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Tester and testing procedure influence clinically determined gait speed

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ABSTRACT

Background: There is a clinical need to be able to reliably detect meaningful changes (0.1 to 0.2 m/s) in usual gait speed (UGS) considering reduced gait speed is associated with morbidity and mortality.
Research question: What is the impact of tester on UGS assessment, and the influence of test repetition (trial 1 vs. 2), timing method (manual stopwatch vs. automated timing), and starting condition (stationary vs. dynamic start) on the ability to detect changes in UGS and fast gait speed (FGS)?
Methods: UGS and FGS was assessed in 725 participants on a 8-m course with infrared timing gates positioned at 0, 2, 4 and 6 m. Testing was performed by one of 13 testers trained by a single researcher. Time to walk 4-m from a stationary start (i.e. from 0-m to 4-m) was measured manually using a stopwatch and automatically via the timing gates at 0-m and 4-m. Time taken to walk 4-m with a dynamic start was measured during the same trial by recording the time to walk between the timing gates at 2-m and 6-m (i.e. after 2-m acceleration).
Results: Testers differed for UGS measured using manual vs. automated timing ($p = 0.02$), with five and two testers recording slower and faster UGS using manual timing, respectively. 95% limits of agreement for trial 1 vs. 2, manual vs. automated timing, and dynamic vs. stationary start ranged from ± 0.15 m/s to ± 0.20 m/s, coinciding with the range for a clinically meaningful change. Limits of agreement for FGS were larger ranging from ± 0.26 m/s to ± 0.35 m/s.
Significance: Repeat testing of UGS should performed by the same tester or using an automated timing method to control for tester effects. Test protocol should remain constant both between and within participants as protocol deviations may result in detection of an artificial clinically meaningful change.

1. Introduction

Gait speed is proposed as the 6th or 'functional' vital sign [1]. Reductions in usual gait speed (UGS) below 1.0 m/s are associated with declines in health and life expectancy [2]. To longitudinally monitor an individual's UGS, there is a need for reliable measures which can detect clinically meaningful changes. Meaningful changes in UGS are reported to range from 0.1 m/s to 0.2 m/s [3,4].

There is no single accepted method of assessing UGS [1]. A common approach is to use a stopwatch to manually time how long an individual takes to walk 4-m from a stationary start [5], although numerous variations have been reported [6–8]. Previous studies have explored the impact of different testing protocols on UGS measurement (see [9] for review); however, analyses were often performed during asynchronous tests where methodological factors were assessed during different trials.

The purpose of this study was to use synchronous testing to explore the impact of tester on UGS assessment, and assess the influence of test repetition (trial 1 vs. 2), timing method (manual stopwatch vs. automated timing), and starting condition (stationary vs. dynamic start) on both UGS and fast gait speed (FGS).

2. Materials and methods

Individuals aged ≥5 years who could ambulate ≥10-m were invited to participate. There were no exclusion criteria in terms of health status or use of gait assistive devices. Prior Institutional Review Board approval was obtained and all participants provided written informed consent.

Gait speed was assessed on a permanent 8-m course (Fig. 1A). Tape lines were positioned every 2-m orthogonal to the direction of travel.

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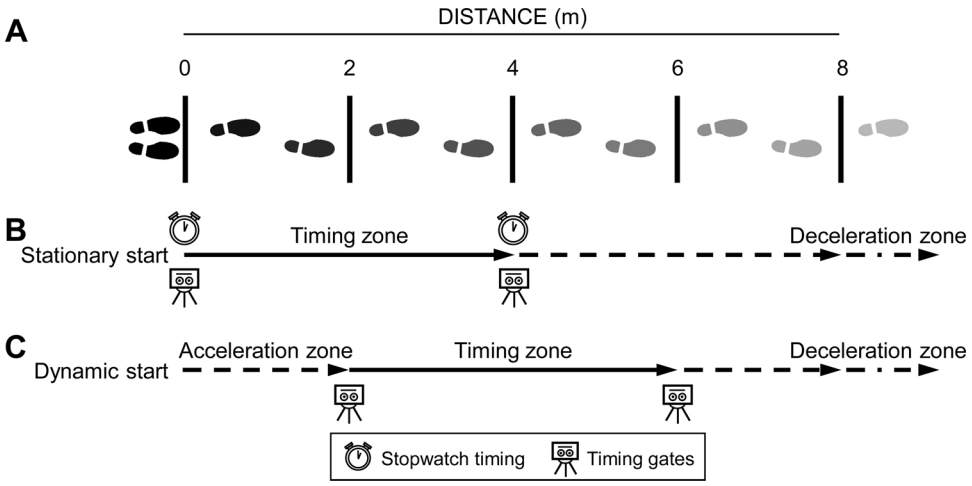

Fig. 1. Schematic of testing set-up. Participants performed tests on an 8-m course with tape lines positioned every 2-m (A). Time to walk 4-m from a stationary start was simultaneously measured manually using a stopwatch and automatically via timing gates positioned at 0-m and 4-m (B). Time taken to walk 4-m with a dynamic start was measured during the same trial via timing gates at 2-m and 6-m (i.e. after 2-m acceleration). Participants continued walking during each trial until the tape at 8-m before decelerating.

Infrared timing gates (TF100 multi-beam timing system; TracTronix, Lenexa, KS) positioned at ankle height were centered on the lines at 0, 2, 4 and 6-m and were triggered when any part of the leading leg crossed the plane of the gate. Participants were positioned with their feet together behind the 0-m line, and were instructed to continue walking during each test until passing the 8-m tape line.

Testing was performed by one of 13 testers trained by a single experienced researcher (S.J.W.) to follow the same procedure and script. The general procedure and script followed gait speed testing in the Short Physical Performance Battery (SPPB) [10]. For UGS, the instruction was: *"Walk at your normal speed, just as if you were walking down the street."* The tester demonstrated the test and participants performed a practice trial before completing two timed trials. The procedure was repeated to measure FGS with the instruction: *"I want you to walk as quickly, but as safely as you can without running."*

Time to walk 4-m from a stationary start (i.e. 0-m to 4-m) was simultaneously measured manually using a stopwatch and automatically via the timing gates positioned at 0-m and 4-m (Fig. 1B). The stopwatch was started as soon as the participant's foot began lifting and stopped when any part of their leading foot crossed the plane of the line at 4-m. Testers stood at the 4-m line during testing to monitor the leading foot. Time taken to walk 4-m with a dynamic start was measured during the same trial via the timing gates at 2-m and 6-m (i.e. after 2-m acceleration) (Fig. 1C).

The influence of tester on UGS from a stationary start was determined from the difference in gait speed between manual and automated timing methods, with the latter removing tester effects. A linear mixed model with tester as a random effect was used to assess between testers. Intraclass correlation coefficients ($ICC_{2,1}$) evaluated reliability between test conditions for both UGS and FGS. Agreement between manually timed trials 1 and 2, manual and automated timing methods, and dynamic and stationary start conditions for both UGS and FGS was evaluated using the Bland-Altman method and calculating 95% limits of agreement (LOA) [11]. The trial with the maximum gait speed was used for analyses exploring the impact of timing method or starting condition, as per the SPPB [10].

3. Results

There were 725 participants (Table 1). Testers assessed an average of 56 ± 36 participants. There were differences between testers for UGS measured using manual versus automated timing ($p = 0.02$). Five testers recorded slower and two testers recorded faster UGS using manual versus automated timing, respectively (all $p < 0.05$). The largest mean difference between testers was 0.095 m/s (95% confidence interval, 0.050-0.141).

Reliability for manually timed trial 1 vs. 2, manual vs. automated timing, and stationary vs. dynamic start for both UGS and FGS was excellent ($ICC_{2,1}$ = 0.93–0.97). Mean differences and 95%LOAs between comparative test conditions are shown in Fig. 2. The 95%LOAs for UGS ranged from ± 0.15 m/s (Fig. 2B) to ± 0.20 m/s (Fig. 2A&C). Sixteen percent of participants had > 0.1 m/s difference in UGS

Table 1
Participant characteristics (n = 725).

Characteristic	
Age (yr)	
Mean ± SD	45.4 ± 17.7
Range	5.6–89.9
Median (IQR)	46.8 (32.0–61.6)
Age frequency (N)	
< 18 yrs	34
18 to < 35 yrs	205
35 to < 50 yrs	166
50 to < 65 yrs	220
> 65 yrs	100
Sex (M:F)	
N	207:518
%	29:71
Height (m)	
Mean ± SD	1.66 ± 0.11
Range	1.10–1.97
Median (IQR)	1.66 (1.60–1.72)
Weight (kg)	
Mean ± SD	74.8 ± 19.3
Range	18.2–155.1
Median (IQR)	72.2 (61.4–85.2)
BMI (kg/m^2)	
Mean ± SD	26.9 ± 6.2
Range	13.8–49.5
Median (IQR)	25.5 (22.6–30.3)
Gait assistive device (Yes:No)	
N	14:711
%	2:98
Usual gait speed (m/s)[†]	
Mean ± SD	1.39 ± 0.22
Range	0.38–2.12
Median (IQR)	1.38 (1.27–1.54)
Fast gait speed (m/s)[†]	
Mean ± SD	1.93 ± 0.32
Range	0.45–3.64
Median (IQR)	1.92 (1.76–2.12)

SD = standard deviation; IQR = interquartile range.
[†] Measured manually (stopwatch) from a stationary start as the maximum from 2 repeat trials.

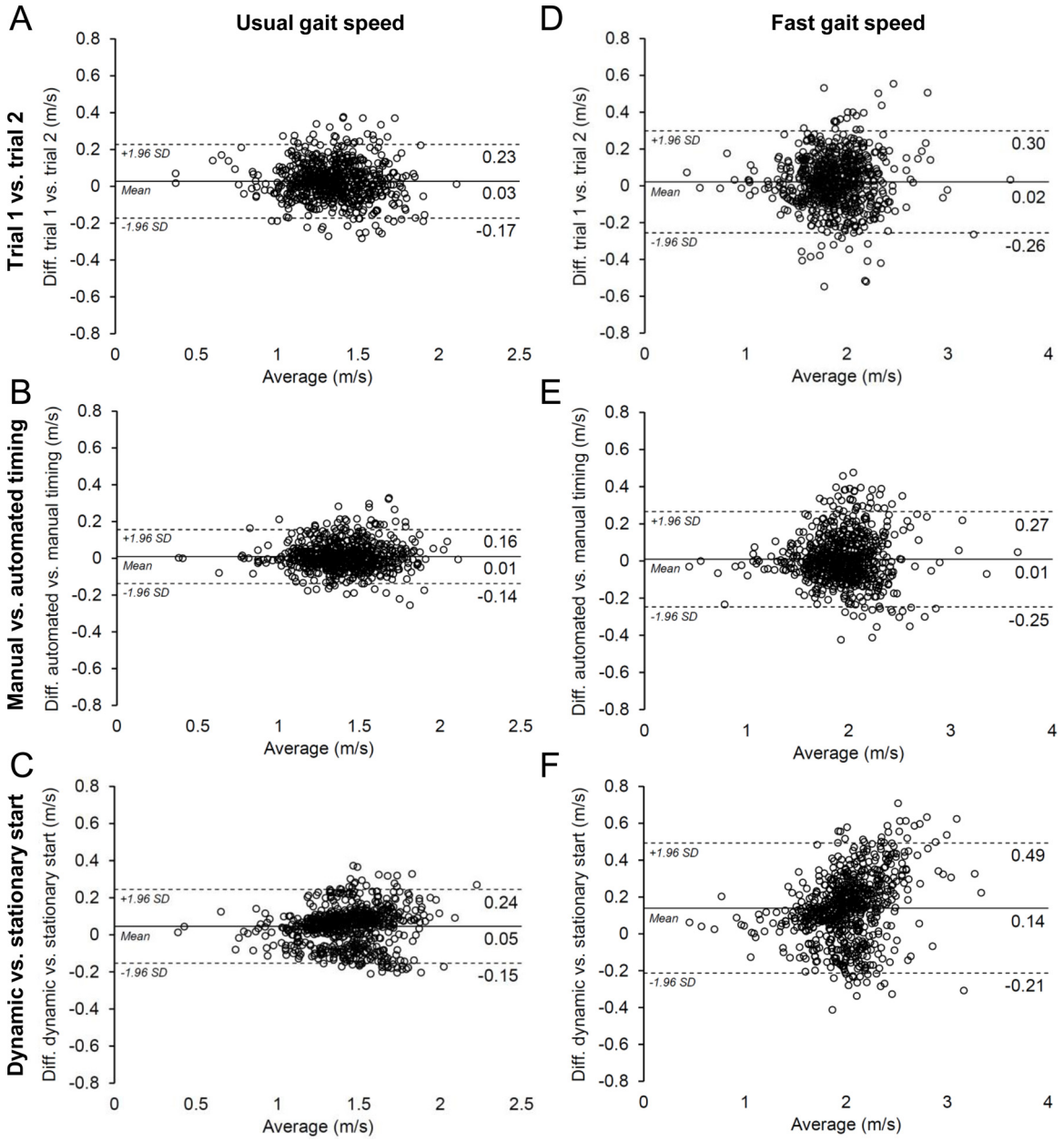

Fig. 2. Bland-Altman plots of agreement (± 95% levels of agreement) for trial 1 vs. 2 (A & D), manual vs. automated timing (B & E), and dynamic vs. stationary (C & F) for usual and fast gait speed.

between manual and automated timing methods. There was no difference between manual and automated timing methods for participants in the slowest (< 1.10 m/s) and fastest (> 1.61 m/s) UGS quartiles (0.02 m/s; 95%LOA, ± 0.13 m/s and -0.01 m/s; 95%LOA, ± 0.15 m/s, respectively).

The 95%LOAs were wider for FGS ranging from ± 0.26 m/s for manual vs. automated timing (Fig. 2D) to ± 0.35 m/s for a dynamic vs. stationary start (Fig. 2F). Participant UGS and FGS was 2.9% (95%CI, 2.4 to 3.4%) and 6.3% (95%CI, 5.7 to 6.8%) faster with a dynamic vs. stationary start, respectively.

4. Discussion

These data show both tester and testing protocol influence clinically determined gait speed. Despite testers being identically trained and using explicit instructions, UGS differed between testers when manual vs. automated timing was used. The origin of the discrepancy is not known, but is likely due to subtle differences in stopwatch triggering between testers. The observation raises questions regarding the inter-tester agreement of manually timed UGS and indicates repeat testing should be performed by the same tester. Alternatively, automated timing could be implemented, when finances permit, as it removes tester effects and may improve the questioned reliability of manual timing [12].

Further support for automated timing is provided by the 95%LOA between UGS determined using manual vs. automated timing. The mean difference in UGS between timing methods (0.01 m/s) was in the range of that previously reported during synchronous testing [13], but the 95%LOA (± 0.15 m/s) was in the range for a meaningful change (0.1 to 0.2 m/s). If we consider UGS determined from automated timing is the 'gold standard' as it removes tester effects, UGS determined via manual timing may not provide acceptable agreement as 16% of participants had a potentially meaningful difference (± 0.1 m/s) between timing methods.

Previous systematic reviews were unable to conclude whether gait speeds following a dynamic start differed from those following a stationary start [7,9]. Our data show UGS and FGS are 0.05 m/s (95%CI, ± 0.01 m/s) and 0.14 m/s (95%CI, ± 0.01 m/s) faster following an initial 2-m acceleration. The benefit of initial acceleration on UGS (+0.05 m/s) in our cohort was less than that reported by Sustakoski et al. [14] (+0.16 m/s) who studied slower (mean speed = 0.97 m/s), older adults (mean age = 77 yrs). It is possible older or slower individuals benefit more from a dynamic start as they can require 2.5-m before steady state walking is achieved [15]. However, the benefit of an acceleration zone on UGS in our cohort did not differ between young (18–35 yrs) and older (> 65 yrs) adults ($p = 0.94$, *unpaired t-test*) or in individuals with the slowest (< 1.0 m/s) and fastest (> 1.5 m/s) UGS ($p = 0.82$, *unpaired t-test*).

Overall, our cumulative data suggest limitations in the assessment of UGS using manual timing methods with both tester and testing protocol potentially impacting the ability to detect a clinically meaningful change over time. To improve the assessment of UGS, automated timing can be considered (when finances permit) to control the influence of tester and the testing protocol should remain constant.

CRediT authorship contribution statement

Stuart J. Warden: Conceptualization, Methodology, Validation, Resources, Data curation, Writing - original draft, Visualization, Supervision, Project administration, Funding acquisition. **Allie C. Kemp:** Validation, Investigation, Data curation, Writing - review & editing. **Ziyue Liu:** Formal analysis, Writing - review & editing. **Sharon M. Moe:** Methodology, Resources, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors have no conflicts of interest.

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