



Gait Speed

Validity of Measurement in Patients With Severe Chronic Lung Disease, Including Prognostic and Practical Implications

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Gait speed is used increasingly to predict function and future well-being among healthy elderly people as well as for those with long-term medical conditions. When selecting outcome measures such as walking speed, it is important to include the circumstances under which the measurement is made to avoid bias and ensure accurate recommendations. We completed a retrospective chart review of walking test results from patients with chronic lung disease to demonstrate the practical implications of reporting gait speed from either a standing or walking start. In this cohort of 99 patients (55 with COPD), gait speed from a standing start underestimated usual gait speed (difference = 6.1 m/min [5.3-6.9 m/min]) with poor agreement (8 m/min [6.6-9.4 m/min]) between the two methods of reporting speed. The standing start speed incorrectly identified some patients as at higher risk for poor health. In a practical example, gait speed from a standing start produced 11 false-negative evaluations of the ability to complete a road crossing at usual speed. We present walking speeds using both methods, which illustrate the importance of construct validity and measurement protocol.

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Usual gait speed (\bar{s}_{usual}) is a simple, accessible, and inexpensive indicator used in a variety of conditions as a marker of a patient's health status as well as a measure of specific capacity and function.¹⁻⁴ Gait speed is the key component of the Short Physical Performance Battery (SPPB), which evaluates balance, gait speed, and getting in and out of a chair, all of which represent essential elements of functional capability and independent living.⁵ In the SPPB, gait speed is measured from a standing start, and

a substantial body of work has evolved regarding its prognostic value. Fast gait speed (\bar{s}_{fast}), measured when an individual is asked to walk fast, has also demonstrated prognostic⁶ and clinical^{7,8} utility.

As with any measure of physical function, the conditions under which a construct is measured influence its measurement properties, such as validity, reliability, and responsiveness. Protocols measuring walking speed have differed by their distance and

ABBREVIATIONS: \bar{s}_{0-4m} = average speed over 4 m from a standing start; \bar{s}_{fast} = fast gait speed; SPPB = Short Physical Performance Battery; \bar{s}_{usual} = usual gait speed

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type of start (if reported at all⁹). Although the test distance used varies considerably in surveys of walking test methodology,^{10,11} the most common distance and start were 10 m and walking (rolling), respectively. When averaged after excluding a brief walking (rolling) start, walk speed measured over short distances^{12,13} is valid and remains consistent with speed determined over long distances.⁸ However, a standing start adds the physical quantity of acceleration. The average speed will underestimate \bar{s}_{usual} because of this acceleration phase. For example, Asher et al¹⁴ observed that a standing start gait speed over a short distance of 8 feet in an older population was lower than the reported norm measured following a rolling start.¹² In this report, which included the reference values for usual walking speed, the authors cautioned that the comparative speed should not include an acceleration phase. Bohannon et al¹⁵ reported that several meters were provided for acceleration (positive or negative) at each end of the test distance, and the stopwatch was only started as the subjects crossed the starting line and was stopped when they passed the finish line. In a subsequent systematic review of normal walking speed,¹² for an article to meet inclusion criteria, gait speed had to be measured with an allowance for acceleration unless the distance was greater than 25 m. Over short distances, the difference between a standing and a rolling start has been reported as > 7.8 m/min.^{10,16} The inaccuracy of estimating \bar{s}_{usual} from walking speed measured from a standing start may have important clinical implications in patients with severe chronic lung disease.

We hypothesized that gait speed, averaged over a short distance (4 m), from a standing start ($\bar{s}_{0-4\text{m}}$) would be less than \bar{s}_{usual} . We used a confusion matrix to describe the accuracy of $\bar{s}_{0-4\text{m}}$ on a classification model used to evaluate the risk of negative health events given that the true value was \bar{s}_{usual} . We also applied the results to a practical example of crossing a street at signal-controlled pedestrian crossings to illustrate an important issue of validity with this simple test of walking ability.

We completed a retrospective analysis of all test results in patients with chronic lung disease who were assessed for ambulatory oxygen therapy at our facility. This use of patient data was approved by the Joint West Park Healthcare Centre/Toronto Central LHIN/The Salvation Army Toronto Grace Health Centre Research Ethics Board. Walking times were measured using optical sensors as part of a protocol with demonstrated reliability and validity, which has been described elsewhere.^{8,17,18} Patients were requested to walk, using their habitual

walking aid, for 18 m at their usual speed, turn around a cone, and return at a fast speed. The timer was triggered from the first movement and by optical sensors placed at 4 and 14 m away. Average walking speed was calculated over the first 4 m ($\bar{s}_{0-4\text{m}}$) as well as over the subsequent 10 m between the first and second sensors (\bar{s}_{usual}). Speed was also calculated during return over the 10 m between the second and first sensors (\bar{s}_{fast}).

The minimal clinically important difference in speed in reference to clinical prognosis has been reported in different cohorts, including those with respiratory disease.¹⁹⁻²¹ Because walking is common and important regardless of health status, we used the most conservative value reported (1.8 m/min), thereby demanding the greatest precision to qualify the agreement²² between $\bar{s}_{0-4\text{m}}$ and \bar{s}_{usual} . The speed required to safely cross a city street is functionally important. In most cities, pedestrian crossing light timings are regulated by local guidelines and follow recommendations of the National Association of City Transportation Officials.²³ Timing typically includes three phases: (1) a solid white or green invitation to cross, which is fixed, for example at 7 s, but is dependent on the next phase; (2) a flashing amber light indicating that a pedestrian can complete the crossing but should not start to cross; and (3) a red “don’t walk” meaning that automobile traffic has been given the signal to proceed. Together the green and amber phases allow a complete crossing at < 60 m/min.²³ However, a speed of 72 m/min is often reported as the minimum speed required to cross because it assumes crossing occurs at the end of the green phase, that is, at the start of the amber signal. This interpretation, which implies that there are no phases, incorrectly applies the faster speed to the total available crossing time.²⁴ Therefore, if they stood at the curb on starting to cross four traffic lanes, equaling a total distance of 14 m, one could estimate the proportion of patients that could safely cross depending on whether they started at the beginning or the end of the green signal (when the amber warning signal appears) from the $\bar{s}_{0-4\text{m}}$, \bar{s}_{usual} , and \bar{s}_{fast} .

The data (149 tests) retrieved was from 99 consecutive patients with chronic lung disease (male to female ratio, 48:51; age, 71 years [SD, 12 years]; BMI, 25.6 kg/m² [SD, 7.5 kg/m²]; and PaO₂, 65 mm Hg [SD, 8 mm Hg]) who were assessed for their exercise oxygen requirements from April 2013 to February 2017. Sixty-eight patients had a primary diagnosis of COPD (FEV₁, 35% of predicted [SD, 17% of predicted]; FEV₁/FVC, 38% [SD, 15%]). All patients walked at their usual and fast speeds

without stopping, but the cohort demonstrated walking impairment ($\bar{s}_{\text{usual}} = 55.2$ m/min [52.2-58.1 m/min], 46% of predicted and $\bar{s}_{\text{fast}} = 73.1$ m/min [69.5-76.7 m/min]). The $\bar{s}_{0-4\text{m}}$ (49.1 m/min [46.2-51.9 m/min], 41% of predicted) measured from standing was significantly less (6.1 m/min [5.3-6.9 m/min]) than the \bar{s}_{usual} , with limits of agreement of 8.0 m/min [6.6-9.4 m/min], demonstrating homoscedasticity (Fig 1). The agreement, determined with suitable precision, is outside the clinically important difference cautioning that an individual's $\bar{s}_{0-4\text{m}}$, even after correcting for bias, is not an acceptable substitute for \bar{s}_{usual} . To put the results in context, although more than one-half of the patients in our study (56 of 99 people) used a walking aid, it had no significant effect on the difference between the $s_{0-4\text{m}}$ and the s_{usual} .

Lusardi's flag model,²⁵ using \bar{s}_{usual} for interpreting outcomes of screening and interventions, provides a risk categorization of the likelihood of encountering the onset of illness, frailty, falls, disability, and mortality. Cut points for \bar{s}_{usual} prompt a green (low), yellow (moderate), or red (high) flag for risk of adverse outcomes. Table 1 describes the performance of $\bar{s}_{0-4\text{m}}$ in prompting the same flag as the \bar{s}_{usual} . The prevalence of true red flags

($\bar{s}_{\text{usual}} < 36$ m/min) in our sample was 8 of 99. Of these eight red flags, categorization of risk using the $\bar{s}_{0-4\text{m}}$ resulted in 12 false-positive results and 1 false-negative result, with an accuracy $[(\sum \text{TP} + \sum \text{TN})/n]$ for $\bar{s}_{0-4\text{m}}$ prompting the same flag as \bar{s}_{usual} of 87%. The prevalence of yellow flags was 58 of 99 and the $\bar{s}_{0-4\text{m}}$ prompted 13 false-positive results and 13 false-negative results, with an accuracy of 73%.

The practical example of crossing a street shows that if one assumes that patients walk only at their usual speed as measured using the $\bar{s}_{0-4\text{m}}$, only seven of 99 subjects would be identified as having greater than the minimum speed to traverse a crosswalk, assuming that they started at the end of the green light (beginning of the amber warning light). In contrast, their true speed, \bar{s}_{usual} , suggests that 16 of 99 people could cross safely. If crossing when the green light first appears, and using $\bar{s}_{0-4\text{m}}$, only 22 of 99 people would be identified as having greater than the minimum speed to safely traverse a crosswalk, whereas when \bar{s}_{usual} is applied, 33 of 99 people would exceed this speed.

Our protocol allows us to examine the practical example of whether an individual can cross four lanes (14 m)

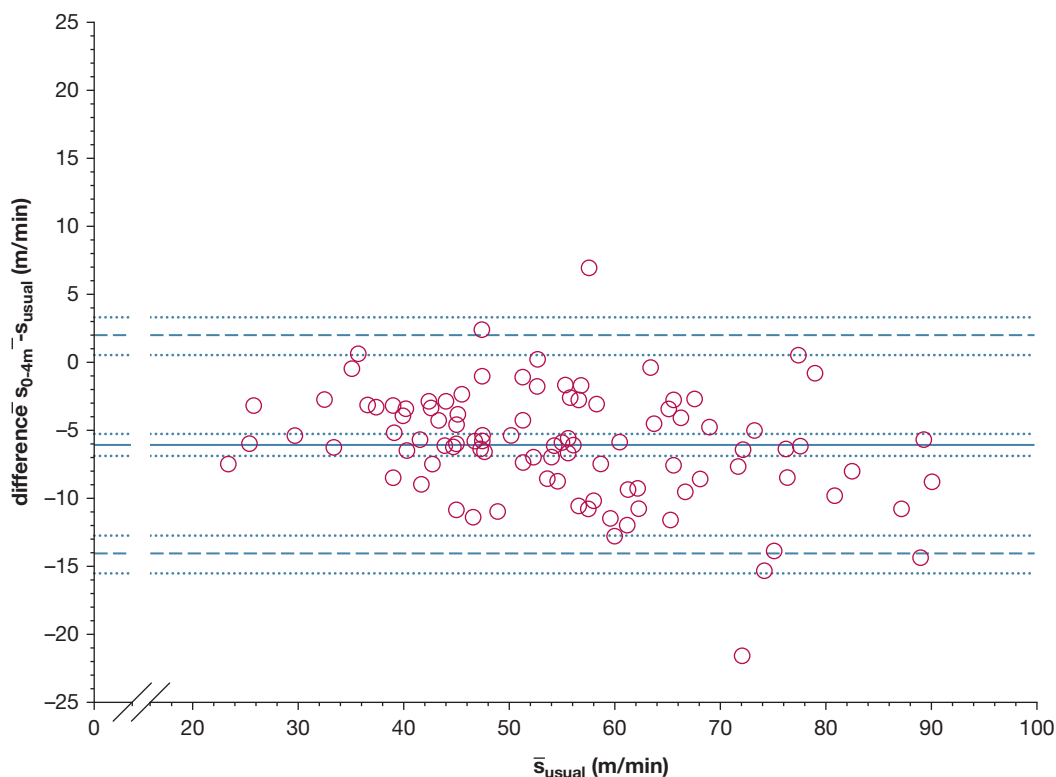


Figure 1 – Bland-Altman plots for agreement between usual gait speed (\bar{s}_{usual}) and the speed measured from a standing start ($\bar{s}_{0-4\text{m}}$). The solid line represents the mean difference (bias). The dashed lines represent the limits of agreement. The 95% confidence limits about each estimate are represented by dotted lines and demonstrate that the agreement was determined with suitable precision.

TABLE 1] Lusardi's Risk Flags Prompted by Different Methods of Measuring Gait Speed

Actual Risk Category	Risk Category Using Standing Start			
	Red < 0.6 m/s	Yellow 0.6 to 1.0 m/s	Green > 1.0 m/s	True Total
Red < 0.6 m/s	7	1	0	8
Yellow 0.6-1.0 m/s	12	45	1	58
Green > 1.0 m/s	0	12	21	33

Bold numbers indicate agreement in classification (true positive and negative) between using \bar{s}_{usual} and $\bar{s}_{0-4\text{m}}$ in prompting the color of flag raised. The remaining cells contain miscategorization when calculating 4 m gait speed from a standing start to estimate usual gait speed. \bar{s}_{usual} = usual gait speed; $\bar{s}_{0-4\text{m}}$ = average speed over 4 m from a standing start.

from a standing start in the time allotted. Our protocol measured how long it took for patients to walk 14 m from a standing start. Knowing each participant's time to trigger the first sensor at 4 m from standing, the time it took for the next 10 m (usual or fast) as well as the timing of phase 1 (2.3 s) and phase 2 (11.7 s) of the crossing signal, the following is true: (1) none of the patients in our sample should expect to cross before the amber warning; (2) 28 of 99 people could cross at \bar{s}_{usual} within both the start plus warning times; (3) 68 of 99 people could cross at \bar{s}_{usual} , and on seeing the warning signal complete the crossing at \bar{s}_{fast} . In other words, 40 of 99 people would have to cross quickly (\bar{s}_{fast}) at some point, but only 18 of 99 people could not cross if they were walking at their demonstrated \bar{s}_{fast} from the invitation to cross. These reported speeds do not take into account reaction to auditory or visual signals, the impact of weather, road conditions, or fear, nor do they consider curb height or the number of other pedestrians crossing. Some patients may be reassured that they can cross the road safely and others should be advised to walk fast for part or all of the crossing. Some should be cautioned that in their current state, they may have trouble crossing in a timely manner even when walking fast. In some jurisdictions in which many individuals are unable to match the required speed to navigate a local crossing, transportation officials will increase the time allotted by the crossing signals.²³

When using gait speed as a guide, it should be stipulated whether it was measured from a standing or rolling start. The standing start underestimates usual speed^{10,16} and may, as in this example, inaccurately suggest that a patient may not safely cross the road.

The gait speed test was conducted over 18 m. If the 10 m (18 minus 4 at each end) were to be reduced to 4 m or even 2.4 m (8 feet) to accommodate the most severely disabled patient, it is unlikely that this would affect the speed as long as there is at least a 2 m start before

measurement. We observed that even patients with very severe limitations who walk at a speed < 30 m/min (< 0.5 m/s) could still walk for > 3 min.

Two often cited reviews of gait speed protocol, compiling the data from thousands of subjects, deserve comment. Our observations differ from those of Graham et al¹⁰ and Peel et al,¹¹ who reported no statistically significant effect of the type of start on gait speed. However, their conclusions are questionable based on their analytical approach and possibly not meeting assumptions when analyzing independent studies,^{22,26,27} as the same individual did not do the same test using the different protocols. Peel et al¹¹ used correlation analysis and based their conclusions on lack of a statistical association between speed and protocol. In fact, Figure 1 also suggests no association between start type and speed. This lack of association should not mean that the different methods provide results that are in agreement and interchangeable.²² Graham et al¹⁰ presented confidence intervals about the point estimates of gait speed, despite a very large sample size, that span > 20 m/min, whereas the precision of our point estimates of agreement using $n = 99$ span < 3 m/min. Graham et al's¹⁰ precision using independent studies is likely inaccurate,^{26,27} and it would therefore be understandable for them to conclude that there was no statistical significance in the difference they observed (7.8 m/min). Graham et al¹⁰ acknowledged that the absolute difference was likely clinically important and that within-group studies were necessary. Subsequently, two separate groups, Wang et al²⁸ and Sustakoski et al,¹⁶ using a within-subject comparison, came to a similar conclusion, consistent with our observations, that the type of start matters. They noted that gait speed from a standing start was significantly less (7.8 and 10.2 m/min, respectively) than gait speed from a walking start. Wang et al²⁸ also examined distance and concluded that in both older and younger groups, gait speed measured over different distances was not different but only when

using a walking start. We have emphasized, using real-life examples, the clinical and practical significance of these differences, which would result in different conclusions for a group (% predicted) and an individual (red flag for prognosis and ability to cross a street).

In summary, tests such as walking speed determination should use valid estimates of the construct consistent with their intended application. Caution should be used when measuring walking speed from a standing rather than a rolling start, as underestimation of the true gait speed could have important clinical and practical implications.

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