Title: Gait speed as a measure in geriatric assessment in clinical settings: a systematic review

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Running title: Gait speed in geriatric assessment
ABSTRACT

Background: Gait speed is a quick, inexpensive, reliable measure of functional capacity with well documented predictive value for major health-related outcomes. Numerous epidemiological studies have documented gait speed in healthy, community-dwelling older people. The purpose of this study is to undertake a systematic review and meta-analysis of gait speed in a specific group with mobility limitations - geriatric patients in clinical settings.

Methods: Relevant databases were searched systematically for original research articles published to February 2011 measuring gait speed in persons aged 70 or older in hospital inpatient or outpatients settings. Meta-analysis determined gait speed data for each setting adjusting for covariates.

Results: The review included 48 studies providing data from 7000 subjects. Across the hospital settings, the gait speed estimate for usual pace was 0.58 m/s (95% Confidence Interval (CI): 0.49 to 0.67) and for maximal pace was 0.89 m/s (95% CI: 0.75 to 1.02). These estimates were based on most recent year of publication (2011) and median percentage of females (63%). Gait speed at usual pace in acute care settings was 0.46 m/s (95 % CI: 0.34 to 0.57), which was significantly slower than the gait speed of 0.74 m/s (95 % CI: 0.65 to 0.83) recorded in outpatient settings.

Conclusion: Gait speed is an important measure in comprehensive geriatric assessment. The consolidation of data from multiple studies reported in this meta-analysis highlights the mobility limitations experienced by older people in clinical settings and the need for ongoing rehabilitation to attain levels sufficient for reintegration in the community.
INTRODUCTION

The ability to walk underlies many basic and community functions necessary for independence [1]. Slowing of movement with ageing appears to be a universal biological phenomenon and is likely to reflect the integrated performance of numerous organ systems. Factors that influence walking ability can be classified into six main physiological subsystems: central nervous system, perceptual system, peripheral nervous system, muscles, bone/joints, and energy production/delivery [2]. When these systems become dysfunctional, for example as a consequence of an acute medical condition such as stroke or hip fracture or as a result of frailty-associated progressive decline, walking slows. The appearance of difficulties in walking marks a critical point such that assessment of gait speed has been described as the “sixth vital sign” [3] with the potential to serve as a core indicator of health and function in ageing and disease [1].

Of the available physical performance measures, gait speed represents one that is suitable to be implemented in the standard clinical evaluation of older persons [4], since it is a quick, inexpensive, reliable measure of functional capacity [5], with high inter-rater and test-retest reliability [6]. It has well documented predictive value for major health-related outcomes such as hospitalisations, nursing home placements, mortality, poor quality of life, physical and cognitive functional decline, and falls [7,8], making it a useful screening measure to identify older persons at risk of such events [5]. Moreover, it has been used as an outcome measure in rehabilitation [9] and in trials of interventions to delay the onset of disability or frailty [10]. Advantages are that the test of gait speed is easy to administer, does not require laboratory equipment and is not limited to a specific health care discipline [8].
However, a recent systematic review of the assessment of gait speed [8] found that protocols for walking tests vary widely, influencing interpretations of physical performance [11]. Timed walking tests varied according to pace (usual or maximal speed), whether static or moving start, distance walked (ranging from 4 to 500 metres) and characteristics of the study group [11]. The lack of consensus regarding walk test protocol may limit intergroup comparisons and broader standardisation of norms [11].

Judgments about how an individual’s gait speed compares to those of the population to which they belong requires the availability of reference values [12]. Numerous large scale epidemiological studies have documented gait speed in healthy, community-dwelling older people [7,13] and normative values have been established specific to this group [12,14]. However there is limited data for groups with mobility limitations. The clinical application of gait speed would benefit from estimates of the distribution of performance scores that are specific to subgroups based on, among other things, age, gender, and setting [1], taking into account test protocol.

The purpose of this paper, therefore, is to undertake a systematic review and meta-analysis of gait speed for geriatric patients in hospital inpatient and outpatient settings.

METHOD

Identification and selection of studies

A comprehensive literature search was undertaken of Medline, Cinahl, EMBASE, Cochrane, Amed and PEDro from inception of the databases to February 2011. Search terms included (aged or elder* or seniors or geriatric or frail) and (walk or gait or physical performance or
lower extremity) and (timed or speed or velocity or accel*). A typical search strategy is outlined in Appendix 1 (see Supplementary Material). Only original studies published in English and reporting gait speed measured over a short distance (maximum 50 feet or 15 metres) in a population sample of at least 20 people aged 70 years and older were eligible for inclusion in this review. Detailed criteria of studies included in this review are outlined in Box 1.

Titles of identified studies were screened (SK) to remove those that were not relevant; for example participants were not human or were aged less than 70 years, such as children. Two authors (NP, SK) independently reviewed abstracts to further eliminate studies not meeting the criteria. If there was doubt about inclusion, the decision was deferred until the entire paper was reviewed. The full papers of all identified studies remaining were retrieved. Studies were further excluded if they did not meet the specified inclusion criteria, were commentaries or reviews of studies, were conference proceedings only or were duplicated records. In addition, reference lists of included studies were hand searched to identify others meeting the inclusion criteria.

For the purposes of this review, only those studies were included if they were conducted in a clinical inpatient or outpatient hospital setting. Inpatient settings were defined as acute care and sub-acute care or rehabilitation. Outpatient settings included day hospital or ambulatory care clinics (for example falls clinics).

**Data extraction**
Data regarding the study origins, the population being studied and protocol used to measure gait speed were extracted from the retrieved studies. Study origin data included authors, country, year of publication and name of study, if appropriate. Study methods and population characteristics recorded were design, setting, diagnostic group, number of participants, age and gender of participants and the study inclusion and exclusion criteria. Information recorded pertaining to the measurement of gait speed included distance walked, timing method, walking pace, static or moving start, whether walking aids were permitted during the test, number of walking trials and if the average or fastest speed of the trials was recorded. The reported gait speed measures, as well as the time point at which the measures were taken (for example, admission or discharge) were recorded. In studies which included patients who were unable to perform the gait speed test, data extracted included the number of non-walkers as well as whether they were allocated a gait speed of zero. Where gait test protocol pertaining to walking pace and type of start were not available in the published study or referenced protocols, clarification was sought from the study authors.

Data were extracted by two reviewers (NP, SK) working independently and entered into a purpose designed spreadsheet. An extraction manual was developed outlining items and specific data requiring extraction. Consensus on data extraction, a method suitable for medical clinical trials [15], was achieved via pilot testing and ongoing regular meetings where coding issues and specific data extracted were compared. Disagreements were resolved through consensus.

**Data analysis**
All reported gait speed measures were converted to metres per second (m/s). For studies which included more than one group of homogenous participants, for example, an intervention group and control group, data were converted to calculate a total study group gait speed mean and standard deviation. If a study reported gait speed measures at two time points (e.g., admission and discharge), only the first time point measure was included in the meta-analysis. Both fixed and random effects models were used to analyse the data. Analyses were performed in “R” by using the Metafor statistical packages, package version 1.6-0 (http://www.R-project.org).

Variables investigated for possible correlation with reported gait speed were publication year, mean age of participants, percentage of females in the study, walking pace (usual or maximal), static or moving start, clinical setting (acute, sub-acute, outpatient/ambulatory), and distance for the timed walk. A meta regression was carried out to find the significant association between these variables and the outcome measure, gait speed, for both usual and maximal pace. The residual heterogeneity estimate was also obtained using restricted maximum-likelihood estimator and the subsequent test, whether the estimate is zero or not, was performed using Cochran's Q-test. In order to evaluate whether the significant effects of some of the variables to the gait speed were genuine, possible interactions of those variables were tested.

**RESULTS**

**Flow of studies through the review**
A total of 4646 articles were retrieved from the initial search strategy and 1300 excluded after screening of the title. Abstracts of remaining 3346 studies were obtained and reviewed based on article type and participant inclusion criteria (Box 1). Duplicates were also identified and removed, leaving 1147 potentially relevant studies for which the full text was obtained. A detailed schematic of the study selection process at Figure 1 shows reasons for exclusion. Hand searching of reference lists of reviews identified 15 further studies, resulting in a total of 460 studies which met the inclusion criteria. Studies were then classified according to the setting from which participants were recruited; community, clinical (hospital inpatient or outpatient) or residential aged care facility. This was done as it likely that gait speed could be measured differently in different settings and the reported gait speed measure may vary across different settings [16-18]. For the purposes of this review, only the studies where gait speed was measured in a clinical setting have been included.

**Characteristics of studies**

Fifty-nine studies (references 19 to 77 in Supplementary Material) were identified which were conducted in a clinical setting. Clinical settings were grouped according to location as acute care, sub-acute or rehabilitation, and outpatient or ambulatory care. Six studies [19-24] were excluded from meta-analysis as they reported results on the same dataset as another included study. In these cases, the study that provided the most complete data was included in this review. In addition, one study [25] was excluded as the gait speed standard deviation was not reported. Two studies [26,27] measured gait speed under different conditions and were also excluded from the meta-analysis. A further two studies [28,29] were excluded when walking pace protocol could not be established.
Study details, including participant characteristics, of the remaining 48 studies (references 30 to 77 in Supplementary Material) are presented for inpatient (acute or sub-acute) and outpatient clinical settings in Tables 1-3 respectively (Tables 1 to 3 in Supplementary Material). A total of 7000 participants were included in the 48 reported studies. Gait speed was recorded for 5428 (78%) of the included participants in clinical settings (52% in acute care, 84% in sub-acute care and 95% in outpatient care). Eight studies were conducted in acute care settings [30-37]; 23 studies [38-60] in sub-acute or rehabilitation settings; and 17 studies [61-77] in outpatient or ambulatory care settings. Common diagnostic groups reported were those with neurological conditions such as stroke [38-40,49,51,55,56,60] and Parkinson’s disease [44,69]; and orthopaedic conditions requiring surgical repair, such as hip fracture [33,50,53,54], or joint replacement [45,68,73,76].

**Gait speed**

*Measurement of gait speed*

As illustrated in Tables 1 to 3 (Supplementary Material), there were variations in the protocol to measure gait speed. Distance for the timed walk ranged from 2 to 15 metres, and one study [33] measured gait speed over two distances (10 feet and 50 feet). Since the gait speeds were comparable and more participants could complete the shorter walk, this measure was included in the meta-analysis. Another variation in protocol was whether timing commenced from a static or moving start. Where a computerised mat was used to measure gait parameters, a moving start was assumed.
Forty-two studies measured gait speed using a self-selected or usual pace. Other terms in the literature to denote gait speed at ‘usual’ pace included ‘comfortable’, ‘habitual’, ‘normal’, or ‘preferred’. Nine studies recorded gait speed at a maximal or fast pace, including two studies in the outpatient/ambulatory setting [66,77] and one study in the post acute/rehabilitation setting [43] measuring gait speed with both a usual and a maximal pace.

Gait speed values

The fit of a random effects model was significantly better than that of a fixed effects model (p-value: <0.01). Significant residual heterogeneity was found (p-value: <0.01). There were two final models; the first with the following covariates: publication year, percentage of females in the study and walking pace. The second model included an extra covariate: the clinical setting (acute, sub-acute or outpatient). Mean age, type of start (static or moving), whether walking aid permitted, and distance were not found to be significantly associated with the recorded gait speed. The mean gait speeds with 95% Confidence Interval (CI) from the included studies (42 with usual, 9 with maximal walking pace) are shown in Figure 2, as well as overall random effects estimates for the two walking paces (the first model).

From a random effects model, faster gait speeds were reported by more recent publications. Gait speed increased by 0.013 m/s (95 % CI: 0.003 to 0.023) per year of publication, which ranged from 1988 to 2011. Studies with a greater percentage of females included in the study population were found to report a significantly slower gait speed. There was an incremental decrease in gait speed of 0.003 m/s (95 % CI: 0.001 to 0.006) for every percent increase in the proportion of female participants in the study population. Gait speed measured using
maximal compared with usual pace was significantly faster by 0.302 m/s (95% CI: 0.158 to 0.447).

The overall gait speed estimate for usual pace for all included studies was 0.58 m/s (95% CI 0.49 to 0.67) and maximal pace was 0.89 m/s (95% CI 0.75 to 1.02) as shown in Figure 2. These estimates are deemed to be determined from the hypothetical population from which the set of studies included in the meta-analysis are assumed to be a random selection. The estimates are calculated based on the most recent year of publication (2011) and median percentage of females (63%).

The addition of clinical setting in the model, found that the studies performed in an outpatient (ambulatory care) setting compared to the acute inpatient setting reported significantly faster gait speed by 0.293 m/s (95% CI: 0.173 to 0.414). There was no significant difference in estimated gait speed between the acute and sub-acute inpatient hospital settings. Table 4 shows the estimates of usual and maximal pace gait speed for each clinical setting.

**DISCUSSION**

The overall gait speed estimate for usual pace was 0.58 m/s (95% CI: 0.49 to 0.67) and maximal pace was 0.89 (95% CI: 0.75 to 1.02). These estimates are slower than that regarded as normal for community dwelling adults over 70 years of age. A comfortable gait speed for healthy women aged between 70 and 79 years is 1.13 m/s and for men 1.26 m/s [14]. For women and men aged 80 to 99 the values are 0.94 m/sec and 0.97 m/sec respectively [14]. In addition, this is a slower gait speed than that measured for
community dwelling older adults deemed as transitioning to frailty (mean 0.97 m/s) [78]. With a recent systematic review proposing a gait speed of 0.8 m/s as a predictor of poor clinical outcomes and 0.6 m/s as a threshold to predict further functional decline in those older adults already impaired [7], the findings of this review highlight the low functional ability and high risk nature of people in clinical settings.

An interesting finding of this review was that more recent publications reported a faster gait speed, even after adjusting for the clinical setting and the walk pace. We found that gait speed increased a mean estimate of 0.013 m/s (95 % CI: 0.003 to 0.023) per publication year. The relevant interaction models also confirmed that similar faster gait speed for recent publications was expected in all three clinical settings and the two walk pace groups. The publication dates of included studies in this review ranged from 1988 to 2011-a total of 23 years. Such a time frame is sufficient to be influenced by improving health and survival rates in older populations. Reviews of morbidity and mortality trends, have shown a significant reduction in the rate of functional decline over the last three decades [79,80].

Other personal factors known to influence gait speed include age and gender [81]. In this meta-analysis age did not influence the estimated gait speed, possibly because this review only included studies where the average participant age was at least 70 years, and thus representative of the geriatric population of interest. Gender did, however, influence the estimated gait speed. Those studies with a higher proportion of female participants reported, on average, a slower gait speed. For every one percent increase in female participants, gait speed slowed by 0.003 m/s (95 % CI: 0.001 to 0.006). Although aerobic capacity and body stature (height and weight) are also known to
influence gait speed [17,82], none of the studies selected in the review adjusted for these factors.

The accuracy of measuring gait speed over distances less than four metres, particularly when using a static start, has been questioned [4]. The use of a moving start to allow for acceleration prior to commencing timing potentially could result in a faster gait speed. A distance of 2.5 metres has been suggested before steady state walking is achieved in frail older people [83]. However, the current review findings showed no significant difference in gait speed adjusting for type of start (static or moving). This is in agreement with a previous review which also demonstrated that although faster gait speeds were recorded when measured with a moving compared to a static start, the findings were not significantly different [11].

Only studies measuring gait speed over distances of 15 metres or less were included in this review, with the majority (34 studies) using a timed walk over less than 10 metres. In agreement with other studies [17,84], this review showed that distance walked during the gait speed test did not influence the recorded gait speed. One study [33] which measured gait speed over two distances (10 and 50 feet) in the same population sample found no difference in gait speed mean or standard deviation for those who could complete the test, while a population-based study measuring normal gait speed over 8 feet and 20 feet [17] showed that speeds over these distances differed significantly but not clinically. The conclusion was that, as gait speed over these short distances was comparable, using the shorter distance appears justifiable [17]. However, results are not consistent and may be dependent on patient diagnosis (e.g., stroke) and time since onset [85].
In reporting the walk test protocol, 31 (64.6%) of selected studies permitted the use of a walking aid if necessary, four studies (8.3%) did not allow the use of assistive devices and 13 (27.1%) did not specify whether or not use of walking aids was permitted during testing. The proportion of patients using a mobility aid ranged from 15% to 98.5% indicating the heterogeneity of included studies with respect to mobility limitations. While the use and type of walking aid may potentially affect the measured gait speed [86], few studies reported the type of walking aid used during the gait test. Only one study [73] compared gait speed for subjects who did, or did not, use a walking aid (cane) and found that individuals with gait aids performed more poorly than those without.

A key issue to consider when measuring gait speed involves handling of those participants who are unable to complete the timed walk. Many of the included studies in this review only recruited participants when they could walk the required distance. Such an inclusion criteria may be reasonable but it does have implications for the interpretation of a study’s findings. Some test protocols, such as the Short Physical Performance Battery [4], suggest that a gait speed of 0 m/s should be assigned to non-walkers or participants who cannot complete the walk test, so that accurate estimates of gait speed in this clinical population are ascertained and progress can be monitored over time. At the very least, the number of non-walkers at each assessment point should be reported.

There were several limitations to our review. Only including studies where the average age was 70 years or more resulted in the exclusion of many studies particularly those with earlier onset of specific diseases, for example, stroke and Parkinson’s disease. Other factors influencing gait speed estimates such as height, weight, and gait aid used
were not included in the models because of the heterogeneity of selected studies and lack of detail in reported walk test protocols. Similarly, diagnoses and underlying pathology such as focal gray matter atrophy associated with motor disturbances in older age [87] were not accounted for in gait speed estimates. Limitations in the methodology reported to extract data for this review were the lack of quantitative measures of inter-rater agreement on variables used in the meta-analysis, as well as independent expert advice on comprehensiveness of the search strategy to include all relevant articles. Identification of articles for inclusion as well as data extraction was done independently by the authors and agreement was achieved by consensus.

Gait speed has been shown to be an important measure in comprehensive geriatric assessment in all clinical settings for the purposes of developing risk profiles and care plans for geriatric patients [88]. The consolidation of data from multiple studies reported in this meta-analysis highlights the mobility limitations experienced by older people in clinical settings and the need for ongoing rehabilitation to attain levels sufficient for reintegration in the community.

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**REFERENCES**


Box 1: Study selection criteria

Article type
- Reporting original research results (ie reviews, editorials, conference abstracts excluded)
- Written in English

Study Design
- Observational and experimental studies (baseline data only)

Participants
- Adults, mean age ≥ 70 years
- Able to undertake bipedal locomotion (ie amputees excluded)
- At least 20 participants from the same population sample

Setting
- Participants recruited in a clinical setting including hospital inpatients (acute, sub-acute care or rehabilitation), and outpatients (ambulatory or day care) (ie studies recruiting participants from residential aged care facilities or in community settings excluded)

Gait speed
- Timed over a short distance (maximum 50 feet or 15 metres)
- Reported as a continuous measure with measures of central tendency (mean, median) and distribution (standard deviation, range) (ie categorical measures excluded)
- Measured as a straight walk on a level indoor surface with no turns (excluding walking on treadmill)
- Timed under same conditions (ie walking under manipulated physical environment, while performing tasks, or on different surfaces excluded).
Tables 1 to 3 in Supplementary Material

Table 1. Summary of studies in the acute inpatient setting included in meta-analysis

Table 2. Summary of studies in the inpatient sub-acute or rehabilitation setting included in meta-analysis

Table 3. Summary of studies in the outpatient or ambulatory setting included in meta-analysis
Table 4. Estimates for usual and maximal pace gait speed in clinical settings

<table>
<thead>
<tr>
<th>Pace</th>
<th>Location</th>
<th>Gait Speed Estimates (m/s)</th>
<th>Standard Error</th>
<th>95 % CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual</td>
<td>Acute</td>
<td>0.455</td>
<td>0.057</td>
<td>0.344 to 0.567</td>
</tr>
<tr>
<td></td>
<td>Sub-Acute</td>
<td>0.529</td>
<td>0.046</td>
<td>0.438 to 0.619</td>
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<td>Ambulatory</td>
<td>0.739</td>
<td>0.046</td>
<td>0.648 to 0.831</td>
</tr>
<tr>
<td>Maximal</td>
<td>Acute</td>
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<td>0.080</td>
<td>0.592 to 0.905</td>
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<tr>
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<td>0.057</td>
<td>0.711 to 0.933</td>
</tr>
<tr>
<td></td>
<td>Ambulatory</td>
<td>1.033</td>
<td>0.063</td>
<td>0.910 to 1.156</td>
</tr>
</tbody>
</table>
Figure 1. Schematic of the study selection process
Figure 2: Mean gait speeds with 95% CI of 42 included studies for usual pace and 9 included studies for maximal pace (3 studies measured both usual and maximal pace). Meta-regression of 48 studies, illustrating overal random effects estimates (mean and 95% CI) for usual and maximal pace.