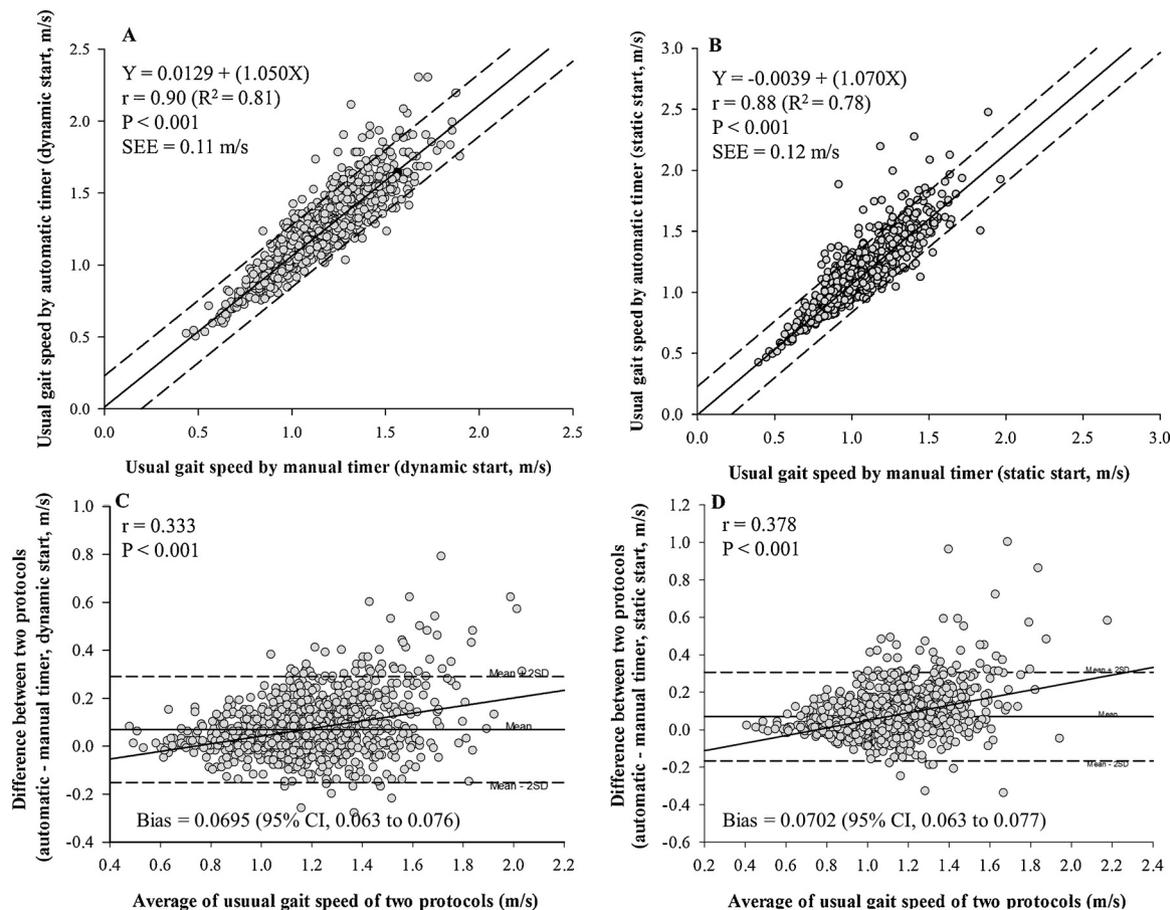
Fig. 1. A–B. Linear regression comparing automatic and manual timer methods. Solid lines, regression; dashed lines, 95% prediction interval. C–D. Bland-Altman plot comparing automatic and manual timer methods. Solid lines, bias (mean difference); dashed lines, limits of agreement (mean difference ± 2 SD).
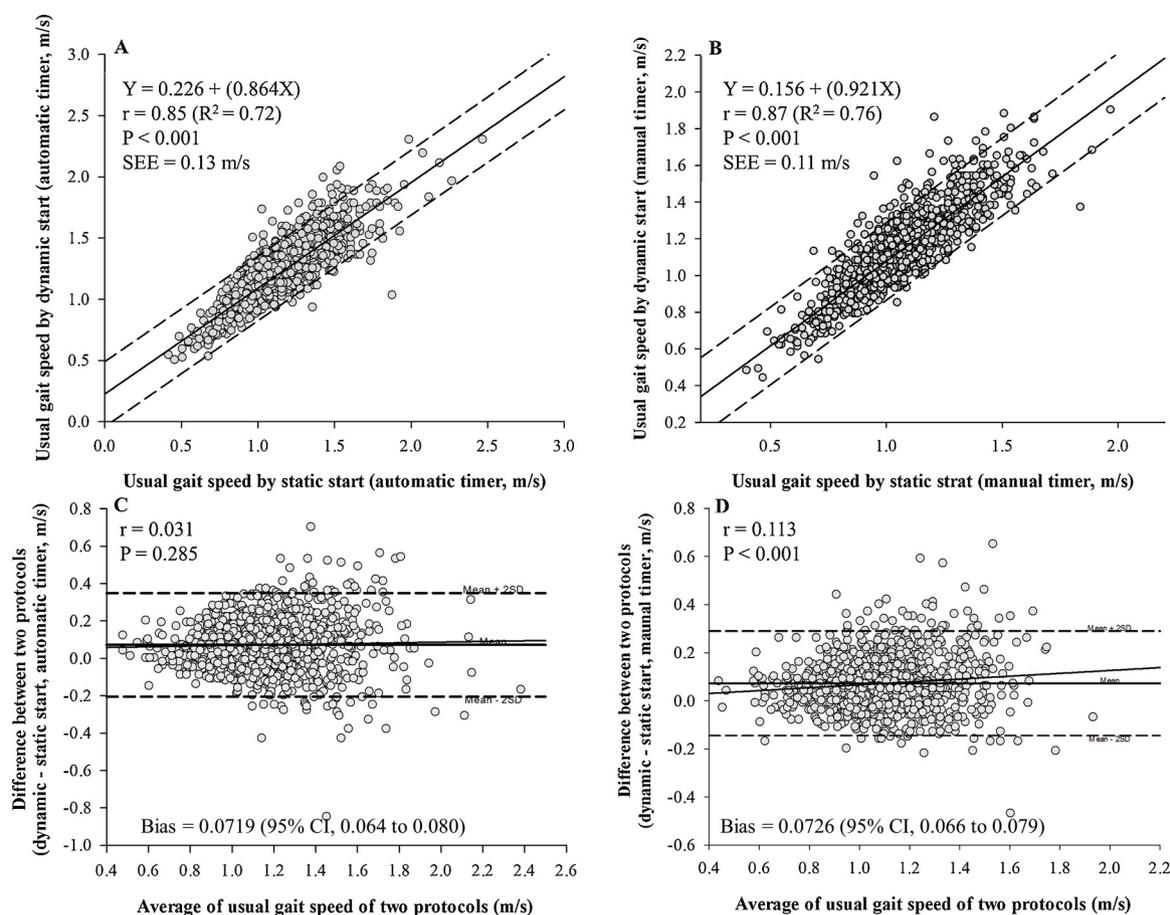
Fig. 2. A–B. Linear regression comparing dynamic start and static start methods. Solid lines, regression; dashed lines, 95% prediction interval. C–D. Bland-Altman plot comparing dynamic start and static start methods. Solid lines, bias (mean difference); dashed lines, limits of agreement (mean difference ± 2 SD).

than the automatic timer with dynamic start method by applying different cut-off points to our study population.

There is a wide range of variability in walking test methodologies according to timing protocols. The manual timer (i.e., handheld stopwatch) is a more accessible instrument and is often used in clinical and research settings to record walking time (Graham, Ostir, Fisher et al., 2008; Peel et al., 2013; Rydwik et al., 2012). However, the handheld stopwatch method requires assessment by trained staff, and intrarater variability and reproducibility of changes over time may vary (e.g., longer time intervals and pre- to postintervention). In our study, assuming the automatic timer is the gold standard, the manual timer systematically underestimated 4-m usual gait speed in both start positions, consistent with findings in previous studies (Karpman et al., 2014; Maggio et al., 2016). Maggio et al. (2016) reported that in 172 non-disabled community-dwellers aged over 65 years, average 4-m usual gait speed measured using a stopwatch (0.91 m/s for men, 0.78 m/s for women) was slower than that using an automatic timer and a tri-axial accelerometer (1.06 m/s for men, 0.89 m/s for women). In validity assessment of stopwatch measurements compared with an automatic dual-beam wireless infrared timing system, outpatients aged 65–99 years showed a mean difference of 0.01 m/s for both 4-m usual and maximum gait speeds (Karpman et al., 2014). Furthermore, study findings that agreed with our results showed proportional bias for manual and automatic timer methods, with underestimation increasing with increasing usual gait speed. For example, the best agreement was seen at slower gait speeds in the variation between the two timing systems. Barry et al. (2018) reported no statistically significant difference between mean usual gait speed (4.27-m) recorded using a radio-frequency identification (RFID)-based system and stopwatch in 50 geriatric outpatients aged 80.9 ± 8.0 years. However, in the Bland-

Altman plot of the difference in gait speed measurements between the RFID device and the stopwatch, the 95% CIs of the upper and lower mean differences indicate that the potential range of individual mean differences was 0.08-0.09 m/s, with increasing usual gait speed. Based on our findings, individuals likely to have faster gait speed were more likely to show bias in measurements using an automatic timer and a stopwatch. Therefore, the automatic timer may be more useful for measurement of gait speed than a stopwatch in healthy older community-dwelling adults in clinical and research settings. In starting protocols, standardized acceleration and deceleration distances are not established and the lack of perceived methodological influence is perhaps best shown by the lack of detailed description of the walk test procedures in many studies (Graham, Ostir, Fisher et al., 2008). This study found a significant difference in gait speeds (0.072 and 0.073 m/s) measured with a dynamic or static start two timer protocols. Similar to our results, 4-m usual gait speed calculated without an acceleration phase was slower than gait speed calculated with a dynamic start protocol, using acceleration and deceleration distances of 2 m or several steps (Bisca et al., 2018; Sustakoski et al., 2015).

Slowness may be as important as vital signs in screening of older adults (Cummings et al., 2014; Studenski et al., 2003, 2011). Studenski et al. (2003) reported that prognostic values of gait speeds < 1.0 m/s in 6-m usual gait speed measured by a stopwatch with static start suggested healthier aging. The slowness has been typically defined as a gait speed less than 0.8 m/s in community-dwelling older people (Abellan van Kan et al., 2009; Studenski et al., 2011). The prevalence of slowness varies widely in diagnosis of sarcopenia and frailty phenotypes, depending on the assessment protocol for usual gait speed and the reference values used (Studenski et al., 2014; Theou et al., 2015; Yuki et al., 2018). Our results showed that the manual timer with static start
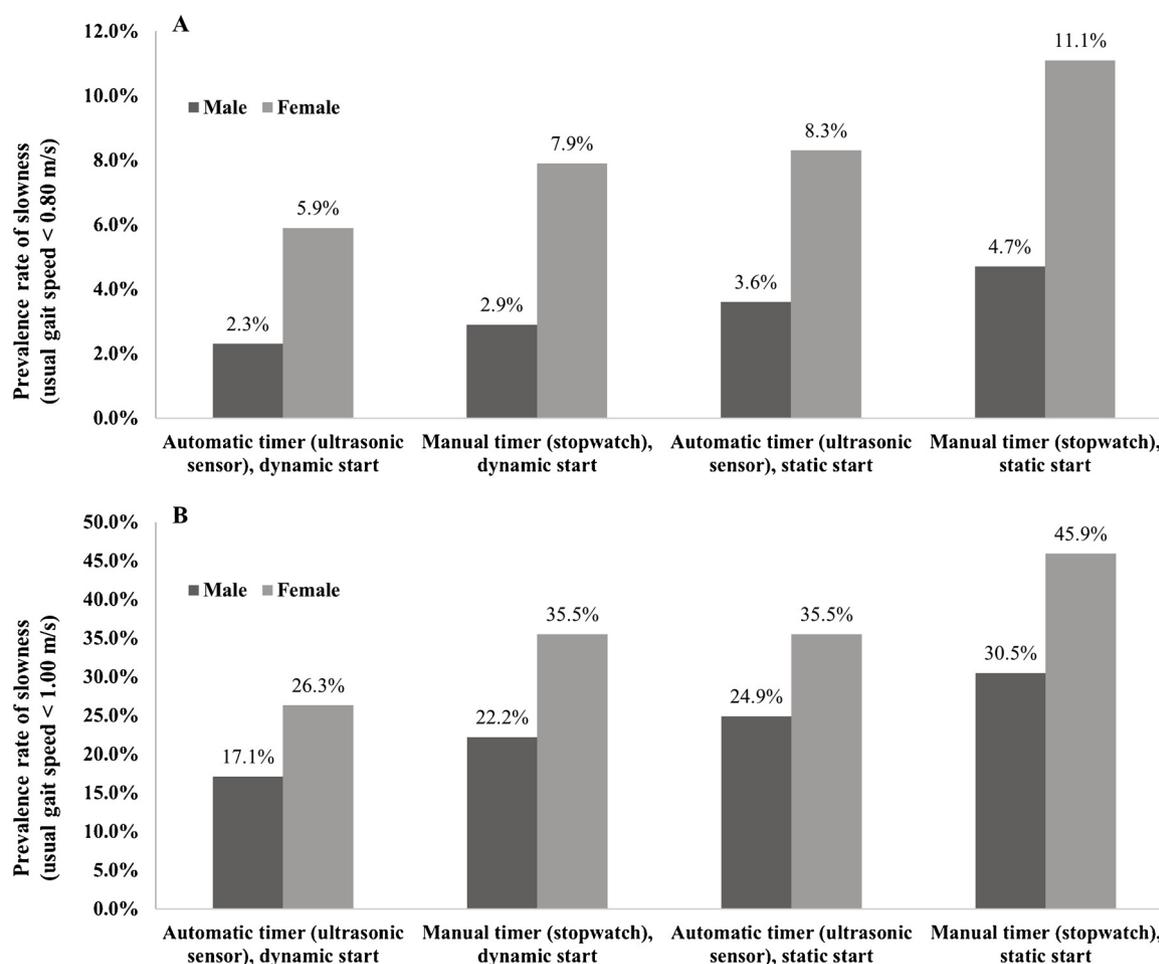
Fig. 3. A–B. Prevalence rate of slowness obtained with different testing protocols for 4-m usual gait speed.
*All values were significantly different between male and female subjects, with P < 0.001.

method showed a higher prevalence of slowness in men and women than the automatic timer with dynamic start. In particular, these differences showed higher gait speed cut-off points of 1.0 m/s than 0.8 m/s. It is possible that individuals who were likely to have faster gait speeds were more likely to show bias in measurements taken with an automatic timer and a stopwatch. Kim et al. (2017) defined as usual gait speed < 1.0 m/s using a 5-m dynamic start with acceleration and deceleration phases of 3 m each from the original definition of slow gait speed (< 0.65 m/s and < 0.76 m/s) measured by 4.5-m static start in the Fried frailty index (Fried et al., 2001). Furthermore, the usual gait speeds measured by dynamic start protocols were significantly faster than those measured by static start protocols (Wang, Chen, Lin, Liu, & Chen, 2012). Similar to our results, the Health, Aging and Body Composition Study involving 2580 participants aged 76–85 years showed that the prevalence of slowness was 8.5% in men and 31.0% in women for < 0.80 m/s, and 27.2% in men and 44.2% in women for < 1.0 m/s in 6-m usual gait speed measured by a stopwatch with static start (Studenski et al., 2014). In a pooled analysis including cross-sectional data from 4683 non-disabled community-dwelling adults aged ≥ 65 years from six cohort studies in Japan showed that mean values of usual gait speed using 5- or 10-m test dynamic start with stopwatch protocols (with acceleration and deceleration phases of 3 m each) tend to be slower than those reported in western cohort studies using static-start protocols (Seino et al., 2014). Yuki et al. (2018) reported a prevalence of slowness of 4.6% in men and 10.3% in women for < 1.00 m/s in 10-m usual gait speed measured using light sensors with static start in community-dwelling Japanese aged 65–84 years To the best of our knowledge, this is the first study to investigate prevalence of slowness

using different testing protocols for 4-m usual gait speed in a large group of non-disabled community-dwelling older adults. Consequently, it is difficult to compare usual gait speed across studies with dissimilar or unspecified testing protocols. Our findings may serve as a guide for clinicians and researchers; for example, depending on the measurement protocol used, the prevalence of slowness may vary with respect to the reference values for the diagnostic criteria in older populations.

Our study has some limitations. We examined the usual gait speed based on starting protocols and timing devices in a cross-sectional study. Our subjects were community-dwelling older adults in a research setting; therefore, our results may not be applicable to populations in nursing homes, hospitals, or other institutions or to individuals who use walking aids (e.g., cane and walker), which limits their generalizability. In the future, additional studies should be performed on individuals who use walking aids using an automated timing system that can differentiate between the participant's foot and the walking aid.

In conclusion, this study indicated that 4-m usual gait speed measured under different testing protocols was able to determine different prevalence rates of slowness among non-disabled community-dwelling older adults. Our study revealed that depending on the measurement protocols used for assessing the gait speed, the prevalence of slowness may vary for the diagnostic criteria compared to the reference values. Meanwhile, the manual timer with the static start method showed a higher prevalence of slowness than the automatic timer with dynamic start protocol among non-disabled community-dwelling individuals. Furthermore, the automatic timer may be useful for measuring gait speed changes in individuals likely to have faster gait speed in community-based research settings. Our findings may be applied to studies

conducted in community settings, and it is important that clinicians and researchers be aware of the significant impact of the testing protocol on the measured usual gait speed, particularly when assessing prevalence of slowness. Future longitudinal studies are needed to determine clinically meaningful changes over time and to develop a clinical standardized protocol for testing the usual gait speed as the gold standard reference, before to recommend the usefulness of the automatic timer in clinical and research settings.

Conflict of interest

The authors confirm no known conflict of interest regarding the work described in the manuscript.

Acknowledgments

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.archger.2018.12.009.

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