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Clinically meaningful change in stair negotiation performance in older adults

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Abstract

Stair negotiation is a key marker for independence among older adults; however, clinically meaningful change has not been established. Our objective was to establish the values of clinically meaningful change in stair negotiation time using distribution- and anchor-based approaches.

Study participants were 371 community residing older adults (age 70) in the Einstein Aging Study with time to ascend and descend 3 steps measured at baseline and at one-year follow-up. Anchor-based estimates were obtained using functional decline (defined as one-point increment in disability score) and change in self-reported walking ability over the one-year follow-up period. Small, moderate, and large meaningful change estimates were 0.28, 0.71, and 1.15 s for stair ascent time (0.31, 0.78, and 1.25 s for stair descent time) using the distribution-based approach of effect size. The estimates of meaningful decline range from 0.47 to 0.53 s for stair ascent time (0.33–0.53 s for stair descent time) using the anchor-based approach. The estimates of meaningful improvement were smaller (0.13–0.18 s for stair ascent, 0.06–0.15 for stair descent) compared to those for decline. Based on general consistency between distribution- and anchor-based approaches, preliminary criteria suggested for stair negotiation time is 0.5 s for meaningful decline and 0.2 s for meaningful improvement.

Keywords

Stair negotiation; Meaningful change; Aged

Stair negotiation is one of the most demanding activities of daily living (ADLs) among older adults with one third of community-dwelling elderly reporting difficulty [1]. In our previous study, ascent and descent times for negotiating three steps were strong predictors of risk of developing decline in ADLs in older adults, including high functioning individuals with gait velocity of 1 m/s and over [2]. Moreover, stair negotiation times also predicted subjective

difficulty in stair negotiation among those without self-reported difficulty at baseline [2]. Therefore, we hypothesized that measurement of stair negotiation may serve as a tool to detect early declines in mobility (ability to move freely and easily) among older adults. However, criteria for clinically meaningful change in stair negotiation performance among older adults have not been established. This is possibly due to lack of standardization in stair performance measure; inconsistency in the unit (i.e. stair negotiation speed, cm/s or steps/s) and number of steps tested, and not distinguishing stair ascent and descent phases [2]. Establishing estimates of meaningful change in stair negotiation performance will be useful in clinical practice as well as in research settings to provide a guide for planning sample sizes for new observational and intervention studies, to assess and monitor progression of functional decline in aging, and as a yardstick to determine the effectiveness of rehabilitative interventions [3].

Perera et al. pioneered the development of meaningful change estimates for mobility performance measures in aging [3]. In a seminal study, they established meaningful change for gait velocity in older adults using both a distribution-based approach [4] that relies on the statistical properties of a measure (effect sizes and standard error of measurement) as well as an anchor-based approach [4] which uses external anchor such as individual's judgment of changes in another measure (i.e. better, same, worse in walking distance) [3]. We and others have extended these approaches to establish meaningful change estimates for other mobility parameters such as gait variability [5], timed up and go test (TUG) [6], and the short physical performance battery (SPPB) [6,7]. Building on these previous studies, we proposed to estimate the magnitude of meaningful change in stair negotiation time (SNT), an important mobility outcome, in community-residing older adults.

1. Methods

1.1. Study population

Six hundred and eighty-five Einstein Aging Study participants were seen between July 2006 and March 2011. Eligibility criteria for Einstein Aging Study include age of 70 and older living in the Bronx County, New York. Exclusion criteria include severe auditory or visual loss, being bedbound, and institutionalization. Of these 685 participants, 42 were disabled (requiring personal assistance or dementia), 58 could not perform stair negotiation due to unsteadiness, pain, or weakness, 40 were not assessed due to tester unavailability. Of the remaining 545 participants, 371 (70.3%) had stair negotiation assessments in two consecutive years. Reasons for missing stair negotiation assessment at the one-year follow-up visit included inability to perform stair negotiation due to unsteadiness, pain, or weakness ($n = 20$), death ($n = 6$), drop out of the study due to sickness ($n = 43$), awaiting one-year follow-up ($n = 20$), refusal ($n = 17$), and loss of contact ($n = 68$). Analysis was limited to an one-year follow-up window since this is a clinically relevant follow-up interval in both clinical and research settings as well as this interval was consistent with previous studies of meaningful change in other mobility measures [3,7]. Study protocol was approved by Institutional Review Board.

1.2. Stair negotiation

Stair negotiation was measured by over three steps as previously described [2]. Stair ascent and descent are distinct in biomechanical requirements and self-efficacy therefore, separate evaluation of stair ascent and descent was chosen. Our previous study showed that climbing three steps was more preferable than a full flight of stairs for seniors [8]. Furthermore, the lesser number of steps would help extending the use of this test to low-functioning individuals. The dimensions of the steps was 18 cm in height, 26 cm in depth, and 110 cm in width, which are among the most frequently encountered in semipublic places and are

within stair dimensions recommended by Occupational Safety and Health Standards [9]. Participants were instructed to climb three steps on a standard flight of indoor stairs at their usual pace. Stair ascent timing was started once the participant began lifting their leading foot from the floor after the tester said “go.” Subjects were allowed to use handrails to steady themselves. The research assistant noted use of handrails or any other difficulty while performing the task. When the participant placed both feet flat on the third step, the timing was stopped. After a brief rest, participants were requested to walk down. The stair descent timing started from the time when the leading foot began lifting from the third step and stopped when both feet were placed flat on the base of the stairs. The SNT was measured to the hundredth of a second with one trial for stair ascent and descent. The test–retest reliability for this measure is excellent (Pearson’s $r = .94$ for ascent time, $r = .93$ for descent time) [2] and this measure has also shown predictive validity for functional decline [2].

1.3. Distribution-based approach

1.3.1. Effect size calculation—Effect size (δ) is a distribution-based method for quantifying a difference between two means on a unitless standard scale [3–5]. Effect size (δ) is defined as mean changes in a variable divided by baseline standard deviation (SD) [10] [$\delta = (\mu_1 - \mu_2)/\sigma_1$, where μ_1 and μ_2 , respectively are the means at baseline and follow-up, and σ_1 is the SD at baseline] [5,11]. Guidelines for interpreting an effect size suggest using 0.2 for small, 0.5 for moderate, and 0.8 for large changes [11]. Distribution-based estimate for a small, moderate, and large change in SNT computed as $0.2\sigma_1$, $0.5\sigma_1$, $0.8\sigma_1$ [3,5].

1.3.2. Standard error of measurement—Standard error of measurement defined as $\sigma_1 \sqrt{1 - r}$, where r is the test–retest reliability, is a distribution-based method of estimating a meaningful individual-level change in a measure [3].

1.4. Anchor-based approach

Anchor-based methods involve estimating the change of an individual’s performance of interest corresponding to another measure (anchor) of clinically relevant change [4]. This study included two anchors using validated questionnaires: self-reported walking ability [3,12] and functional status in performing ADLs [2,13]. Change in self-reported walking ability has been previously used to determine the meaningful changes in gait performance [3,5] and other performance measures including 6 min walk test and SPPB [3,14]. Self-reported walking ability was evaluated by asking the participant “How far can you walk in one hour on level ground?” and the response was recorded as “less than a quarter mile,” “a quarter to a half mile,” “a half mile to one mile,” or “greater than a mile.” This question has established reliability ($r = 0.76$) and validity in our cohort [12]. The change in response at one-year follow-up from baseline was categorized as no change, improvement, or decline. We did not analyze the data by the degree of improvement or decline due to small number of participants with more than one level of change. For the functional status anchor, participants were asked about the difficulty and need of personal assistance for each of the 7 ADLs (bathing, dressing, grooming, feeding, toileting, walking around home, and getting up from a chair) [2,13]. Score 0 was given for no difficulty, 1 for reporting difficulty, 2 for need for personal assistance in each of the 7 ADLs (range 0–14). This interview has been reported to have excellent test–retest reliability ($\kappa = 1.0$) [15]. Functional decline was defined as an increment in disability score by 1-point or more and improvement was defined by 1-point decrease at one-year follow-up. The 1-point increment could represent a participant who had no difficulty in all 7 ADLs at baseline reporting a new difficulty to perform any of the ADLs or a participant who reported difficulty in ADLs at baseline transitioning to disability during follow-up. We did not use subjective difficulty in stair negotiation as an anchor due to large proportion (132, 35.5%) of participants at floor (reporting difficulty in stair negotiation both

in initial and follow-up) and only small (36, 9.7%) number of participants reported improvement. To corroborate our findings, we also examined as an alternate anchor measure of difficulty in performing stair negotiation observed by the tester such as hesitation in initiation of the first step or unsteadiness while negotiating stairs.

1.5. Analysis

Both distribution- and anchor-based approaches were used to estimate clinically meaningful change in stair ascent time (SAT) and stair descent time (SDT) following the methodology used in previous studies [3,5]. For anchor-based approach, the mean change in stair ascent and descent time between those with change (decline or improvement) and with no change in three anchors were examined. In terms of walking ability, participants at floor (reporting ability of less than 1/4 mile at baseline and follow-up) who could not report further decline were excluded [3]. Similarly, those with difficulty noted by the tester at baseline and follow-up were excluded for analysis using the alternative anchor (tester observed stair negotiation difficulty). Because there is no known statistical formula to combine these estimates from both approaches, recommended criteria were based on the overall consistency and preference for rounded numbers were applied for practical use, as done in similar efforts to develop criteria for meaningful change [3,5].

2. Results

2.1. Sample characteristics

Demographic and clinical characteristics of 371 participants were summarized in Table 1. Mean age was 80.2 with 39.6% of men. Approximately 39% of the participants reported being able to walk more than a mile during an hour. The SNT at baseline was longer in 20 individuals who were not able to perform stair negotiation at follow-up compared to those with 2 consecutive stair assessments (4.22 versus 2.67 s in SAT, 4.34 versus 2.71 s in SDT). However, there was no difference in SNT between those with 2 consecutive stair assessment and those with missing SNT due to loss of contact, refusal, or sickness at the one-year follow-up visit.

2.2. Estimates of meaningful changes: distribution-based methods

Estimates of meaningful change based on the effect size were 0.28, 0.71, and 1.15 s respectively for small, moderate, and large change in SAT. The corresponding values for SDT were 0.31, 0.78, and 1.25 s. The standard error of measurement for SAT and SDT was 0.45 and 0.49 s respectively (Table 2).

2.3. Estimates of meaningful change: anchor-based methods

Estimates of meaningful change based on the self-reported anchors are presented for the decline and improvement (Table 3). In terms of disability score, no change was reported in 197 (53.1%), decline (increase in disability score) in 113 (30.5%), and improvement (decrease in disability score) in 61 (16.4%). There was no significant difference in mean age, proportion of females, and SPPB scores at baseline among the three groups (Table 3). Walking ability was stable in 137 (36.9%), declined in 83 (22.4%), improved in 96 (25.9%) and 55 at floor (14.8%, reporting ability of less than 1/4 mile at baseline and follow-up). There was no significant difference in mean age, however, the proportion of males and SPPB scores at baseline was higher among the group with no change compared to the other two groups. The estimates for clinically meaningful decline range from 0.47 to 0.53 s in stair ascent, from 0.33 to 0.53 s in stair descent using the two anchors. The estimates for clinically meaningful improvement range from 0.13 to 0.18 s for stair ascent and from 0.06 to 0.15 s for stair descent. With the alternative anchor (difficulty noted by the tester in stair

negotiation), the estimate of meaningful decline in stair negotiation was 1.23 and 1.27 s for stair ascent and descent, respectively, and the estimates for improvement were 0.95 and 1.05 s for stair ascent and descent.

3. Discussion

We have previously reported that SNT is a valid measure for predicting decline in ADLs among high functioning older adults without difficulty in stair climbing at baseline [2]. In the current study, we report clinically meaningful change in stair ascent and descent time in non-demented older adults using both distribution-based and anchor-based approaches.

The estimates of change derived from distribution-based approach are based on statistical criteria and these values might vary from one sample to another, whereas, the estimates derived from anchor-based approaches are relatively sample independent [4]. For instance, meaningful change estimates using an anchor-based approach for gait velocity over one-year was consistent between our [5] and another cohort [3]. However, anchor-based approach also has its limitations including recall bias due to retrospective judgment of change and reliability of the measure for 'true' change [4,16]. Since the changes in the instrument being investigated are correlated with changes in other related measures (anchors), test-retest reliability and validity is particularly important for the measures used as anchors [16,17]. It is reassuring that the anchors used in this study showed excellent reliability and validity. To overcome the limitations of distribution and anchor based approaches, recent studies have examined clinically meaningful changes in mobility and other measures using multiple anchor- and distribution-based estimates as in our study [5,18,19].

Overall, the estimates of meaningful decline in stair negotiation derived from both anchors (rounded number near the center of the range of computed estimates; 0.5 s) were the values between minimal and moderate change derived from effect size analysis, and close to the values of standard error of measure in distribution-based approach. The estimates of meaningful decline were larger than those of meaningful improvement (0.2 s) using both anchors. These correspond to Cohen's interpretation of small to very small effect sizes [11]. There may be a possibility that the group with no change included those who improved in walking distance, which can result in overestimation of decline and underestimation of improvement. Presence of healthier individuals may have led to faster baseline stair ascent and descent times in the group with no functional change. The magnitude of the estimate was relatively smaller using functional decline in ADL as the anchor compared to the values derived from a walking ability anchor. This is likely due to differences in sensitivity of anchors as well as variability in self-report in defining grades of change in walking abilities. The magnitude of estimates of meaningful change (1.2 s for decline, 1.0 s for improvement) derived from our alternative anchor (stair climbing difficulty noted by the tester) was similar to those of 'large change' derived from distribution-based approach. These findings support that clinically meaningful declines in stair negotiation may occur prior to declines in stair negotiation that can be observed by an examiner.

The strengths of this study included the relatively large sample of well characterized elderly, exclusion of demented and disabled individuals to improve the reliability of data, and the use of reliable and valid measures of stair negotiation [2]. In this study, clinically meaningful values are estimated based on a stairway that is three steps long. This short distance is actually a strength of the study allowing for greater ease of replicating the test in both clinical and research settings. Several limitations need to be considered. Twenty individuals who no longer could perform stair negotiation at follow-up were not included in the analysis for which approach results in possible under-estimation of effects. These individuals showed worse performance in SNT at baseline compared to those with two

consecutive stair assessments. The estimates only pertain to change over a one-year period and should not be applied to longer follow-up intervals. However, a one year period is a common interval for arranging follow-up visits in clinics as well as in most prospective cohort studies [3,5,7]. Hence, the generalizability to clinical and research settings may be higher than change over intervals longer than one year. The effect of intervening events such as hospitalizations, acute medical events, or medication changes on change estimates was not examined. Lastly, the pattern of stepping pattern was not accounted for in this study. Stepping pattern is a clinically important aspect of stair negotiation and it should be investigated further to provide insights into physiological processes underlying stair negotiation.

4. Conclusion

Preliminary estimates for criteria for clinically meaningful change in SNT of three steps were 0.5 s for decline and 0.2 s for improvement based both on distribution- and anchor-based approaches. Future studies will be necessary to confirm these preliminary estimates and examine whether these magnitudes of meaningful change is achievable with intervention.

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Table 1

Demographic and medical characteristics of study population (n = 371).

	Characteristics
Age	80.2 ± 4.9
Men (%)	147 (39.6)
Ethnicity White (%)	260 (70.1)
Illness index summary score	1.4 ± 1.1
Geriatric depression scale	1.9 ± 1.8
Blessed test score	1.7 ± 1.9
Disability score	0.8 ± 1.2
SPPB* score	9.6 ± 1.9
Past fall (%)	94 (25.3)
Fear of falling (%)	118 (31.8)
Self-report of walking distance in an hour	
>1 mile	143 (38.6)
>1/2-1 mile	78 (21.0)
1/4-1/2 mile	71 (19.1)
<1/4mile	79 (21.3)
Self-report of limitation in walking 1 mile	185 (49.9)
Reporting difficulty in stair ascent	167 (45.0)
Reporting difficulty in stair descent	114 (30.7)
Stair ascent time (s)	2.67 ± 1.41
Stair descent time (s)	2.71 ± 1.56

Abbreviation, *SPPB; short physical performance battery.

Values for continuous variables expressed as mean ± standard deviation (SD).

Table 2

Distribution-based estimates for changes in stair ascent and descent time.

	<u>Effect size^a</u>			Standard error of measurement
	Small	Moderate	Large	
Stair ascent time (s)	0.28	0.71	1.15	0.45
Stair descent time (s)	0.31	0.78	1.25	0.49

^aSmall effect size = $0.2\sigma_1$; moderate effect size = $0.5\sigma_1$; large effect size = $0.8\sigma_1$.

Table 3

Stair negotiation time in groups of no change, decline, and improvement in 2 anchors and the estimates of anchor-based meaningful changes.

Functional change in ADL	No change in disability score (n = 197)	Increased in disability score (worsening) by 1 points at f/u ^a (n = 113)	Meaningful decline estimate	Decrease in disability score (improvement) by 1 points at f/u ^a (n=61)	Meaningful improvement estimate
Age at baseline	80.1 ± 5.1	80.5 ± 4.4		79.9 ± 4.9	
Female (%)	117 (60.0)	68 (60.2)		39 (63.9)	
SPPB score at baseline	10.0 ± 1.8	9.2 ± 2.0		9.2 ± 2.0	
Stair ascent time (s)					
Initial	2.55 ± 1.44	2.82 ± 1.42		2.82 ± 1.28	
Follow-up	2.31 ± 1.05	3.05 ± 2.22		2.45 ± 1.16	
Change	-0.24 ± 1.36	0.23 ± 1.83	0.47	-0.37 ± 1.20	0.13
Stair descent time (s)					
Initial	2.51 ± 1.49	2.90 ± 1.40		2.76 ± 1.29	
Follow-up	2.23 ± 1.33	2.90 ± 1.55		2.33 ± 1.04	
Change	-0.28 ± 1.23	0.05 ± 1.83	0.33	-0.43 ± 1.32	0.15
Self-reported walking ability	Reported no change in walking distance (n = 137)	Reported walking less at f/u (n= 83)	Meaningful decline estimate	Reported walking more at f/u (n = 96)	Meaningful improvement estimate
Age at baseline	79.7 ± 5.0	80.1 ± 4.9		80.5 ± 4.7	
Female (%)	69 (50.3)	52 (62.7)		63 (65.6)	
SPPB score at baseline	10.3 ± 1.5	9.6 ± 1.7		9.4 ± 2.1	
Stair ascent time (s)					
Initial	2.28 ± 1.23	2.48 ± 1.00		2.86 ± 1.42	
Follow-up	2.03 ± 0.73	2.77 ± 1.44		2.42 ± 1.02	
Change	-0.25 ± 1.28	0.28 ± 1.25	0.53	-0.43 ± 1.38	0.18
Stair descent time (s)					
Initial	2.24 ± 1.18	2.52 ± 1.02		2.84 ± 1.38	
Follow-up	1.87 ± 0.74	2.65 ± 1.25		2.38 ± 1.03	
Change	-0.40 ± 1.07	0.13 ± 1.19	0.53	-0.46 ± 1.41	0.06

^af/u, follow-up. Values expressed as mean ± standard deviation (SD).