J. Phys. Ther. Sci.
27: 1087–1090, 2015

Original Article

Factors affecting the coefficient of variation of stride time of the elderly without falling history: a prospective study

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Abstract. [Purpose] The purpose of this study was to investigate the factors affecting the coefficient of variation (CV) of stride time in an exercise intervention for the elderly without falling history. [Subjects and Methods] The subjects were 42 elderly women who had participated in a care prevention program for 12 weeks. Stride time CV, motor function, movement ability, balance, Modified Falls Efficacy Scale (MFES) score, and Life-space Assessment (LSA) score before and after the intervention were examined for significant differences using the paired t-test. Multiple regression analysis was used to determine the factors that changed in the stride time CV. [Results] There were significant differences in muscle strength, sit-and-reach flexibility, the one-leg standing time (eyes open), the maximum walking speed, local stability of trunk acceleration, The Timed Up and Go Test (TUG-T), the MFES score, and the LSA score between the pre-intervention and post-intervention. Stepwise multiple regression analysis revealed that improvement of quadriceps muscle strength, sit-and-reach flexibility, the one-leg standing time, TUG-T, local stability of trunk acceleration (vertical direction) and MFES score were independent variables explaining the reduction in stride time CV. [Conclusion] The results was suggested that it might be possible to reduce the stride time CV by improving strength, flexibility and dynamic balance, and reducing fear of falls through interventions.
Key words: Coefficient of variation of stride time, Prospective study, Fear of falling

(This article was submitted Oct. 23, 2014, and was accepted Dec. 4, 2014)

INTRODUCTION

Falls by the elderly occur in various settings, and more than half are believed to occur while walking. Thus, efforts to prevent falls that focus on the walking ability of the elderly are crucial. The gait of the elderly is primarily characterized by a decrease in walking speed and increased variability in aspects of walking in relation to duration and distance[1, 2)]. Gait speed reduces with age and might reflect the functional decline of the elderly people[3)]. Gait variability is defined as fluctuations in gait measures from one stride to the next, and fluctuation in the duration of a single stride measure of gait variability[4)]. In a prospective study, Hausdorff et al. reported that the duration of a single stride varied significantly more among elderly individuals who had previously fallen than among elderly individuals who had not suffered a fall, although they found no significant differences between the two groups in terms of walking speed or results of the Timed Up and Go Test[5)]. Based on the results of multiple logistic regression analysis, Hausdorff et al. also reported that the coefficient of variation of stride time was the only variable that predicted falls[5)]. Based on these findings, stride time CV is closely associated with falls, and stride time CV is a useful way of assessing the risk of falling for the elderly. However, few studies have reported on the association between the effectiveness of interventions for the elderly and their association with changes in stride time CV. The aims of this study was to investigate the change in the stride time CV after an exercise intervention for the elderly with no history of falls.

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SUBJECTS AND METHODS

Subjects

The subjects were 42 of the elderly women aged over 65 years old (76.5±3.4 years) potentially requiring nursing care or requiring support. Those subjects were requested to participate in a municipal care projects of the aiming to purpose of improvement their motor function. All subjects were 42 women (76.5±3.4 years) who consented to participation in this study. Subjects were surveyed about the state of their health on the day in question, their exercise habits, and what medications they were taking. Individuals with diminished cognitive function severe enough to preclude their understanding of how their physical function was being assessed, individuals who were unable to participate in all of the tests due to a visual or physical impairment, and individuals whose medication might have affected the test results were excluded. The details of this study were fully explained to subjects and their consent was obtained in writing. This study was approved by the Ethics Committee of the International University of Health and Welfare (approval no. 10-42).

Methods

The intervention sessions took place twice a week for 3 months, for a total of 24 sessions. The intervention consisted of stretching, muscle strength training, balance training, instructions in walking, and individualized instruction. Group training was conducted for stretching and balance exercises. The muscle strength training focused on the upper extremity and lower extremity and used training machines. The intensity of strength training was determined by a load test 10 repetitions were performed for one set which was carried out three times. A physical therapist conducted tutoring or walking guidance once a month. The contents of individual guidance dealt with pain control and exercise guidance as a home program. Evaluation feedback was conducted before and after the exercise intervention. All subjects were assessed using the following 11 measurements at pre-intervention and post-intervention: (1) quadriceps muscle strength, (2) hip abductor muscle strength, (3) grip strength, (4) sit-and-reach flexibility, (5) one-leg standing time (eyes open and eyes closed), (6) the timed up-and-go test (TUG-T), (7) walking speed (maximum and comfortable), (8) stride time CV, (9) local stability of trunk acceleration, (10) Modified Falls Efficacy Scale (MFES), (11) Life-Space Assessment.

The quadriceps muscle strength was measured by using a hand-held dynamometer (an isometric muscle strength measurement device by Anima Co., Ltd.) in the sitting position with the knee flexion of 90 degrees. For measurement of hip abductor muscle strength, a hand-held dynamometer was affixed to a pillar directly above the lateral malleolus while subjects assumed a supine position with their waist immobilized by a belt. Isometric hip abductor muscle strength was measured twice on each side with maximum effort in an intermediate position between hip adduction and abduction and between hip internal and external rotation, measurement was performed twice on each side, and the greatest values were adopted.

Grip strength, sit-and-reach flexibility, and one-leg standing with the eyes open were measured in accordance with a Ministry of Education, Culture, Sports, Science and Technology (MEXT) fitness test for the elderly[6]. Hand grip strength was measured using by a digital dynamometer (Takei Scientific Instruments Co., Ltd.). Subjects were instructed to stand with their arms straight at their sides. Measurement was performed twice on each side, and the greatest value (relative to the subject's weight) was adopted. The sit-and-reach flexibility test also followed the New Physical Fitness Test for the Elderly of MEXT[6]. Subjects were instructed to sit on the floor with their legs equally stretched out in front of them with their knees straight and their ankle joints at 90 degrees. Measurement was performed twice using a digital sit-and reach flexibility measurement device (Takei Scientific Instruments Co., Ltd.), and the longest distance was adopted.

The ability to stand on one foot with the eyes open and eyes closed was measured as directed by the New Physical Fitness Test for the Elderly of MEXT[6]. A digital stopwatch was used for timing with a maximum time of 120 seconds. The time was recorded twice for each foot and the longest time was adopted. Subjects were instructed to stand without their shoes, place their arms at their sides, at a target placed 2 m in front of them.

TUG-T was conducted using the method of Podsiadlo D and Richardson S[7], and a chair height of 45 cm. The time needed to stand up from the chair, walk to and around a target 3 m away, take a change of direction from the right side of the object, and return to sit on the chair again, was measured using a digital stopwatch. The measurement was performed 2 times and the minimum value was adopted.

To measure the walking speed, subjects were instructed to walk at a comfortable speed over a flat 16 m course at their maximum speed. The walking times over the middle 10 m of the course were measured twice at both walking speeds using a digital stopwatch, and the fastest speed was adopted. Sufficient rest was allowed between the trails. The subject took a sufficient rest. Then, maximum walking speed measurement was conducted 2 times.

Stride time CV and local stability of trunk acceleration were measured by attaching an accelerometer (MA3-04AC from MicroStone) to the spinous process of the L3 vertebra. Subjects walked twice at a comfortable speed along a straight path about 16 m long, and the duration of a single stride was calculated based on data on acceleration date recorded during walking. The coefficient of variation was calculated based on the duration of successive single strides, and this value served as the stride time CV. Local stability of trunk acceleration was determined by selecting the data of 5 gait cycles from among the acceleration date of walking. The root mean square (RMS) of the upwards and downwards displacements, and the mediolateral and anteroposterrior sway were calculated, and used as an indicators of local stability of trunk acceleration. The RMS was normalized by dividing the results by the square of the walking speed.

Fear of falling was assessed using the Japanese version of the MFES, developed by Hill et al., with a modified scale[8]. Individual activity levels were assessed using the score of the LSA instrument developed by Baker et al[9].

For statistical analysis, the paired t-test was used to compare the data of pre-intervention and post-intervention. Pearson's correlation coefficient was used to assess the correlation between independent variables and the change in stride time CV. Stepwise multiple regression analysis was with the changes in stride time CV as the dependent variable and to variables with $p<0.25$ in the Pearson's correlation for changes in stride time CV as the independent variables. To minimize the effects of multicollinearity among independent variables, correlations were examined beforehand. If a substantial correlation existed (r ≥ 0.8), the variable was excluded as a variable. These analyses were performed using the SPSS for Windows version 15.0 J.

RESULTS

The comparisons of pre-intervention and post-intervention results indicated that quadriceps muscle strength, hip abductor muscle strength, sit-and-reach flexibility, the one-leg standing time (eyes open), the maximum walking speed, the MFES score, and the LSA score increased significantly, while local stability of trunk acceleration (vertical direction), TUG-T, and the stride time CV decreased significantly (Table 1). The results of stepwise multiple regression analysis revealed that quadriceps muscle strength, sit-and-reach flexibility, the one-leg standing time (eyes open), TUG-T, local stability of trunk acceleration (vertical direction), and changes in the MFES score were independent variables explaining the reduction in stride time CV (Table 2).

DISCUSSION

The comparisons of pre- and post-intervention results revealed there were improvements in muscle strength, static balance (one-leg standing), and dynamic balance (local stability of trunk acceleration in vertical direction). In addition, improvements in mobility (maximum walking speed and TUG-T) and the LSA score, and alleviation of the fear of falling were noted as a result of the intervention program. A previous study[10] reported that exercise intervention for elderly community residents reduced their fear of falling, and the current results corroborate that finding.

It has been reported that the stride time CV of the healthy elderly population is 1.7 to 2.6%[11], and that that of the elderly population with a history of fall is 3.0±2.8%[5]. Our subjects showed a value close to that of the healthy elderly with no history of fall. This result suggests that the risk of falling was decreased by the exercise intervention which also significantly decreased the stride time CV. Stepwise regression analysis indicated that quadriceps muscle extension strength, sit-and-reach flexibility, the duration of one-leg standing (eyes open), and changes in local stability of trunk acceleration (vertical direction) were important factors that explained the reduction in stride time CV. It has been reported that decreased muscle strength with respect to postural stability is associated with decreased muscle strength and impaired balance in healthy elderly individuals[12]. This study noted increased muscle strength as a sign of the effectiveness of intervention, and the increased strength was presumably associated with improved balance. A study of dynamic stability while walking reported that instability was an important risk factor of falls for the elderly and that it was associated with gait variability[13]. This study used local

Table 1. Camprison of the between pre-intervention and post-intervention data

Parameter	Pre-intervention	Post-intervention
Age (years)	77.6±5.2	77.8±4.8
BMI (kg/m^2)	21.9±4.1	22.1±4.8
Muscle Strength (Nm/kg)		
[Knee extension]	0.3±0.1	0.4±0.1*
[Hip abductors]	0.3±0.1	0.4±0.1*
Grip strength (kg)	24.4±6.3	24.2±6.4
Sit -and reach flexibility (cm)	32.8±6.9	34.1±6.0
One leg standing [eyes open] (sec)	11.8±15.7	17.1±10.5*
One leg standing [eyes close] (sec)	2.8±2.3	3.6±3.5
TUG-T (sec)	7.7±2.3	7.0±2.2*
Gait speed [comfortable] (m/sec)	1.5±0.4	1.5±0.3
Gait speed [maximum] (m/sec)	1.6±0.3	1.8±0.4*
stride time CV (%)	2.2±1.3	1.8±0.7*
Local stability of trunk acceleration		
RMS [VT]	2.0±0.5	1.9±0.5*
RMS [M-L]	1.1±0.4	1.0±0.3
RMS [A-P]	1.5±0.5	1.4±0.4
MFES(score)	114.6±24.1	121.3±17.9*
LSA (score)	49.5±14.5	53.5±15.9*

RMS: root mean square; VT: vertical direction; M-L: medio-lateral direction; A-P: anterior-posterior direction; MFES: Modified Falls Efficacy Scale; LSA: Life Space Assessment; *p<0.05; Data are mean ±SE

Table 2. Stepwise multiple regression analysis model summary of reduced stride time CV.

Independent Variable	Changes in stride time CV				
	R	R^2	Unstandardized β (Standard Error)	Standardized β	p value
	0.80	0.64			
Qaudriceps muscle strength			0.03 (0.05)	0.08	0.03
Sit -and reach Flexibility			−0.05 (0.02)	−0.33	0.04
One leg standing [eyes open]			0.10 (0.04)	0.17	0.04
TUG-T			0.32 (0.11)	0.33	0.01
Local stability of trunk acceleration					
RMS [VT]			−0.58 (0.33)	−0.27	0.04
MFES			−0.08 (0.02)	−0.66	0.00

RMS: root mean square; VT: vertical direction; MFES: Modified Falls Efficacy Scale stability of trunk acceleration as an indicator of dynamic balance. Local stability of trunk acceleration (vertical direction) decreased significantly before and after the intervention and was found to be correlated with changes in stride time CV (r = −0.51). Acceleration RMS in the vertical direction is useful in the gait analysis, and step symmetry and stride regularity in the vertical direction are useful as indices showing the degree of deviation from normal gait[14].

The degree of change in the MFES score was found to be correlated with the degree of changes in stride time CV (r = −0.55). Activity restrictions and fear of falling are reported to diminish the walking ability of healthy elderly individuals and increase their gait variability[15]. In the study for the elderly with no history of falls, the gait instability caused by the instability of trunk and muscle weakness suggests possibility to become the factor of the fear of falling[16]. In this study, associated with the significant reduction in MFES, local stability of trunk acceleration (vertical direction), and muscle strength improvement. A decrease in MFES reflects the improvements in the trunk movement and lower extremity muscle strength. Thus, these improvements were considered to be indirectly related to the decrease of stride time CV. Our present results suggest that motor function, (which is closely associated with a reduction in stride time CV), and comprehensive intervention involving alleviation of the fear of falling are crucial for fall prevention.

This study revealed that a 3-month exercise intervention for elderly women potentially requiring assistance or care was effective because it improved motor function, it reduced stride time CV, and it alleviated their fear of falling. Thus, improved muscle strength, flexibility, and balance, and alleviation of the fear of falling were effective at reducing stride time CV. The novelty of this study is that it prospectively investigated factors related to the decrease of stride time CV. Further studies are needed to clarify the reciprocal relationship between the fear of falling, gait variability, and high-risk of falls among elderly.

The sample size and duration of the intervention used may limit the generalization of the results.

REFERENCES

1) Ferrandez AM, Pailhous J, Durup M: Slowness in elderly gait. Exp Aging Res, 1990, 16: 79–89. [Medline] [CrossRef]
2) Blin O, Ferrandez AM, Serratrice G: Quantitative analysis of gait in Parkinson patients: increased variability of stride length. J Neurol Sci, 1990, 98: 91–97. [Medline] [CrossRef]
3) Shimada H, Kim H, Yoshida H, et al.: Relationship between age-associated changes of gait and falls and life-space in elderly people. J Phys Ther Sci, 2010, 22: 419–424. [CrossRef]
4) Hausdorff JM: Gait variability: methods, modeling and meaning. J Neuroeng Rehabil, 2005, 2: 19. [Medline] [CrossRef]
5) 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: 1050–1056. [Medline] [CrossRef]
6) Ministry of Education: Culture, Sports, Science and Technology: http://www.mext.go.jp/ a_menu/ sports/ stamina/ 03040901.htm (Accessed Oct 1, 2011) (in Japanese)
7) Podsiadlo D, Richardson S: The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc, 1991, 39: 142–148. [Medline]
8) Hill KD, Schwarz JA, Kalogeropoulos AJ, et al.: Fear of falling revisited. Arch Phys Med Rehabil, 1996, 77: 1025–1029. [Medline] [CrossRef]
9) Baker PS, Bodner EV, Allman RM: Measuring life-space mobility in community-dwelling older adults. J Am Geriatr Soc, 2003, 51: 1610–1614. [Medline] [CrossRef]
10) Zijlstra GA, van Haastregt JC, van Rossum E, et al.: Interventions to reduce fear of falling in community-living older people: a systematic review. J Am Geriatr Soc, 2007, 55: 603–615. [Medline] [CrossRef]
11) Owings TM, Grabiner MD: Variability of step kinematics in young and older adults. Gait Posture, 2004, 20: 26–29. [Medline] [CrossRef]
12) Orr R: Contribution of muscle weakness to postural instability in the elderly. A systematic review. Eur J Phys Rehabil Med, 2010, 46: 183–220. [Medline]
13) Toebes MJ, Hoozemans MJ, Furrer R, et al.: Local dynamic stability and variability of gait are associated with fall history in elderly subjects. Gait Posture, 2012, 36: 527–531. [Medline] [CrossRef]
14) Osaka H, Shinkoda K, Watanabe S, et al.: Validity of evaluation index utilizing three components of trunk acceleration during walking. J Phys Ther Sci, 2013, 25: 81–84. [CrossRef]
15) Rochat S, Büla CJ, Martin E, et al.: What is the relationship between fear of falling and gait in well-functioning older persons aged 65 to 70 years? Arch Phys Med Rehabil, 2010, 91: 879–884. [Medline] [CrossRef]
16) Toebes MJ, Hoozemans MJ, Furrer R, et al.: Associations between measures of gait stability, leg strength and fear of falling. Gait Posture, 2015, 41: 76–80. [Medline] [CrossRef]