Factors Associating with Shuttle Walking Test Results in Community-Dwelling Elderly People.

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Short Title: Factors associated with SWT results

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Abstract

Background: The shuttle walking test (SWT) is a simple, widely used method for assessing endurance performance in the elderly. Despite widespread community use, its associated factors are unclear.

Aims: We aim to identify previously undefined SWT association factors in community-dwelling elderly people.

Methods: Herein, 149 healthy elderly Japanese subjects performed the SWT, and were assessed for height, weight, smoking history, 10-m walk time, Timed Up and Go (TUG) scores, handgrip strength, skeletal mass index (SMI), forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), cardio-ankle vascular index, and ankle brachial index. We divided men and women into higher and lower SWT score groups, compared between-group parameters, and performed stepwise multivariate logistic regression analysis to identify factors independently associated with SWT scores.

Results: Age, BMI, 10-m walk time, TUG score, SMI, FVC (lit.; %-predicted), and FEV_1 (lit.; %-predicted) were significantly different between SWT score groups for men, while in women, significant differences were observed in age, TUG score, handgrip strength, FVC (lit.; %-predicted), and FEV_1 (lit.; %-predicted) ($p < 0.05$). In the multivariate logistic regression model, 10-m walk time, and FEV_1 showed significant associations with SWT results in men; among women, age was the only significantly associated factor ($p < 0.05$).

Conclusions: Results indicate that better lung function and shorter walk time independently associate with SWT results in community-dwelling men; in women, age is the only association. Our findings may offer insight when considering the focus of community exercise programs among the elderly.

Keywords: shuttle walking test; endurance function; community-dwelling elderly people; lung function

Introduction

In our currently aging society, it has been shown that preserving higher endurance in elderly populations increases their level of physical activity [1] and prevents frailty [2], cardiovascular disease [3], and even mortality [4]. The accepted standard for endurance evaluation is the measuring of maximum oxygen consumption (VO_2 max) via treadmill. However, this requires technical equipment and the expertise of a tester, and is instituted only in laboratory or hospital settings. Thus, to preserve endurance among the community-dwelling elderly, a more straightforward and acceptable endurance assessment is required.

The incremental shuttle walking test (SWT) was developed by Singh [5] to assess the endurance of patients with chronic obstructive pulmonary disease (COPD) [5] or chronic heart failure [6, 7]. The SWT required subjects to walk back and forth along a 10-m flat course, with progressive increases in pace imposed by audio signals, until the subject was no longer able to maintain the pace [5]. The SWT can yield a physiological response similar to a treadmill test [8]. Therefore, use of the SWT is pervasive as a reliable endurance assessment test. The SWT can be administered in the local community; some previous studies have demonstrated its usefulness for evaluating endurance in community-dwelling people [9-11]. Moreover, to evaluate large numbers of people in varied non-laboratory settings, the SWT is a simpler and lower-cost method than the treadmill test, which is regarded as the most precise endurance test for community-dwelling elderly.

In recent years, SWT results have been shown to associate with various factors such as age [10, 11], sex [11], body composition [10], gait parameter [7, 10, 12], lung function [13] and cardiovascular function [14]. However, the enrolled study subjects were of varied age, and presented with an array of health conditions ranging from healthy subjects to patients suffering from COPD or heart failure. For the community-dwelling elderly, investigating the determinants of SWT data may reveal what function physicians should focus on to increase endurance performance of this demographic. However, relatively few studies exist that aim to investigate SWT results in such an age group. Therefore, the aim of the present study was to determine the factors associated with SWT results in community-dwelling elderly people.

Material and Methods

Subjects

Elderly community-dwelling subjects were recruited through local press advertising from November 11–12, 2012. A total of 149 subjects (73 men and 76 women aged 74 ± 4 years) were enrolled upon having met the inclusion criteria (age ≥ 65 years, able to walk independently). Exclusion criteria were using walking aids such as a cane or walker, having a medical history (or post-operative history) of severe cardiac, musculoskeletal, or pulmonary disease, and having significant hearing impairment. Demographic data including age, body mass index (BMI), and smoking history were obtained. To assess smoking history, the pack-years index [15] was calculated for each subject by multiplying the number of cigarette packs smoked per day by the number of smoking years.

Written informed consent was obtained from each subject in accordance with the guidelines of the Kyoto University Graduate School of Medicine and the 1995 Declaration of Helsinki. This study protocol was approved by the ethics committee of the Kyoto University Graduate School of Medicine.

SWT

The SWT required subjects to walk back and forth along a 10-m flat course, with progressive increases in pace imposed by audio signals, until the subject was no longer able to maintain the pace. Up to 50 successions of the SWT were performed (500 m total walking). We divided subjects into 2 groups based on SWT scores: ≤40 or >41 [16].

Motor function tests

All subjects were assessed using the 10-m walk test, Timed Up and Go (TUG) test, and handgrip strength test. In the 10-m walk test, subjects walk along 10-m flat pathways at a comfortable speed [17]. In the TUG test, participants were instructed to stand up from a standard chair with a seat height of 40 cm, walk a distance of 3 m at their fastest pace, turn, walk back to the chair, and sit down. The time elapsing from the verbal command to begin the task until completion was recorded with a stopwatch [18]. The 10-m walk time and TUG scores were defined as the mean time in seconds recorded at the subjects' second trials. In the handgrip strength test, participants used a hand-held dynamometer with the arm kept to the side of the body. Participants squeezed the dynamometer with maximum isometric effort. No other body movement was allowed [19]. The handgrip test score was defined as the better performance of two trials.

Skeletal muscle mass index (SMI)

A bioelectrical impedance data acquisition system (Inbody 430; Biospace Co., Ltd., Seoul, Korea) was used to determine body composition [20]. Participants were asked to stand on two metallic electrodes and hold metallic grip electrodes while the system applied a constant current of 800 mA at 50 kHz through the body. The data acquisition system calculated the resistance value and muscle mass of the respective body parts (right arm, left arm, right leg, left leg, and trunk). Appendicular skeletal muscle mass was determined using segmental body composition and muscle mass excluding the trunk; a value for the appendicular skeletal muscle mass was determined and used for the current analysis. SMI was obtained by dividing the appendicular skeletal muscle mass by the square of height (kg/m^2). This index has been used and well-documented in several epidemiological studies[21].

Lung function

All subjects underwent spirometric evaluation. Forced vital capacity (FVC), and forced expiratory volume in 1 s (FEV_1) were measured by a spirometer (Spiro Sift SP-370; Fukuda Denshi Co., Ltd., Tokyo, Japan). Next, we calculated percent predicted FVC and FEV_1, corrected for height and age. Pulmonary function tests were carried out according to the guidelines of the Japanese Respiratory Society [22]. The formulae for calculating percent predicted FVC and FEV_1 were derived from Japanese criteria [23]. The FEV_1/FVC ratio was also calculated.

Cardiovascular function

All subjects underwent cardio-ankle vascular index (CAVI) evaluation and ankle brachial index (ABI) evaluation, which were determined using the VaSera-1500 (Fukuda Denshi Co., Ltd., Tokyo, Japan) as previously reported [24, 25].

CAVI is a novel method for measuring arterial stiffness. Until recently, pulse wave velocity (PWV) was the most popular measure; however, PWV was dependent on blood pressure at the time of measurement. CAVI was calculated based on parameter β, independent of blood pressure [26]. Scores ≤9.00 were considered normal while scores >9.00 were considered indicative of suspected arteriosclerosis [27]. The ABI described the arterial occlusion with a ratio of the ankle to brachial systolic blood pressure [28]. Normal values 0.91 ≤ ABI ≤ 1.30 and values ≤0.90 indicated suspected peripheral artery disease (PAD) [29].

When measuring CAVI and ABI, subjects were supine and had blood pressure cuffs on both of the brachia and ankles. Measurements were taken once per subject, and mean values of the right and left CAVI and ABI scores were calculated. Using these index values, we calculated the population (%) with suspected arteriosclerosis and PAD.

Statistical analyses

We analyzed the difference in each variable between men and women, and between subjects with higher and lower SWT results. We performed a Chi-squared (χ^2) test to analyze the population with suspected arteriosclerosis and PAD. Moreover, statistical tests such as t-tests were also conducted to assess the influence of other variables.

Next, we examined factors associated with the SWT results using a stepwise multivariate logistic regression model. We assigned the high SWT results group as a dependent variable and age, BMI, SMI, 10-m walk time, handgrip strength, FVC (lit.), FEV_1 (lit.), FEV_1/FVC ratio, and suspected arteriosclerosis population as explanatory variables.

All statistical analyses were performed with SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). A p-value <0.05 was considered statistically significant for all analyses.

Results

Measurements of the 149 subjects are summarized in Table 1. There were significant differences between men and women in the pack-years index, TUG score, handgrip strength, SMI, FVC (lit.), FEV_1 (lit.), FEV_1 (%-predicted), and suspected arteriosclerosis population ($p < 0.05$).

Forty-two men and 26 women were classified into the higher SWT results group and 31 men and 50 women were classified into the lower SWT results group. Among men, there were significant differences between higher and lower SWT results groups in age, BMI, 10-m walk time, TUG score, SMI, FVC (lit.), FVC (%-predicted), FEV_1 (lit.), and FEV_1 (%-predicted) ($p < 0.05$). In women, there were significant differences between higher and lower SWT results groups in age, TUG score, handgrip strength, FVC (lit.), FVC (%-predicted), FEV_1 (lit.), and FEV_1 (%-predicted) ($p < 0.05$).

In the multivariate logistic regression analysis, variables that remained in the final step of the regression model were considered to be significantly correlated with a higher SWT result. In men, these were 10-m walk time ($p = 0.001$), and FEV_1 ($p < 0.001$), whereas in women, age ($p < 0.001$) was the only significantly correlated variable (Table 2).

Discussion

We analyzed the association between SWT results and age, body composition, motor function, lung function, and cardiovascular function in community-dwelling elderly people. We found that younger age, higher FEV_1, and shorter 10-m walk time were associated with higher SWT results in men, and that younger age associated with higher SWT results in women. To date, there are few studies of the relationship between lung function and SWT results in community-dwelling elderly people. The results of the present study suggest that maintaining better lung function and walk speed is the key to preserving endurance in community-dwelling elderly men.

It has been previously shown that a decrease in FEV_1 increases dyspnea during exercise and results in decreased walk speed and endurance in patients with airflow limitation [13, 30, 31]. We considered that in community-dwelling elderly populations, a lower capacity for lung function would increase subjects' dyspnea during the SWT test, resulting in decreased walk speed and SWT results. According to the American College of Chest Physicians guidelines [32], it is still unclear which lung function is improved by pulmonary rehabilitation in airflow limitation patients. Moreover, there are only a few studies that report that pulmonary rehabilitation improves lung function among community-dwelling elderly people. Therefore, we consider that pulmonary exercises, such as improving thorax and respiratory muscle mobility, and employing breathing techniques, may sustain better lung function and preserve endurance performance in this demographic. Further investigation, such as measuring dyspnea following the SWT, is needed to prove this hypothesis. In addition, we demonstrated an association between lung function and endurance exclusively among men. This may be attributed to the difference in smoking history between men and women in our study. As shown in Table 1, compared to women, men had a significantly higher pack-years index and significantly lower FEV_1. Smoking is one of the strongest risk factors for respiratory disease [33]. Our results in community-dwelling elderly men indicate that smoking may decrease lung function, resulting in lower SWT results. To better understand the association between lung function and endurance in community-dwelling elderly women, further research should be conducted in another population that includes women with a history of smoking.

We have shown that age associates with SWT results in women. Reports indicate that age can adversely affect a person's cardiovascular function and endurance level [34, 35]. Moreover, it is possible to separate factors that affect endurance according to utilization theory and presentation theory [36]. Utilization theory acts on the premise that endurance is determined by the oxygen (O_2)-consuming parties, while presentation theory states that it is determined by the O_2-supplying party. Saltin et al. showed that endurance is more markedly affected by O_2 presentation than by utilization [36]. In the present study, lung function, considered to be a presentation theory component, affected endurance performance more so than SMI, cardiovascular function, and motor function, which are components of the utilization theory. We also considered that our findings, with regard to age, may be associated with low cardiac function, which could potentially yield decreased SWT results. It would have been beneficial to additionally measure cardiovascular function parameters, such as stroke volume and pulse.

There are several limitations to the scope of our research. First, because this is a cross-sectional study, the causal relationship between endurance and lung function, walk speed, or age is uncertain. Moreover, the study sample did not include women with a history of smoking. As smoking history has great impact on lung function, this may be a source of sampling bias; therefore, the scope of our investigation should be extended to subjects in other communities. Another source of study limitation is that we were unable to assess other SWT-affecting factors, although these may indeed affect SWT results. In addition to cardiovascular function and dyspnea factors, previous studies have shown that step length can affect SWT or 6 min walk test results [7, 37]. Thus, further analysis should be undertaken to identify additional factors that may be of importance to endurance performance.

Conclusion

We found a significant association between lung function, walk speed, and SWT results in community-dwelling elderly men, and between age and SWT results in women. In this society, prevention for bedridden and taking care is an important issue in terms of medical economics. Elderly men with a high level of expiratory function display high endurance performance. Although this is a cross-sectional study, our results may help advise physicians of ways in which they can promote endurance performance among the elderly, through focusing and adapting community exercise programs. However, further investigation is required to assess the impact of cardiovascular function on SWT results in community-dwelling elderly populations.

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Table 1. Comparison of demographic characteristics and measurements

	Men				Women				
	All (n = 73)	Higher level SWT (n = 42)	Lower level SWT (n = 31)	*p*-value*	All (n = 76)	Higher level SWT (n = 26)	Lower level SWT (n = 50)	*p*-value*	*p*-value **
General characteristics									
Age, years (SD)†	73.7 (4.6)	72.3 (4.1)	75.6 (4.7)	0.002	73.4 (4.3)	70.2 (3.5)	75.1 (3.7)	<0.001	0.71
BMI, kg/m^2 (SD)†	23.4 (3.1)	24.1 (3.0)	22.6 (3.1)	0.048	23.3 (2.7)	22.6 (2.3)	23.7 (2.8)	0.09	0.81
Smoking-pack-years index (SD)†	29.0 (30.0)	27.2 (33.7)	29.9 (24.6)	0.81	0 (0)	0 (0)	0 (0)	-	<0.001
Motor function									
10-m walk time, s (SD)†	7.3 (1.0)	6.9 (0.7)	7.8 (1.1)	<0.001	7.3 (1.3)	6.9 (0.8)	7.5 (1.5)	0.06	0.81
TUG, s (SD)†	6.4 (1.1)	6.1 (0.9)	7.0 (1.0)	<0.001	6.9 (1.1)	6.4 (0.8)	7.2 (1.1)	0.004	0.008
Handgrip strength, kg	33.4 (5.9)	34.4	32.4 (5.9)	0.09	23.0	24.3 (3.1)	22.3 (3.9)	0.02	<0.001

(SD)†		(5.8)			(3.8)				
Body composition									
SMI, kg/m^2 (SD)†	7.3 (0.7)	7.5 (0.7)	7.0 (0.6)	0.01	5.8 (0.6)	6.0 (0.6)	5.7 (0.5)	0.02	<0.001
Lung function									
FVC, lit. (SD)†	3.2 (0.6)	3.4 (0.5)	3.0 (0.4)	<0.001	2.2 (0.5)	2.5 (0.4)	2.1 (0.5)	<0.001	<0.001
FVC, %-predicted (SD)†	96.2 (13.8)	99.1 (12.7)	92.2 (14.3)	0.03	97.6 (16.0)	104.5 (15.6)	94.0 (15.1)	0.01	0.56
FEV_1, lit. (SD)†	2.3 (0.6)	2.5 (0.5)	2.0 (0.5)	<0.001	1.6 (0.5)	1.9 (0.4)	1.5 (0.4)	<0.001	<0.001
FEV_1, %-predicted (SD)†	88.1 (18.4)	92.5 (17.3)	82.1 (18.4)	0.02	96.9 (21.1)	105.5 (20.2)	92.4 (20.3)	0.01	0.007
FEV_1/FVC, % (SD)†	71.0 (10.5)	72.7 (8.9)	68.8 (12.1)	0.11	72.6 (11.2)	75.5 (11.9)	71.1 (10.6)	0.10	0.39
Cardiovascular function									

Suspected arteriosclerosis, %††	72.6	71.4	74.2	0.79	48.6	34.6	56.0	0.08		0.003
Suspected PAD, % ††	5.5	0	0	-	1.3	0	2.0	0.47		0.56

Note: BMI, body mass index; TUG, Timed Up and Go; SMI, skeletal mass index; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; PAD, peripheral artery disease.

†: t-test, ††: χ^2-test

*: comparison between higher and lower level of SWT

**: comparison between men and women

Table 2. Multivariate logistic regression model with stepwise selection to determine the association with shuttle walking test level

	Odds ratio	95% CI	*p*-value
Men			
10-m walk time (s)	0.24	0.11–0.54	0.001*
FEV_1 (lit.)	12.80	3.05–53.70	0.001*
Women			
Age	0.69	0.57–0.82	< 0.001**

*: $p < 0.05$, **: $p < 0.001$

Note: CI, confidence interval; FEV_1, forced expiratory volume in 1 s.