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Original Article

Agreement between two walking speeds measured by different walkway lengths: Comparison between 5- and 2.4-m walkways

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ABSTRACT

Background/Objectives: Walking speed is known as a useful index for assessing health status and functioning in older individuals. However, the optimal walkway length for measuring walking speed has not been clarified, and measurements have been made using a variety of lengths. This study examined the agreement between two walking speeds collected using different walkway lengths, shorter than in previous studies, for older individuals.

Methods: Participants comprised 206 community-living participants ≥65 years old who were able to perform activities of daily living independently. Comfortable and maximum walking speeds were measured using 5- and 2.4-m walkways. Agreements between 5- and 2.4-m walking speeds under each condition (comfortable and maximum) were investigated using Bland-Altman analysis.

Results: Intraclass correlation coefficients (ICCs) between 5- and 2.4-m walking speeds under conditions of comfortable and maximum pace were 0.945 (95% confidence interval (CI), 0.928~0.958; p <0.001) and 0.923 (95%CI, 0.899~0.941; p <0.001), respectively. Mean differences between 5- and 2.4-m walking speeds under conditions of comfortable and maximum pace were -0.01±0.07 m/s (5 m: 1.44±0.20 m/s; 2.4 m: 1.45±0.20 m/s) and -0.02±0.09 m/s (5 m: 1.86±0.23 m/s; 2.4 m: 1.88±0.23 m/s), respectively. No proportional bias for differences between 5- and 2.4-m walking speeds was found under both comfortable and maximum pace conditions.

Conclusion: Agreement between 5- and 2.4-m walking speeds was close to excellent in older individuals. The 2.4-m walking speed was slightly faster than 5-m walking speed, but the mean difference was extremely small and ignorable. Walking speed measured on a short walkway may be reliable and useful.

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INTRODUCTION

Walking speed is known as a useful index for assessing health status and functioning in older individuals. Indeed, some longitudinal cohort studies have associated slow walking speed with mortality and functional dependence in older individuals.[1-6] Furthermore, walking speed has also been defined as one of the diagnostic criteria for frailty and sarcopenia in older people.[7,8] However, no consensus has been reached regarding the best walkway length for measuring walking speed, and a variety of lengths have been used. For instance, walkway lengths used in previous studies have included 10 m,[9] 8 m,[5] 7.62 m,[10] 6 m,[1,3,6] 5 m,[4] 4.57 m and 2.4 m.[2,7,11,12]

With regard to this issue, previous studies have investigated differences in walking speeds obtained from a variety of walkway lengths, but agreement of walking speeds obtained from relative short walkway lengths such as 2.4 m has not been investigated.[13-15] Whether walking speeds measured using different, relatively short walkway lengths yield consistent results has not been clarified. To assess physical performance using walking speed in older individuals, knowledge of the effects of different walkway lengths on walking speed is clinically important and necessary. The aim of this study was to determine the agreement between walking speeds collected using different lengths, shorter than in previous studies, for older individuals.

MATERIALS AND METHODS

Subjects

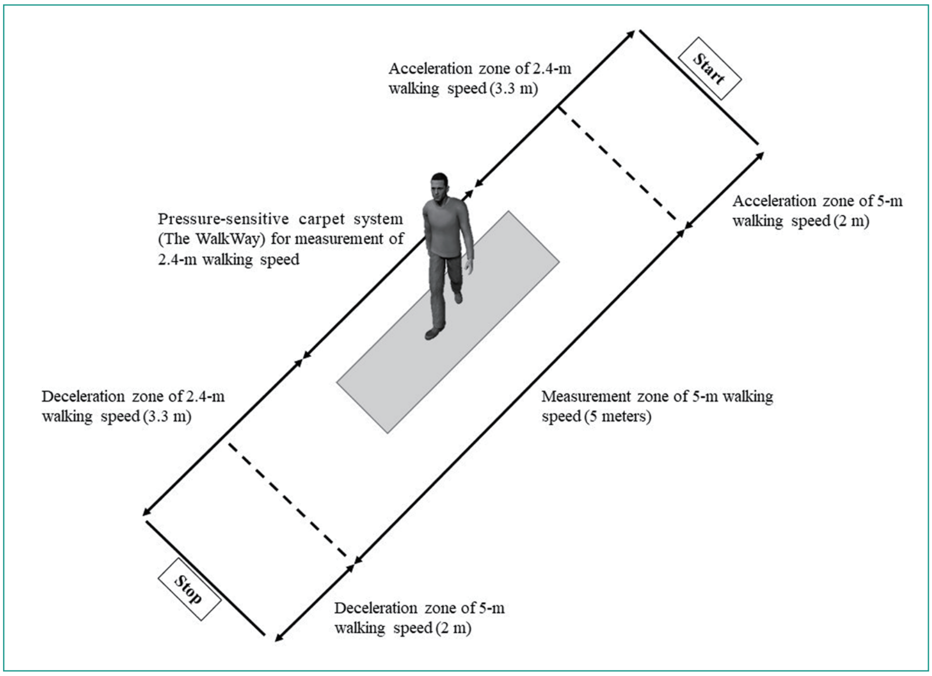
Participants in this study comprised 212 community-dwelling individuals ≥65 years old, recruited from Sagamihara City in Kanagawa prefecture using advertisements in newspapers and community newsletters. The present study included participants who were able to perform activities of daily living (ADL) independently, and who were able to independently attend the location set as the research center for the study. Participants' ADL were confirmed by interview at recruitment, and ADL was defined as independent for individuals lacking certification by long-term care insurance. Individuals with suspected dementia based on interviews with researchers experienced in assessing eligibility were excluded, as were those with acute diseases.

The present study was approved by the Institutional Review Board of the School of Allied Health Sciences at Kitasato University (approval number 2016-G021B), and written informed consent was obtained from all participants.

Procedure

In this study, both 5- and 2.4-m walking speeds were measured under two conditions: comfortable pace; and maximum pace. The 5- and 2.4-m walking speeds were measured simultaneously using the same walkway. Total length of the walkway was set at 9 m, including acceleration and deceleration zones at the start and end of the walkway. A thin carpet 2.4 m in length (width, 0.6 m) into which 14,440 pressure sensors were embedded (WalkWay, MW-1000; ANIMA Corp., Tokyo, Japan) was set in the middle of the walkway (Figure 1). The WalkWay pressure-sensitive carpet system was used to record temporal and spatial gait cycle parameters as the subject walked on the carpet, but only walking speed was analyzed in this study. Sampling frequency of the system was set at 100 Hz. The 5-m walking speed was obtained from the middle of the walkway, then landmarks were located at points 2 m from the start and end of the walkway, and passing time for the 5-m length in the middle of the walkway was measured using a digital stopwatch. The measured time for passing 5 m was converted into the 5-m walking speed (m/s). While the time for 5 m was measured, 2.4-m walking speed was obtained simultaneously from the WalkWay system located in the middle of the walkway. Comfortable walking speed was measured first, followed by maximum walking speed. For measurement of comfortable walking speed, subjects were instructed to walk straight at a "usual" pace. For the measurement of maximum walking speed, subjects were instructed to walk in a straight line as fast as possible. One practice trial was performed at both comfortable and maximum walking speeds, then the measurement trial was performed once.

Figure 1. Diagram of measurement system to obtain 5- and 2.4-m walking speeds



As for other physical performance tests other than walking speed, the timed up-and-go test (TUG) and 5-repetition chair stand time (5CST) were also measured, as physical performance tests associated with walking speed,[16,17] measurements were executed in accordance with the methods described by previous studies.[18,19] Further, instrumental ADL (IADL) was assessed using the sub-items of the Tokyo Metropolitan Institute of Gerontology index of competence (score range, 0-5; higher score indicates higher function, full score is 5 points).[20] Body mass index, medical history of chronic diseases, medication and presence of pain (knee joint and low back) were investigated using a questionnaire.

Statistical analysis

Agreements between 5-m walking speed and 2.4-m walking speed under each condition (comfortable and maximum) were investigated using Bland-Altman analysis.[21] Concordance between 5- and 2.4-m walking speeds under each condition was analyzed using the intraclass correlation coefficient (ICC). Mean values and standard deviations (SDs) for differences between 5- and 2.4-m walking speeds under each condition were calculated (5-m walking speed minus 2.4-m walking speed). For consistent bias, mean difference in 5- and 2.4-m walking speeds were analyzed using the one-sample t-test (null hypothesis: difference between the two walking speeds was zero). The 95% limit of agreement (95%LOA) between 5- and 2.4-m walking speeds under each condition was determined using the following formula: mean difference of two walking speed ±1.96*SD.[21] For proportional bias, correlations between the mean difference in 5- and 2.4-m walking speeds and the mean of 5- and 2.4-m walking speeds were investigated using Pearson's product-moment correlation.

In addition, relationships between 5- and 2.4-m walking speeds and other physical performance tests (TUG and 5CST) were analyzed by Pearson's product-moment correlation and multiple regression analysis adjusting for potential confounding factors (age, sex and IADL score). Statistical differences in correlation coefficients between walking speeds and other physical performance tests were investigated using Hotelling's statistic.[22] For statistical processing, the statistical analysis software R Programming Language and Environment (R version 3.2.2) and EZR package on R Commander (version 1.30) were used, with the level of statistical significance set at 5%.[23,24]

RESULTS

Basic characteristic, results of walking speed and other physical performance tests in all subjects are shown in Table 1. Data from 6 participants were excluded from further statistical analysis, because of missing data for the 2.4-m walking speed (in total, 206 data points were analyzed).

Table 1. Basic characteristics and physical function in all subjects

Variables	Mean±SD	Range
Age (years)	70.8±4.3	(65–83)
Body height (cm)	155.9±7.3	138.0-177.0
Body weight (kg)	54.8±9.2	38.0-85.0
Score of instrumental ADL (maximum, 5)	4.9±0.3	(3-5)
Medical history, n	0.9±0.9	(0-4)
Medication use, n	1.1±1.1	(0-5)
5-m comfortable walking speed (m/s)	1.44±0.20	(1.01-2.07)
2.4-m comfortable walking speed (m/s)	1.45±0.20	(1.03-1.96)
5-m maximum walking speed (m/s)	1.86±0.23	(1.23-2.43)
2.4-m maximum walking speed (m/s)	1.88±0.23	(1.20-2.55)
5-repetition chair stand test (s)	6.2±1.3	(3.5-10.2)
Timed up-and-go test (s)	5.6±0.8	(4.0-8.7)
	Number (%)	
Sex (male)	44 (20.8)	-
Knee pain (yes)	74 (34.9)	-
Low back pain (yes)	80 (37.7)	-

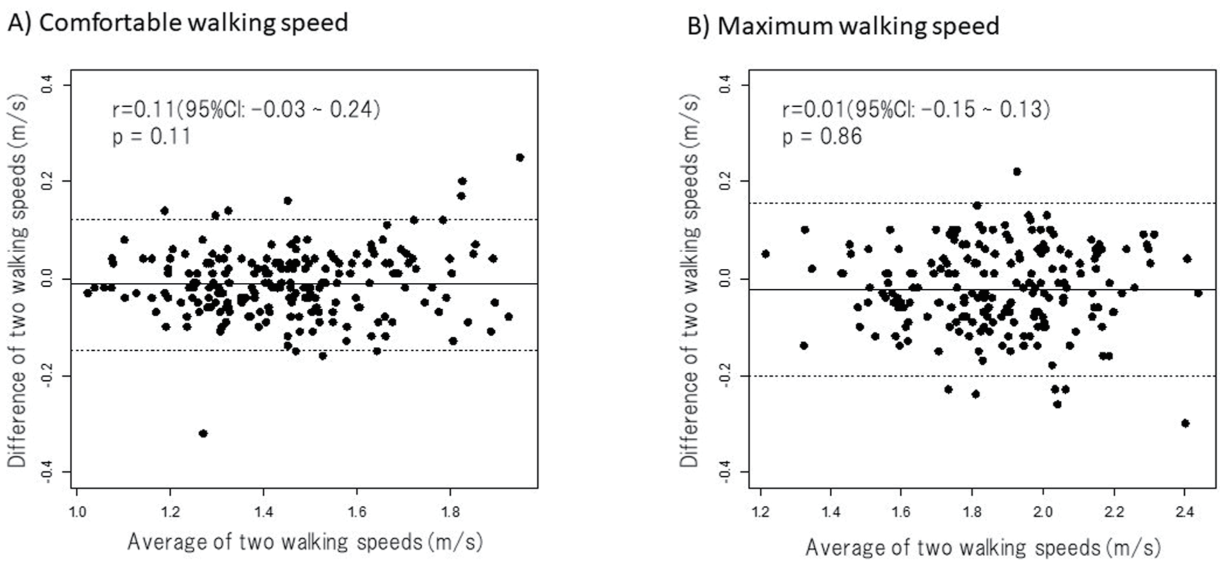
ICCs between 5- and 2.4-m walking speeds under conditions of comfortable and maximum pace were 0.945 (95% confidence interval [CI], 0.928~0.958; p <0.001) and 0.923 (95%CI, 0.899~0.941; p <0.001), respectively. Mean values and SDs in the difference between 5- and 2.4-m walking speeds under conditions of comfortable and maximum pace were -0.01±0.07 m/s and -0.02±0.09 m/s, respectively. In terms of consistent bias, 2.4-m walking speed was significantly faster than 5-m walking speed under both comfortable and maximum pace conditions (comfortable, p=0.016, effect size of Cohen's d=-0.06; maximum, p <0.001, effect size of Cohen's d=-0.09). The 95%CI for the mean difference in the two comfortable walking speeds was -0.02 m/s to -0.002 m/s, and the mean difference in the two maximum walking speeds was -0.04 m/s to -0.01 m/s. Furthermore, 95%LAO for the two comfortable walking speeds was -0.15 m/s to 0.13 m/s, and that for maximum walking speed was -0.20 m/s to 0.16 m/s. On the other hand, as for proportional bias, significant correlations between the mean difference in 5- and 2.4-m walking speeds and mean 5- and 2.4-m walking speeds were not apparent under either condition (comfortable: r=0.11, 95%CI, -0.03~0.24, p=0.116; maximum: r=0.01, 95%CI, -0.15~0.13, p=0.863). Bland and Altman plots were drawn to visually depict the above results for agreements between 5- and 2.4-m walking speeds (Figure 2). Furthermore, differences between 5- and 2.4-m walking speeds under both comfortable and maximum conditions were not associated with age or sex (data not shown). Difference in the two walking speeds under comfortable conditions was unrelated to medical history, but a weak correlation with the difference in maximum pace was identified (Spearman's rank correlation coefficient=0.153, p=0.03).

As for relationships between 5- and 2.4-m walking speeds and other physical performance tests (TUG and 5CST), 5- and 2.4-m walking speeds correlated significantly with TUG and 5CST under both comfortable and maximum pace conditions (Table 2). Also, in multiple regression analysis adjusting for age, sex and IADL score, 5- and 2.4-m walking speeds were significantly related to results from the TUG and 5CST under both conditions (Table 2). At maximum walking speed, the difference in correlation coefficients between walking speed and TUG was not significant (5-m and TUG: r=-0.68; 2.4-m and TUG: r=-0.70; difference of two correlation coefficients, p=0.313). The same difference in correlation coefficients between walking speeds and 5CST was also not significant (5-m and 5CST: r=-0.44; 2.4-m and 5CST: r=-0.45; difference of two correlation coefficients; p=0.865). A similar relationship was seen between comfortable walking speeds and both TUG and 5CST.

DISCUSSION

This study investigated whether agreement exists between 5- and 2.4-m walking speeds in older individuals. Under both comfortable and maximum walking speeds, ICCs between 5- and 2.4-m walking speeds were extremely high and good (all ICCs

Figure 2. Bland-Altman plots for the two walking speeds under each condition



A) Bland-Altman plot for 5- and 2.4-m walking speeds at comfortable pace. Mean difference in the two walking speeds was -0.01 m/s (95%LOA, -0.15 m/s to 0.13 m/s). B) Bland-Altman plot for 5- and 2.4-m walking speeds at maximum pace. Mean difference in the two walking speeds was -0.02 m/s (95%LOA, -0.20 m/s to 0.16 m/s; p <0.01)

Table 2. Relationship between 5- and 2.4-m walking speeds and other physical performance tests

	Timed Up-and-go Test		5-repetition Chair Stand Test	
	r† (95% CI)	B‡ (95% CI)	r† (95% CI)	B‡ (95% CI)
5-m comfortable walking speed	-0.44*** (-0.54,-0.32)	-0.11*** (-0.15,-0.07)	-0.41*** (-0.52,-0.29)	-0.06*** (-0.08,-0.01)
2.4-m comfortable walking speed	-0.47*** (-0.57,-0.35)	-0.12*** (-0.16,-0.08)	-0.42*** (-0.53,-0.31)	-0.06*** (-0.08,-0.01)
5-m maximum walking speed	-0.68*** (-0.75,-0.60)	-0.17*** (-0.21,-0.13)	0.44*** (-0.56,-0.34)	-0.07*** (-0.09,-0.05)
2.4-m maximum walking speed	-0.70*** (-0.76,-0.62)	-0.17*** (-0.21,-0.13)	0.45*** (-0.55,-0.33)	-0.07*** (-0.09,-0.05)

†Pearson's product-moment correlation coefficient; ‡Unstandardized regression coefficient (adjusting for age, sex and IADL score); ***p <0.001.

>0.75),[25] and no proportional bias was statistically evident. On the other hand, in terms of consistent bias, 2.4-m walking speed was slightly faster than 5-m walking speed under conditions of both comfortable and maximum pace. Previous studies that have investigated differences between 10- and 4-m walking speeds also found differences between walking speeds,[13,15] supporting the results of our study. However, mean differences between 5- and 2.4-m walking speeds were 0.01 m/s at a comfortable pace and 0.02 m/s at maximum pace, representing extremely small mean differences. Furthermore, effect sizes between 5- and 2.4-m walking speeds were also too small under both conditions to define the clinical meaning (-0.06 at comfortable pace, -0.09 at maximum).[26] That is, differences between 5- and 2.4-m walking speeds were suggested to be ignorable because of the extremely small mean differences. Agreement between 5- and 2.4-m walking speeds could thus be defined as close to excellent in older individuals. In other words, even if walking speeds were obtained from different environments such as the patient's house and the clinic, these walking speeds may be comparable to each other as reference. Nevertheless, full consideration of the 95%LOA suggests that about ±0.1 m/s in comfortable walking speed and about ±0.2 m/s in maximum walking speed might possibly represent the differences between 5-m walking speed and 2.4-m walking speed. Therefore, when comparing walking speeds in older individuals obtained using different methods, careful interpretation seems necessary.

The reason for differences between 5- and 2.4-m walking speeds cannot be clarified. In the experimental procedures of previous studies,[13-15] agreement for different walking speeds was investigated by repeated measurements, but measurement error, learning effects and fatigue may all result from repeated measurements in general. In fact, a previous study found that even if walkway length differed, when measurements of walking speed were repeated, walking speed in the second trial was significantly faster than that in the first trial.[27] On the other hand, for our experimental procedure, data for 5- and 2.4-m walking speeds were obtained at the same time from the same walkway on second trial to control for measurement errors, learning effects and fatigue. To determine the level of agreement among walking speeds obtained from different walkway lengths, experimental conditions except for walkway length needed to be unified. That is, sources of potential bias such as measurement error and learning effect should be removed to the greatest extent possible. The present study therefore adopted a simultaneous measurement system (Figure 1) for 2.4- and 5-m walking speeds to control for potential bias. Conversely, length of acceleration and deceleration zones inevitably differed between 5- and 2.4-m walking speeds in the present study. However, a previous study indicated that differences in the lengths of the acceleration and deceleration zones had no influence on walking speed.[28] Therefore, even in this study, the influence of acceleration and deceleration zones on walking speeds is difficult to define as a reason for differences between the two walking speeds. After all, in comparing the walking speeds of older individuals obtained from different walkway lengths, a small but consistent bias was suggested to constantly appear. Thus, in cases requiring assessment of walking speed repeatedly over time for the same subjects, interchanging walking speeds obtained from different walkway lengths is not recommended.[29]

We also investigated relationships between 5- and 2.4-m walking speeds and the TUG and 5CST in order to compare the validity for both 5- and 2.4-m walking speeds. TUG and 5CST are useful physical performance tests for older individuals, and those tests have affinity with walking speed.[16,17] As a result, correlation and regression coefficients between the two walking speeds and the TUG and 5CST were equivalent. Thus, 5- and 2.4-m walking speeds were suggested to offer equivalent validity and utility as indices of health status and functioning in older individuals.

This study had several limitations. First, agreement between the 2.4-m walking speed and other walking speeds such as 10-m walking speed was unclear, because of a lack of data regarding that issue in the present study. Second, we investigated older individuals who were independent in ADL, and frail older people were not included in this study. We thus cannot make any comment regarding whether the present results are applicable to such individuals. Last, 2.4-m walking speed was obtained from a walkway with a total length of 9 m in this study. On the other hand, we cannot provide clear evidence regarding whether 2.4-m walking speed measured on a walkway less than 9 m in length is in concordance with walking speed in this study. Careful consideration of this point is warranted.

In conclusion, agreement between 5- and 2.4-m walking speeds was close to excellent among older individuals. The 2.4-m walking speed was slightly faster than the 5-m walking speed, but that mean difference was extremely small and able to be ignored. Therefore, even walking speed measured on a short walkway such as 2.4 m may be reliable and useful clinically, similar to that measured on a longer walkway.

CONFLICTS OF INTEREST STATEMENT

All contributing authors declare that they have no conflicts of interest.

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REFERENCES

01. Cesari M, Kritchevsky SB, Penninx BW, Nicklas BJ, Simonsick EM, Newman AB, et al. Prognostic value of usual gait speed in well-functioning older people -results from the Health, aging and body composition study. *J Am Geriatr Soc.* 2005;**53**:1675-80.

02. Ostir GV, Kuo YF, Berges IM, Markides KS, Ottenbacher KJ. Measures of lower body function and risk of mortality over 7 years of follow-up. Am J Epidemiol 2007;**166**:599-605.

03. Stanaway FF, Gnjidic D, Blyth FM, Le Couteur DG, Naganathan V, Waite L, et al. How fast does the Grim Reaper walk? Receiver operating characteristics curve analysis in healthy men aged 70 and over. *BMJ.* 2011;**343**:d7679.

04. Shinkai S, Watanabe S, Kumagai S, Fujiwara Y, Amano H, Yoshida H, et al. Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. *Age Ageing.* 2000;**29**:441-6.

05. Montero-Odasso M, Schapira M, Soriano ER, Varela M, Kaplan R, Camera LA, et al. Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. *J Gerontol A Biol Sci Med Sci.* 2005;**60A**:1304-9.

06. Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Tokimura F, et al. Incidence of certified need of care in the long-term care insurance system and its risk factors in the elderly of Japanese population-based cohorts: The ROAD study. *Geriatr Gerontol Int.* 2014;**14**:695-701.

07. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci.* 2001;**56A**:M146-56.

08. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis. Report of the European Working Group on Sarcopenia in Older People. *Age Ageing.* 2010;**39**:412-23.

09. Seino S, Shinkai S, Fujiwara Y, Obuchi S, Yoshida H, Hirano H, et al. Reference values and age and sex differences in physical performance measures for community-dwelling older Japanese: a pooled analysis of six cohort studies. *PLoS ONE.* 2014;**9**:e99487.

10. Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. *Age Ageing.* 1997;**26**:15-9.

11. Doi T, Shimada H, Park H, Makizako H, Tsutsumimoto K, Uemura K, et al. Cognitive function and falling among older adults with mild cognitive impairment and slow gait. *Geriatr Gerontol Int.* 2015;**15**:1073-8.

12. Shimada H, Makizako H, Doi T, Makizako H, Tsutsumimoto K, Uemura K, et al. Combined prevalence of frailty and mild cognitive impairment in a population of elderly Japanese people. *J Am Med Dir Assoc.* 2013;**14**:518-524.

13. Wang CY, Chen TR, Lin YH, Liu MH, Chen YC. Gait speed measure: the effect of different measuring distances and the inclusion and exclusion of acceleration and deceleration. *Percept Mot Skills.* 2012;**114**:469-78.

14. Ng SS, Ng PC, Lee CY, Ng ES, Tong MH, Fong SS, et al. Assessing the walking speed of older adults. The influence of walkway length. *Am J Phys Med Rehabil.* 2013;**92**:776-80.

15. Pasma JH, Stijntjes M, Ou SS, Blauw GJ, Meskers CG, Maier AB. Walking speed in elderly outpatients depends on the assessment method. *Age.* 2014;**36**:9736.

16. Podsiadro D, Richardson S. The timed "up & go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc.* 1991;**39**:142-8.

17. Nishimura T, Arima K, Okabe T, Mizukami S, Tomita Y, Kanagae M, et al. Usefulness of chair stand time as a surrogate of gait speed in diagnosing sarcopenia. *Geriatr Gerontol Int.* 2017;**17**:659-61.

18. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol.* 1994;**49**:M85-94.

19. Shumway-Cook A, Brauer S, Woollacott M. Prediction the probability for falls in community-dwelling older adults using the timed up & go test. *Phys Ther.* 2000;**80**:896-903.

20. Koyano W, Shibata H, Nakazato K, Haga H, Suyama Y. Measurement of competence: reliability and validity of the TMIG index of competence. *Arch Gerontol Geriatr.* 1991;**13**:106-16.

21. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet.* 1986;**i**:307-10.

22. Steiger JH. Tests for comparing elements of a correlation matrix. *Psychological Bulletin.* 1980;**87**:245-51.

23. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Accessed on 4 September 2015 at: https://www.R-project.org/.

24. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. *Bone Marrow Transplant.* 2013;**48**:452-8.

25. Leung K, Trevena L, Waters D. Development of an appraisal tool to evaluate strength of an instrument or outcome measure. *Nurse Res.* 2012;**20**:13-9.

26. Cohen J. A power primer. *Psychological Bulletin.* 1992;**112**:155-9.

27. Lyons JG, Heeren T, Stuver SO, Fredman L. Assessing the agreement between 3-meter and 6-meter walk tests in 136 community-dwelling older adults. *J Aging Health.* 2015;**27**:594-605.

28. Ng SS, Au KK, Chan EL, Chan DO, Keung GM, Lee JK, et al. Effect of acceleration and deceleration distance on walking speed of people with chronic stroke. *J Rehabil Med.* 2016;**48**:666-70.

29. Peters DM. Fritz SL, Debra KE. Assessing the reliability and validity of a shorter walk test compared with the 10-Meter Walk Test for measurements of gait speed in healthy, older adults. *J Geriatr Phys Ther.* 2013;**36**:24-30.