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Relationship between Age-Associated Changes of Gait and Falls and Life-Space in Elderly People

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Abstract. [Purpose] The aim of this study was to identify the age-associated changes in gait speed, stride length, cadence and step width, and to examine the relationship between these gait variables with a history of falls and life-space experience among elderly people. [Subjects] The participants were 848 healthy elderly adults (mean age 80 years, range 73–91, 76.8% women) living independently at home. [Methods] Gait speed, stride length, cadence and step width were measured at a normal pace using WalkWay, a device for measuring the distribution of foot pressure during walking. Any history of falls in the previous year was investigated by self-report and a life-space assessment was used to investigate the activity status of the subjects. [Results] Gait speed and stride length decreased markedly from age 85 years in women, and from age 90 years in men. Cadence and step width did not change consistently with aging. Gait speed was associated significantly with a history of falls and with life-space restriction, although these relationships were weak. [Conclusion] Gait speed reduces with age and might reflect a functional decline in elderly people.

Key words: Stride length, Cadence, Step width

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INTRODUCTION

Healthy elderly people have less muscle mass, strength and power production than healthy young people[1–8)]. These functional declines are associated with a slower gait speed, shorter stride length, shorter leg swing phase and less range of motion at the hip, knee and ankle joints during walking[9–16)]. In turn, reduced gait performance is strongly associated with a reduced ability to undertake activities of daily living[17,18)] and an increased risk of falls in older people[19,20)]. Therefore, evaluation of gait is a priority for geriatric health and intervention programs.

Kinesiological studies using kinetic or kinematic analyses have identified the characteristics of gait in older people[9–16)]; although, the measurements of laboratory-based assessments are inapplicable to population-based field surveys. We analyzed gait characteristics of the elderly using a device for measuring the distribution of foot pressure during walking. The device can measure gait speed, stride length, cadence and step width easily in field surveys. Thus, we were able to analyze gait characteristics using population-based data in a community setting.

The purpose of this study was to identify the age-associated changes in gait speed, stride length, cadence and step width and to examine the determinants of risk of falls and life-space restriction among elderly people. Because falls and reduced life-space relate closely to physical performance[21–25], functional decline[26,27] and frailty[28] in elderly people, we used a self-reported history of falls and life-space assessment (LSA)[24] as outcomes for a precursor index of functional decline.

SUBJECTS AND METHODS

Gait assessment was conducted on 1,124 elderly participants who attended health checkups in Tokyo. The following were excluded from this study: participants with a history of stroke (n = 84), osteoarthritis of the hip (n = 39), chronic obstructive pulmonary disease (n = 21), those who could not use public transportation independently (n = 41), those could not complete six trials in the gait test (n = 41) and those with missing values in the gait assessment (n = 50). The remaining 848 healthy elderly adults (mean age 80 years, range 73–91; 76.8% women) were analyzed in this study. The participants were fully informed about the purpose, nature and potential risks of the experiments and they gave their written, informed consent before participating in the study. The Ethics Committee of the Tokyo Metropolitan Institute of Gerontology approved the study protocol, which conforms to the Declaration of Helsinki.

Gait variables were measured using a WalkWay device (WalkWay MW-1000, Anima Co., Tokyo, Japan), which measures the distribution of foot pressure during walking. The WalkWay measures 800 × 2,400 mm (5 mm thick) and is mounted with strain gages placed 10 mm apart (14,000 points). The participants walked on the WalkWay at their normal pace for 3 m. A 1.5 m approach was allowed before reaching the starting edge of the WalkWay so that the participants were walking at their normal pace before reaching the WalkWay. The participants were also instructed to continue walking past the end of the WalkWay for a further 1.5 m to ensure that their walking pace was consistent throughout the task (Fig. 1). The mean scores of six trials in gait speed, stride length, cadence and step width were calculated from the distributions of foot pressure. Step width was calculated for the left and right feet separately and was determined from the lateral displacement of the left or right foot based on the previous position of the opposite foot.

A fall was defined as “an event that resulted in a person coming to rest unintentionally on the ground or another lower level that did not result from a major intrinsic event or an overwhelming hazard”[29]. Falls were measured retrospectively for one-year period using a self-report questionnaire.

Life-space mobility was measured using a Japanese translation of the LSA[27]. A repeated forward-backward translation procedure was adopted to produce the Japanese version of the LSA. The translation was done by a native English-speaking translator and three Japanese translators and confirmed by “Dr Patricia S. Baker” who published “Measuring Life-Space Mobility in Community-Dwelling Older Adults”. The LSA is used to derive a score based on the distance a person reports moving during the 4 weeks before the assessment. The five life-space level questions range from the room where individuals sleep to beyond the individual’s town, asking specifically about movement to: (1) “other rooms of your home besides the room where you sleep?”; (2) “an area outside your home such as your porch, deck or patio, hallway (of an apartment building) or garage, in your own yard or driveway?”; (3) “places in your neighborhood, other than your own yard or apartment building?”; (4) “places outside your neighborhood, but within your town?”; (5) “places outside your town?”. For each life-space level, participants were asked how often they traveled to that area (less than once a week; 1–3 times each week; 4–6 times each week; or daily) and whether they needed assistance from another person or from an assistive device (“yes” or “no”). The LSA scores range from 0 (“totally room-bound”) to 120 (“travel out of town every day without assistance”)[24].

All statistical analyses used SPSS software (Version 17; SPSS Inc., Chicago, IL, USA). Analysis of variance (ANOVA) and Scheffe’s post hoc test were used to compare gait variables between age grades for each 5 years in women and men. The participants were divided into four groups in terms of gait pattern: long stride and fast cadence; long stride and slow cadence; short stride and fast cadence, and short stride and slow cadence. Medians of the stride and cadence scores in women and men were used as cutoff points for classifying the participants. Multiple logistic regression analysis (forced entry) was used to determine the correlates of history of falls in the subjects. The independent variables included age, gender, gait speed, stride length, cadence, step width of left foot and gait pattern, because there was a high correlation between left and right step width ($r = 0.85$). Relationships between LSA score and gait variables were examined using Pearson's correlation analysis. Stepwise linear regression analysis was used to determine any independent correlates of the LSA score. The independent variables included age, gender, gait speed, stride length, cadence and step width of left foot. The variance inflation factor (VIF) was used to assess multicollinearity among the independent variables in the regression model. All reported p values are two-tailed and $p<0.05$ was considered significant.

RESULTS

Gait speed and stride length decreased with aging and showed significant differences between the groups aged<80 years and ≥80 years in women and between those aged<90 years and ≥90 years in men. The women showed higher cadence values in the groups aged<80 years than among those aged ≥80 years, although the differences were not consistent according to age. Step widths for the left and right feet increased more significantly in women aged 80–84 years than among those aged<80 years. There were no significant differences in cadence and step width in men at any age (Table 1). Median values of stride length and cadence were 104.5 cm and 123.9 steps/min in women and 114.0 cm and 116.0 steps/min in men, respectively.

During the one-year period, 142 (16.7%) out of 846 participants fell at least once and 41 (4.8%) participants experienced recurrent falls. A multiple logistic model showed a significant relationship between history of falls and gait speed, cadence and gait pattern in our participants. A fast cadence increased the risk of falls in an analysis of cadence alone, but a combined index of stride length and cadence showed that the short stride and slow cadence combination increased the risk of falls in these participants (Table 2).

LSA correlated significantly with gait speed, stride length, cadence and step width for both feet, but the significances were weak ($r = -0.14$ to 0.30; Table 3). In the multivariate model, gait speed and age were significant determinants of LSA, although the multiple correlation coefficient of the model was low ($r2 = 0.10$). Beta estimates of gait speed (0.28) were higher than those for age (–0.08). The VIF values among the determinants were low in the regression model (gait speed = 1.14; age = 1.14). Therefore, there was little multicollinearity among the independent variables in this model.

DISCUSSION

Walking performance decreases with advancing age. One longitudinal study showed a significant interaction between age group and normal gait speed in elderly people[30)]. The results demonstrated that elderly adults aged 75 years and over showed a greater decrease in gait speed than did the elderly aged 65 to 74 years. The mean decreases in gait speeds over 4 years in young-old and old-old adults were about 6% and 10%, respectively[30)]. A previous cross-sectional study, participants aged 19–102 years, indicated that the age of 62 years coincided with an accelerated decline in the speed of walking. Before that age, there was a 1–2% per decade decline in normal walking speed. After 63 years of age, women showed a 12.4% decrease per decade and men showed a 16.1% decrease per decade. Moreover, the elderly participants had significantly slower speed of walking and shorter step lengths than the younger adults[31)]. The present study showed a significant decline in gait speed and stride length with age. These declines in physical performances were apparent at age 80 years and over in women and at age 90 years and over in men. In our participants, there was a 12% decrease in normal gait speed between women aged 70 and 80 years compared with only a 4% decrease for men. Further study is needed to identify whether the sex difference in age-related decline of gait speed is caused by physiological changes or other characteristics of the participants.

Gait speed, cadence and the short stride/slow cadence gait pattern were associated with a history

Table 1. Differences in gait items between 5-year age groups of elderly men and women

		Women				Men			
	Age (year)	N	Mean	SD		N	Mean	SD	
Gait speed (cm/s)	73–74 [a]	80	126.2	15.4	a>c, d, e	0			
	75–79 [b]	279	121.0	17.5	b>c, d, e	55	117.4	20.6	b>e
	80–84 [c]	216	112.2	19.7	c>e	98	116.7	18.7	c>e
	85–89 [d]	68	104.4	22.9		36	109.4	17.5	d>e
	≥90[e]	8	90.6	21.5		8	83.3	16.7	
	All	651	116.6	19.9		197	114.2	20.1	
Stride length (cm)	73–74 [a]	80	112.8	12.9	a>c, d, e	0			
	75–79 [b]	279	110.9	14.4	b>c, d, e	55	115.8	16.8	b>e
	80–84 [c]	216	104.3	14.6	c>e	98	113.6	16.6	c>e
	85–89 [d]	68	98.6	17.6		36	106.7	16.8	d>e
	≥90[e]	8	86.8	14.3		8	88.4	12.1	
	All	651	107.3	15.5		197	111.9	17.4	
Cadence (steps/min)	73–74 [a]	80	125.9	9.5	a>d	0			
	75–79 [b]	279	125.3	10.7	b>c ,d	55	116.2	10.7	ns
	80–84 [c]	216	122.1	11.6		98	117.3	10.9	
	85–89 [d]	68	120.0	12.5		36	116.7	9.5	
	≥90[e]	8	121.4	13.1		8	107.7	12.9	
	All	651	123.7	11.3		197	116.5	10.8	
Step width of left foot (cm)	73–74 [a]	80	7.8	2.2	a<d	0			
	75–79 [b]	279	8.2	2.3		55	10.2	3.0	ns
	80–84 [c]	216	8.4	2.4		98	9.8	2.6	
	85–89 [d]	68	9.2	2.9		36	11.0	3.0	
	≥90[e]	8	8.7	1.9		8	12.0	3.8	
	All	651	8.3	2.4		197	10.2	2.9	
Step width of right foot (cm)	73–74 [a]	80	7.2	2.2	a<d	0			
	75–79 [b]	279	7.5	2.3	b<d	55	9.2	3.1	ns
	80–84 [c]	216	7.7	2.5		98	9.1	2.7	
	85–89 [d]	68	8.6	3		36	10.1	2.9	
	≥90 [e]	8	8.1	1.2		8	11.2	3.9	
	All	651	7.7	2.4		197	9.4	2.9	

ns; not significance.

of falls in these elderly adults. A short stride and slow cadence gait pattern was the cause of a slow gait, and a logistic model showed significant relationships between falls and slow gait speed and the short stride/slow cadence gait pattern. Our previous studies identified that slower gait speed is a strong determinant of occurrence of falls in elderly adults[32,33]. This study is consistent with previous findings, although the association between fast cadence and risk of falls in the elderly adults remains unclear.

Restrictions physical activity are associated with deteriorations in gait performance and activities of daily living (ADL) independence[34], even in elderly adults with an otherwise low risk of gait disturbance[35]. Thus, the measurement of mobility in terms of how far and how often people go to various destinations can be used to potentially predict the risk of ADL decline in elderly adults without gait impairment. The LSA used in the present study as a mobility assessment was associated with all gait variables, but only gait speed was associated with the LSA independently, although the correlation was weak. LSA score is associated with physical performance as well as sociodemographic factors. Peel et al. reported that 45.5% of the variability in LSA scores could be explained by measures of physical abilities (ADL, instrumental ADL and physical performance test), 12.7% could be explained by sociodemographic

Table 2. Relationship between a history of falls and gait variables (n=846)

	Odds ratio (95% CI †)
Age, (year)	1.02 (0.97–1.07)
Sex, women/men	0.87 (0.52–1.47)
Gait speed, (cm/sec)	0.97 (0.94–1.00)*
Stride length, (cm)	1.03 (0.99–1.07)
Cadence, (steps/min)	1.06 (1.02–1.10)**
Step width of left foot, (cm)	1.01 (0.93–1.08)
Gait pattern	
Long stride & fast cadence	1
Long stride & slow cadence	1.11 (0.55–2.24)
Short stride & fast cadence	1.14 (0.56–2.29)
Short stride & slow cadence	2.33 (1.03–5.24)*

* $p<0.05$, ** $p<0.01$, † 95% confidence interval.

Table 3. Correlation coefficients between life-space and gait variables (n=846)

Age, (year)	–0.17*
Gait speed, (cm/sec)	0.30*
Stride length, (cm)	0.25*
Cadence, (steps/min)	0.16*
Step width of left foot, (cm)	–0.14*
Step width of right foot, (cm)	–0.14*

* $p<0.01$.

variables such as age, race, sex, income, availability of transportation and urban versus rural residence in elderly people[25]. Our results confirm that LSA was more strongly associated with gait speed than the other gait variables.

A limitation of this study was the issue of sampling bias. Only healthy participants were analyzed. Therefore, further investigation of the validity of these findings in elderly people recruited using random sampling is recommended.

This study presents a method for measuring gait variables in a community setting. In this sample of 848 community-dwelling elderly adults, gait speed and stride length were reduced with age, although cadence and step width were not associated with advancing age. There were significant correlations found between gait speed and history of falls and life-space in multiple regression models. Therefore, the objective evaluation of gait speed might be important for identifying the risk of physical impairments or functional limitations among elderly people. Future research is required to validate these results using random sampling.

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