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The test–retest reliability and minimal detectable change of spatial and temporal gait variability during usual over-ground walking for younger and older adults[☆]

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Abstract

Gait variability is a marker of gait performance and future mobility status in older adults. Reliability of gait variability has been examined mainly in community dwelling older adults who are likely to fluctuate over time. The purpose of this study was to compare test–retest reliability and determine minimal detectable change (MDC) of spatial and temporal gait variability in younger and older adults. Forty younger (mean age = 26.6 ± 6.0 years) and 46 older adults (mean age = 78.1 ± 6.2 years) were included in the study. Gait characteristics were measured twice, approximately 1 week apart, using a computerized walkway (GaitMat II). Participants completed 4 passes on the GaitMat II at their self-selected walking speed. Test-retest reliability was calculated using Intra-class correlation coefficients ($ICCs_{(2,1)}$), 95% limits of agreement (95% LoA) in conjunction with Bland-Altman plots, relative limits of agreement (LoA%) and standard error of measurement (SEM). The MDC at 90% and 95% level were also calculated. ICCs of gait variability ranged 0.26–0.65 in younger and 0.28–0.74 in older adults. The LoA% and SEM were consistently higher (i.e. less reliable) for all gait variables in older compared to younger adults except SEM for step width. The MDC was consistently larger for all gait variables in older compared to younger adults except step width. ICCs were of limited utility due to restricted ranges in younger adults. Based on absolute reliability measures and MDC, younger had greater test–retest reliability and smaller MDC of spatial and temporal gait variability compared to older adults.

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Keywords

Reliability; Gait; Variability; Younger; Older

1. Introduction

Gait variability is a quantifiable feature of walking defined as fluctuations in the spatial and temporal gait characteristics from one step or stride to the next [1–3]. Gait variability has recently gained much attention in research and clinical studies. Measures of gait variability might provide additional insights into the neuromotor control of walking, assist in identifying mobility dysfunction and fall risk in older adults, above and beyond mean values of gait parameters such as average gait speed or step time [4–6]. In this sense, measures of spatial and temporal gait variability are becoming important clinical tools.

Test–retest reliability is a fundamental psychometric requirement for any measure. However, the reliability of spatial and temporal gait variability is not well established [1,6–8]. The reliability of gait variability has mainly been examined in community dwelling older adults with a mean group age in the 8th decade. The reliability of gait variability in older adults is inconsistent; ranging from poor to excellent, with intra-class correlation coefficients (ICCs) ranging from 0.11 to 0.98 depending on the variables reported [6,7]. Lack of knowledge of the reliability of gait variability measures limits the interpretation of gait variability from evaluative, diagnostic, prognostic and intervention studies [3,6]. In this regard, it is important to know the minimal detectable change (MDC) to support the use of gait variability as an outcome measure in clinical or research settings. The MDC allows investigators to determine if an observed change is a true change or simply a result of a measurement error [9].

Healthy older adults exhibit greater variability in basic spatial and temporal measures of gait when compared to healthy young adults [10–12]. Gait variability is thought to be a function of the neurological integration of numerous sensory inputs (e.g. visual, auditory, vestibular, proprioceptive, etc.) and feedback processes that take place during the generation of each gait cycle [13]. An increase in gait variability is indicative of a decline in the coordination of the locomotor control system and its complex integration of interdependent components [14]. Older adults may fluctuate in their walking from hour to hour, day to day, week to week which could impact the reliability of gait variability whereas walking in younger adults is more stable (fluctuates less), thus potentially leading to more consistent measurements or greater test/retest reliability. In older adults, it is possible that underlying subclinical pathology in important neural locomotor regions might contribute to inconsistent walking over time and low reliability estimates [10].

The purpose of this study was to (i) compare the test–retest reliability and (ii) determine the minimal detectable change (MDC) of spatial and temporal gait variability in younger and older adults over one week. Younger adults are more stable and fluctuate less in their walking over time compared to older adults [10]. Therefore, we hypothesized that younger adults will have greater test–retest reliability and smaller MDC of spatial and temporal gait variability compared to older adults.

2. Methods

2.1. Participants

Forty younger and 46 older adults were included in the study. The younger adults were recruited through fliers posted throughout the University of Pittsburgh. The younger participants were of age 19–47 years, ambulated independently, and had no diagnosed neuromuscular, cardiopulmonary, or orthopedic conditions that would affect walking. The younger participants were first screened over the phone to determine initial eligibility. Subjects who passed the phone screen were scheduled for a one hour clinic visit which included a physical exam (range of motions and muscle testing) to determine final eligibility followed by measurement of gait characteristics using a computerized walkway.

Older participants were identified from a prospective longitudinal study of gait and balance in older adults [15]. The inclusion criteria for the older adults were age 65 or older; self-reported ability to tolerate a five-hour session (with rest periods) of answering questionnaires and performing walking tests; ability to walk a household distances (approximately 50 ft) at a minimum, with or without an assistive device and without the assistance of another person. Also, the older adults had to be free of (a) neuromuscular disorders that impair movement (including but not limited to Parkinson's disease, stroke, and multiple sclerosis); (b) cancer with active treatment (specifically radiation or chemotherapy) within the past 6 months; (c) non-elective hospitalization for a life-threatening illness or major surgical procedure in the past 6 months; (d) severe pulmonary disease requiring supplemental oxygen or resulting in difficulty breathing at rest or with minimal exertion (such as walking between rooms in their home); and (e) chest pain with activity or a cardiac event, such as heart attack within the past 6 months. The older participants were first screened over the phone to determine initial eligibility. Subjects who passed the phone screen were scheduled for a clinic visit which included a physical exam to determine final eligibility. Older adults completed 5 h of testing, including a measurement of gait characteristics which occurred within the first hour of testing. Both studies of younger and older adults were approved by the University of Pittsburgh Institutional Review Board, and all participants provided informed consent prior to participation.

2.2. Gait characteristics

Spatial and temporal gait characteristics were collected using a computerized walkway (GaitMat II) (EQ Inc., Chalfont, PA) [16]. The GaitMat II is an automated gait analysis system, based on the opening and closing of pressure sensitive switches on the walkway that are displayed on the computer screen as footprints when the participant walks. The reliability and validity of the computerized walkway has been established for quantification of the spatial and temporal mean gait characteristics for a variety of populations including children [17], healthy young adults [18], healthy older adults [1,18], and individuals with Parkinson's disease [19] and Huntington disease [20].

For younger adults, the GaitMat II was approximately 12 m in length. The initial and final 2 m were inactive sections to allow for acceleration and deceleration of the participant. The middle 8 m were active and used for data collection. For older adults, the GaitMat II was

approximately 8 m in length. The initial and final 2 m were inactive sections to allow for acceleration and deceleration of the participant. The middle 4 m were active and used for data collection.

Each participant completed two practice walks the length of the walkway to become familiar to walking on mat. Each walk was considered one pass. Four passes were collected at the subject's self-selected walking speed for data collection. Participants completed two test sessions approximately one week apart.

2.3. Data processing

GaitMat II data was inspected and cleaned for half foot-prints (footprints that occur at the beginning and the end of the mat) and extraneous points. Step length, step width, step time, stance time, swing time, and double support time were determined for each individual step. These spatial and temporal gait characteristics were commonly used in studies of gait variability [1,11,14,21,22]. Definitions of each of the spatial and temporal characteristics are listed below in Table 1. We first looked for asymmetries between left and right steps, as asymmetries can impact measures of gait variability [7]. There were no asymmetries between left and right steps, so left and right steps were combined and the standard deviation from all steps was calculated as the measure of gait variability.

2.4. Statistical analysis

All statistical analyses were conducted with SAS version 9.3. We computed appropriate descriptive statistics to describe the study sample. The mean and standard deviation of gait variability of spatial and temporal gait characteristics for younger and older adults were calculated. Absolute differences of gait variability between visit 1 and visit 2 were computed. Independent sample *t*-tests were used to compare the absolute differences between younger and older adults.

To assess test–retest reliability of gait variability in younger and older adults, intra-class correlation coefficients (ICCs) (2, 1 model) were computed. ICCs were interpreted as follows: less than 0.4, poor; 0.4–0.75, fair to good; and more than 0.75, excellent [23]. ICCs represent the relative reliability which is the degree to which individuals maintain their test results in a sample with repeated measurements [24].

Given that ICCs may be affected by limited range of data [25], especially among younger adults, absolute measures of reliability were also calculated. Absolute reliability, which reflects agreement (i.e. measurement error occurring with repeated testing), was assessed using the following analyses: 95% limits of agreement (95% LoA) in conjunction with Bland-Altman plots, relative limits of agreement (LoA%) and standard error of measurement (SEM) [7,24]. 95% limits of agreement (95% LoA) express the degree of error proportional to the mean in the measurement units, and was calculated as follows: 95% LoA = mean $\pm$ 2 SD [26]. Bland–Altman plots were generated to provide a visual presentation of gait variability by plotting the difference of gait variability measured at visit 1 and visit 2 against the average of gait variability from visit 1 and visit 2 [26]. Relative limits of agreement (LoA%) express the absolute difference of gait variability measured at visit 1 vs

visit 2 as a percentage of the group mean of gait variability measured at visit 1 and visit 2 [7,27]. Standard error of measurement (SEM) quantifies the error in the units of the measured variable, and was computed as follows:

$$SD_{\text{pooled}} \times \text{SQRT}(1 - \text{ICC}),$$

where SD is the pooled standard deviation of test–retest measures and the ICC is the calculated intra-class coefficient correlation for the test–retest measures [24].

We also calculated the minimal detectable change (MDC) which is the smallest change that indicates a real change in an individual beyond that attributed to measurement error. The MDC at 90% and 95% level were calculated using the following equations: $\text{MDC}_{90} = \text{SEM} \times 1.65 \times \text{SQRT}2$; $\text{MDC}_{95} = \text{SEM} \times 1.96 \times \text{SQRT}2$ [9].

3. Results

3.1. Participant characteristics

Younger adults (10 male and 30 female), with a (mean $\pm$ standard deviation) age of 26.6 ± 6.0 years were included in the study. Older adults (11 male and 35 female), with age 78.1 ± 6.2 years were included in the study. On average, older adults walked slower, with a shorter step length and a wider step width compared to younger adults (Table 2).

3.2. Gait variability of spatial and temporal gait characteristics

The mean gait variability of spatial gait characteristics for younger and older adults ranged 0.02–0.03 m and for temporal gait characteristics ranged 0.02–0.04 s. Younger adults were less variable and had a smaller range of values compared to older adults. The absolute differences of gait variability between visits 1 and 2 were greater in older adults compared to younger for all gait variables. The absolute differences of gait variability between visits 1 and 2 were significantly different between younger and older adults for all gait variables except step length and stance time (Table 3).

3.3. Reliability and minimal detectable change of spatial and temporal gait variability

Intra-class correlation coefficients of gait variability (ICCs) ranged 0.26–0.65 in younger and 0.28–0.74 in older adults. In younger adults, step length was the most reliable with $\text{ICC} = 0.65$, whereas step width was the least reliable with $\text{ICC} = 0.29$. In older adults, step width was the most reliable with $\text{ICC} = 0.50$ and step length was the least reliable with $\text{ICC} = 0.28$ (Table 4).

Relative limits of agreement (LoA%) were consistently higher (i.e. less reliable) for all gait variables in older compared to younger adults. Relative limits of agreement (LoA%) ranged from 16.7% to 24% in younger adults and from 26.7% to 40% in older adults (Table 4). In younger adults, step length was the most reliable with $\text{LoA}\% = 16.7\%$, whereas step width was the least reliable with $\text{LoA}\% = 24\%$. In older adults, step width and double support time were the most reliable with $\text{LoA}\% = 26.7\%$ and step time and swing time were the least reliable with $\text{LoA}\% = 40\%$ (Table 4). The SEM were consistently higher (i.e. less reliable) for

all gait variables in older adults compared to younger except for step width. The MDC was consistently larger for all gait variables in older adults compared to younger except for step width. Fig. 1 illustrates the Bland–Altman plot for step time variability and plots of other spatial and temporal gait variability were similar. The Bland–Altman plots showed that there was no negative or positive trend; however, participants with greater gait variability tended to be less reliable.

The gait variability values for younger adults were calculated using a mean of 38 steps, whereas for older adults the gait variability values were calculated using a mean of 23 steps. To ensure the number of steps used in the calculation of gait variability did not impact our results, we repeated the analysis using the same number of steps for younger and older adults (number of steps = 23). Sensitivity analyses including the same number of steps in the calculations for younger and older adults did not significantly alter the findings.

4. Discussion

When examining the test–retest reliability of spatial and temporal gait variability in younger and older adults using both absolute and relative reliability our findings were inconsistent. Using a relative measure of reliability, the ICCs, reliability of gait variability ranged from poor to fair in both younger and older adults, whereas using absolute measures of reliability, the younger were more reliable than the older adults. The discrepancy between relative and absolute measures of reliability highlights an important difference between the approaches. A low ICC may be obtained in situations where there is a small range of values in the sample and does not necessarily mean that a test is not acceptable [18] as ICC is influenced by the heterogeneity of the sample and variability of data [24,26]. Given the limited range in the younger adults in our sample, the ICC may not be the best measure of reliability. In contrast, absolute reliability statistics are not affected by these sample characteristics; therefore, the discussion will focus on the absolute reliability findings. Similar studies who have examined the reliability of gait variability and dealt with issues of limited range data have also reported absolute reliability [7,27–29].

Younger adults had smaller absolute differences compared to older adults in all gait variability parameters. Also, with LoA% and SEM younger adults were consistently more reliable than the older adults in all gait variables except SEM for step width. The MDC₉₀ and MDC₉₅ values were consistently lower in younger adults compared to the older adults in all gait variables except step width. These results of absolute reliability and MDC support our hypothesis that younger adults are more stable from time to time and fluctuate less over time compared to older adults. Therefore, our findings suggest that in older adults, some age-related decline in the organization and stability of the gait cycle is expected, which may be indicative of the overall health and control of the locomotor system. The findings also help to expand our knowledge about reliability and minimal detectable change of gait variability in younger and older adults. Furthermore, the current findings may suggest the use of spatial and temporal gait variability as a valuable measure for assessing the stability of the locomotor system.

To our best knowledge, no previous study has investigated the test–retest reliability and the MDC of gait variability in healthy young and older adults in the same analysis. Previous studies investigated the reliability and MDC of gait variability either only in young or only in older adults [7,27,28,30]. The majority of previous studies which investigated the test–retest reliability of gait variability report the ICC, which had limitations in our study sample [1,6,8]. Of the studies that investigated the test–retest reliability of spatial and temporal gait variability, only Galna et al. [7] examined similar gait variability characteristics as our study and reported relative limits of agreement (LoA%) as a measure of absolute reliability. When comparing LoA% of gait variability for healthy older adults during intermittent walks, our values were lower than Galna et al. [7]. In our study ($n = 46$), LoA% ranged from 26.7% to 40%, whereas Galna et al. [7] ($n = 27$) reported LoA% ranged from 55% to 87%, the higher (greater) values of LoA% which represent poorer absolute reliability may be partly explained by the smaller sample size.

Interestingly, the Bland–Altman plots showed that in older adults greater gait variability was associated with a greater difference in gait variability from visit 1 to visit 2 (i.e. greater inconsistency). However, many of the older adults with low gait variability had a small difference in gait variability from session to session (i.e. consistent gait variability) which is similar to the younger participants.

Potential limitations of this study should be acknowledged. First, gait variability was collected during intermittent walks with a limited number of passes. Testing protocol can impact the reliability of gait variability. Recently, Galna et al. [7] suggested using a continuous walking protocol instead of short intermittent walks with no fewer than 30 steps to improve the reliability of gait variability. The purpose of our study was to compare the reliability of gait variability between younger and older adults, as commonly measured over short distances, and not to maximize the reliability estimate of gait variability. Second, the SEM and the MDC results in our study should be interpreted with caution since the ICC is used in their calculations. In our study, the ICCs may have been influenced by a limited range of values.

Future research should further investigate inconsistency of gait variability as a potential early indicator of a decline in mobility. For example, measuring gait variability at more frequent time intervals whether it is daily or hourly to see if this inconsistency in gait variability is a true phenomenon which could be a marker of early decline in the locomotor control and stability and not simply an indicator of a measurement error.

5. Conclusion

Younger adults had greater test–retest reliability and smaller MDC of spatial and temporal gait variability compared to older thus supporting the hypothesis that younger are more stable and fluctuate less over time compared to older adults.

References

1. Brach JS, Perera S, Studenski S, Newman AB. The reliability and validity of measures of gait variability in community-dwelling older adults. *Arch Phys Med Rehabil.* 2008; 89(12):2293–6. [PubMed: 19061741]
2. Brach JS, Perera S, Studenski S, Katz M, Hall C, Verghese J. Meaningful change in measures of gait variability in older adults. *Gait Posture.* 2010; 31(2):175–9. [PubMed: 19889543]
3. Callisaya ML, Blizzard L, Schmidt MD, McGinley JL, Srikanth VK. Ageing and gait variability – a population-based study of older people. *Age Ageing.* 2010; 39(2):191–7. [PubMed: 20083617]
4. Brach JS, Berlin JE, VanSwearingen JM, Newman AB, Studenski SA. Too much or too little step width variability is associated with a fall history in older persons who walk at or near normal gait speed. *J Neuroeng Rehabil.* 2005; 2:21. [PubMed: 16042812]
5. Brach JS, Studenski SA, Perera S, VanSwearingen JM, Newman AB. Gait variability and the risk of incident mobility disability in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci.* 2007; 62(9):983–8. [PubMed: 17895436]
6. Lord S, Howe T, Greenland J, Simpson L, Rochester L. Gait variability in older adults: a structured review of testing protocol and clinimetric properties. *Gait Posture.* 2011; 34(4):443–50. [PubMed: 21920755]
7. Galna B, Lord S, Rochester L. Is gait variability reliable in older adults and Parkinson's disease? Towards an optimal testing protocol. *Gait Posture.* 2013; 37(4):580–5. [PubMed: 23103242]
8. Moe-Nilssen R, Aaslund MK, Hodt-Billington C, Helbostad JL. Gait variability measures may represent different constructs. *Gait Posture.* 2010; 32(1):98–101. [PubMed: 20434916]
9. Haley SM, Fragala-Pinkham MA. Interpreting change scores of tests and measures used in physical therapy. *Phys Ther.* 2006; 86(5):735–43. [PubMed: 16649896]
10. Kobsar D, Olson C, Paranjape R, Hadjistavropoulos T, Barden JM. Evaluation of age-related differences in the stride-to-stride fluctuations, regularity and symmetry of gait using a waist-mounted tri-axial accelerometer. *Gait Posture.* 2014; 39(1):553–7. [PubMed: 24139685]
11. Owings TM, Grabiner MD. Step width variability, but not step length variability or step time variability, discriminates gait of healthy young and older adults during treadmill locomotion. *J Biomech.* 2004; 37(6):935–8. [PubMed: 15111081]
12. Owings TM, Grabiner MD. Variability of step kinematics in young and older adults. *Gait Posture.* 2004; 20(1):26–9. [PubMed: 15196516]
13. Chau T, Young S, Redekop S. Managing variability in the summary and comparison of gait data. *J Neuroeng Rehabil.* 2005; 2:22. [PubMed: 16053523]
14. Hausdorff JM, Rios DA, Edelberg HK. Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehabil.* 2001; 82(8):1050–6. [PubMed: 11494184]
15. Brach JS, Perera S, VanSwearingen JM, Hile ES, Wert DM, Studenski SA. Challenging gait conditions predict 1-year decline in gait speed in older adults with apparently normal gait. *Phys Ther.* 2011; 91(12):1857–64. [PubMed: 22003167]
16. Craik, R.; Oatis, CA., 1st, editors. *Gait analysis: theory and application.* 1st. Vol. xv. St. Louis: Mosby; 1995. p. 471
17. Thorpe DE, Dusing SC, Moore CG. Repeatability of temporospatial gait measures in children using the GAITRite electronic walkway. *Arch Phys Med Rehabil.* 2005; 86(12):2342–6. [PubMed: 16344033]
18. Menz HB, Latt MD, Tiedemann A, Mun San Kwan M, Lord SR. Reliability of the GAITRite walkway system for the quantification of temporo-spatial parameters of gait in young and older people. *Gait Posture.* 2004; 20(1):20–5. [PubMed: 15196515]
19. Nelson AJ, Zwick D, Brody S, Doran C, Pulver L, Rooz G, et al. The validity of the GaitRite and the Functional Ambulation Performance scoring system in the analysis of Parkinson gait. *NeuroRehabilitation.* 2002; 17(3):255–62. [PubMed: 12237507]
20. Rao AK, Quinn L, Marder KS. Reliability of spatiotemporal gait outcome measures in Huntington's disease. *Mov Disord.* 2005; 20(8):1033–7. [PubMed: 15838854]

21. Hausdorff JM, Edelberg HK, Mitchell SL, Goldberger AL, Wei JY. Increased gait unsteadiness in community-dwelling elderly fallers. *Arch Phys Med Rehabil.* 1997; 78(3):278–83. [PubMed: 9084350]
22. Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. *J Am Geriatr Soc.* 1997; 45(3):313–20. [PubMed: 9063277]
23. Rosner, B., 4th, editor. *Fundamentals of biostatistics.* 4th. Vol. xi. Duxbury Press; Belmont, CA: 1995. p. 682
24. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med.* 1998; 26(4):217–38. [PubMed: 9820922]
25. Hopkins WG. Measures of reliability in sports medicine and science. *Sports Med.* 2000; 30(1):1–15. [PubMed: 10907753]
26. Bland JM, Altman DG. Measurement error. *BMJ.* 1996; 313(7059):744. [PubMed: 8819450]
27. Hartmann A, Murer K, de Bie RA, de Bruin ED. Reproducibility of spatio-temporal gait parameters under different conditions in older adults using a trunk tri-axial accelerometer system. *Gait Posture.* 2009; 30(3):351–5. [PubMed: 19628391]
28. Konig N, Singh NB, von Beckerath J, Janke L, Taylor WR. Is gait variability reliable? An assessment of spatio-temporal parameters of gait variability during continuous overground walking. *Gait Posture.* 2014; 39(1):615–7. [PubMed: 23838361]
29. Paterson KL, Hill KD, Lythgo ND, Maschette W. The reliability of spatiotemporal gait data for young and older women during continuous overground walking. *Arch Phys Med Rehabil.* 2008; 89(12):2360–5. [PubMed: 19061748]
30. Hars M, Herrmann FR, Trombetti A. Reliability and minimal detectable change of gait variables in community-dwelling and hospitalized older fallers. *Gait Posture.* 2013; 38(4):1010–4. [PubMed: 23790571]

Fig. 1.

Bland–Altman plots of step time variability difference vs average step time variability with 95% limits of agreements in (A) younger and (B) older adults.

Table 1

Descriptions of spatial and temporal gait characteristics [1,4].

Gait characteristics	Description
Spatial parameters	
Step length	Distance between 2 consecutive footprints, measured from the heel of 1 footprint to the heel of the next footprint and was recorded in meters
Step width	Distance between the outermost borders of 2 consecutive footprints and was recorded in meters
Temporal parameters	
Step time	Time between initial foot-floor contact of one foot to the initial foot-floor contact of the contralateral side for two consecutive steps, recorded in seconds
Stance time	Amount of time 1 foot is in contact with the floor (i.e. from initial foot-floor contact until final foot-floor contact), recorded in seconds
Swing time	Time elapsed between the last contacts of the current footfall to the initial contact of the next footfall of the same foot, recorded in seconds
Double support time	Double support occurs when both feet are in contact with the ground simultaneously; double support time is the sum of the time elapsed during two periods of double support in the gait cycle, recorded in seconds

Table 2

Characteristics of younger and older participants.

Characteristics	Younger (<i>n</i> = 40)	Older (<i>n</i> = 46)	<i>P</i> value
Demographics			
Age (years)	26.60 (6.0)	78.09 (6.2)	0.000*
Gait characteristics			
Gait speed (m/s)	1.29 (0.19)	0.95 (0.28)	0.000*
Step length (m)	0.70 (0.06)	0.53 (0.12)	0.000*
Step width (m)	0.04 (0.02)	0.06 (0.04)	0.008*
Step time (s)	0.55 (0.05)	0.58 (0.10)	0.082
Swing time (s)	0.42 (0.03)	0.44 (0.05)	0.009*
Stance time (s)	0.69 (0.07)	0.73 (0.15)	0.140
Double support time (s)	0.13 (0.03)	0.14 (0.06)	0.375

Note: Values are mean (standard deviation) unless otherwise noted.

* A significant difference ($P < 0.05$) between characteristics of younger and older adults using independent sample *t*-tests.

Table 3

Description of variability of gait characteristics for younger and older adults, mean $\pm$ standard deviation (range).

Gait variability	Younger		Older		Absolute difference between visit 1 and visit 2		P value
	Visit 1	Visit 2	Visit 1	Visit 2	Younger	Older	
Step length (m)	0.03 $\pm$ 0.01 (0.02–0.05)	0.03 $\pm$ 0.01 (0.02–0.04)	0.03 $\pm$ 0.02 (0.02–0.14)	0.03 $\pm$ 0.01 (0.02–0.06)	0.005 $\pm$ 0.003	0.009 $\pm$ 0.016	0.081
Step width (m)	0.02 $\pm$ 0.01 (0.01–0.04)	0.03 $\pm$ 0.01 (0.02–0.04)	0.03 $\pm$ 0.01 (0.01–0.06)	0.03 $\pm$ 0.01 (0.01–0.07)	0.006 $\pm$ 0.004	0.008 $\pm$ 0.009	0.021*
Step time (s)	0.03 $\pm$ 0.01 (0.01–0.04)	0.03 $\pm$ 0.01 (0.01–0.05)	0.03 $\pm$ 0.02 (0.01–0.09)	0.03 $\pm$ 0.02 (0.01–0.08)	0.006 $\pm$ 0.004	0.012 $\pm$ 0.014	0.002*
Swing time (s)	0.02 $\pm$ 0.00 (0.02–0.04)	0.02 $\pm$ 0.00 (0.02–0.03)	0.03 $\pm$ 0.02 (0.01–0.11)	0.03 $\pm$ 0.02 (0.01–0.09)	0.004 $\pm$ 0.004	0.012 $\pm$ 0.016	0.001*
Stance time (s)	0.03 $\pm$ 0.01 (0.02–0.06)	0.03 $\pm$ 0.01 (0.02–0.06)	0.04 $\pm$ 0.02 (0.02–0.09)	0.04 $\pm$ 0.02 (0.02–0.11)	0.007 $\pm$ 0.006	0.011 $\pm$ 0.009	0.071
Double support time (s)	0.02 $\pm$ 0.00 (0.01–0.03)	0.02 $\pm$ 0.00 (0.01–0.03)	0.03 $\pm$ 0.01 (0.01–0.06)	0.03 $\pm$ 0.02 (0.01–0.09)	0.004 $\pm$ 0.002	0.008 $\pm$ 0.009	0.000*

Absolute difference is the absolute difference of spatial and temporal gait variability between visit 1 and visit 2.

* A significant difference ($p < 0.05$) of the absolute differences between younger and older adults using independent sample t -tests.

Table 4

Test–retest reliability and MDC of gait variability for younger and older adults.

Gait variability	ICC (CI 95%)		95% LoA		LOA %		SEM		MDC ₉₀		MDC ₉₅	
	Younger	Older	Younger	Older	Younger	Older	Younger	Older	Younger	Older	Younger	Older
Step length (m)	0.65 (0.43, 0.80)	0.28 (−0.02, 0.52)	−0.012 to 0.011	−0.036 to 0.039	16.7	30.0	0.006	0.017	0.014	0.040	0.016	0.047
Step width (m)	0.29 (0.03, 0.56)	0.50 (0.24, 0.68)	−0.016 to 0.011	−0.025 to 0.023	24.0	26.7	0.008	0.007	0.020	0.017	0.023	0.020
Step time (s)	0.54 (0.29, 0.73)	0.43 (0.15, 0.64)	−0.016 to 0.013	−0.037 to 0.036	20.0	40.0	0.007	0.015	0.016	0.035	0.019	0.042
Swing time (s)	0.26 (−0.05, 0.53)	0.36 (0.07, 0.58)	−0.012 to 0.010	−0.040 to 0.040	20.0	40.0	0.000	0.016	0.000	0.037	0.000	0.044
Stance time (s)	0.56 (0.30, 0.74)	0.74 (0.57, 0.84)	−0.020 to 0.016	−0.025 to 0.030	23.3	27.5	0.007	0.010	0.015	0.024	0.018	0.028
Double support time (s)	0.45 (0.17, 0.66)	0.38 (0.10, 0.60)	−0.009 to 0.007	−0.036 to 0.033	20.0	26.7	0.000	0.008	0.000	0.018	0.000	0.022

Abbreviations: ICC, intra-class correlation coefficient; CI 95%, 95% confidence interval for the ICC; 95% LoA, Bland and Altman 95% limits of agreement; LoA%, relative limits of agreement; SEM, standard error of measurement; MDC₉₀, minimal detectable change with a confidence level of 90%; MDC₉₅, minimal detectable change with a confidence level of 95%.