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

3
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11 **Short Title:** Factors associated with SWT results

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33 **Abstract**

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

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

39 **Methods:** Herein, 149 healthy elderly Japanese subjects performed the SWT, and were
40 assessed for height, weight, smoking history, 10-m walk time, Timed Up and Go (TUG)
41 scores, handgrip strength, skeletal mass index (SMI), forced vital capacity (FVC),
42 forced expiratory volume in 1 s (FEV₁), cardio-ankle vascular index, and ankle brachial
43 index. We divided men and women into higher and lower SWT score groups, compared
44 between-group parameters, and performed stepwise multivariate logistic regression
45 analysis to identify factors independently associated with SWT scores.

46 **Results:** Age, BMI, 10-m walk time, TUG score, SMI, FVC (lit.; %-predicted), and
47 FEV₁ (lit.; %-predicted) were significantly different between SWT score groups for men,
48 while in women, significant differences were observed in age, TUG score, handgrip
49 strength, FVC (lit.; %-predicted), and FEV₁ (lit.; %-predicted) ($p < 0.05$). In the
50 multivariate logistic regression model, 10-m walk time, and FEV₁ showed significant
51 associations with SWT results in men; among women, age was the only significantly
52 associated factor ($p < 0.05$).

53 **Conclusions:** Results indicate that better lung function and shorter walk time
54 independently associate with SWT results in community-dwelling men; in women, age

55 is the only association. Our findings may offer insight when considering the focus of

56 community exercise programs among the elderly.

57

58 **Keywords:** shuttle walking test; endurance function; community-dwelling elderly

59 people; lung function

60

61 **Introduction**

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

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

82 In recent years, SWT results have been shown to associate with various factors

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

92

93 **Material and Methods**

94 *Subjects*

95 Elderly community-dwelling subjects were recruited through local press
96 advertising from November 11–12, 2012. A total of 149 subjects (73 men and 76
97 women aged 74 ± 4 years) were enrolled upon having met the inclusion criteria (age \geq
98 65 years, able to walk independently). Exclusion criteria were using walking aids such
99 as a cane or walker, having a medical history (or post-operative history) of severe
100 cardiac, musculoskeletal, or pulmonary disease, and having significant hearing
101 impairment. Demographic data including age, body mass index (BMI), and smoking
102 history were obtained. To assess smoking history, the pack-years index [15] was
103 calculated for each subject by multiplying the number of cigarette packs smoked per
104 day by the number of smoking years.

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

109

110 *SWT*

111 The SWT required subjects to walk back and forth along a 10-m flat course, with
112 progressive increases in pace imposed by audio signals, until the subject was no longer
113 able to maintain the pace. Up to 50 successions of the SWT were performed (500 m
114 total walking). We divided subjects into 2 groups based on SWT scores: ≤ 40 or >41
115 [16].

116

117 *Motor function tests*

118 All subjects were assessed using the 10-m walk test, Timed Up and Go (TUG)
119 test, and handgrip strength test. In the 10-m walk test, subjects walk along 10-m flat
120 pathways at a comfortable speed [17]. In the TUG test, participants were instructed to
121 stand up from a standard chair with a seat height of 40 cm, walk a distance of 3 m at
122 their fastest pace, turn, walk back to the chair, and sit down. The time elapsing from the
123 verbal command to begin the task until completion was recorded with a stopwatch [18].
124 The 10-m walk time and TUG scores were defined as the mean time in seconds
125 recorded at the subjects' second trials. In the handgrip strength test, participants used a
126 hand-held dynamometer with the arm kept to the side of the body. Participants squeezed

127 the dynamometer with maximum isometric effort. No other body movement was
128 allowed [19]. The handgrip test score was defined as the better performance of two
129 trials.

130

131 *Skeletal muscle mass index (SMI)*

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

143

144 *Lung function*

145 All subjects underwent spirometric evaluation. Forced vital capacity (FVC), and
146 forced expiratory volume in 1 s (FEV_1) were measured by a spirometer (Spiro Sift
147 SP-370; Fukuda Denshi Co., Ltd., Tokyo, Japan). Next, we calculated percent predicted
148 FVC and FEV_1 , corrected for height and age. Pulmonary function tests were carried out

149 according to the guidelines of the Japanese Respiratory Society [22]. The formulae for
150 calculating percent predicted FVC and FEV₁ were derived from Japanese criteria [23].
151 The FEV₁/FVC ratio was also calculated.

152

153 *Cardiovascular function*

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

157 CAVI is a novel method for measuring arterial stiffness. Until recently, pulse
158 wave velocity (PWV) was the most popular measure; however, PWV was dependent on
159 blood pressure at the time of measurement. CAVI was calculated based on parameter β ,
160 independent of blood pressure [26]. Scores ≤ 9.00 were considered normal while scores
161 > 9.00 were considered indicative of suspected arteriosclerosis [27]. The ABI described
162 the arterial occlusion with a ratio of the ankle to brachial systolic blood pressure [28].
163 Normal values $0.91 \leq \text{ABI} \leq 1.30$ and values ≤ 0.90 indicated suspected peripheral artery
164 disease (PAD) [29].

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

169

170 *Statistical analyses*

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

176 Next, we examined factors associated with the SWT results using a stepwise
177 multivariate logistic regression model. We assigned the high SWT results group as a
178 dependent variable and age, BMI, SMI, 10-m walk time, handgrip strength, FVC (lit.),
179 FEV₁ (lit.), FEV₁/FVC ratio, and suspected arteriosclerosis population as explanatory
180 variables.

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

184

185 **Results**

186 Measurements of the 149 subjects are summarized in Table 1. There were
187 significant differences between men and women in the pack-years index, TUG score,
188 handgrip strength, SMI, FVC (lit.), FEV₁ (lit.), FEV₁ (%-predicted), and suspected
189 arteriosclerosis population ($p < 0.05$).

190 Forty-two men and 26 women were classified into the higher SWT results group
191 and 31 men and 50 women were classified into the lower SWT results group. Among
192 men, there were significant differences between higher and lower SWT results groups in

193 age, BMI, 10-m walk time, TUG score, SMI, FVC (lit.), FVC (%-predicted), FEV₁ (lit.),
194 and FEV₁ (%-predicted) ($p < 0.05$). In women, there were significant differences
195 between higher and lower SWT results groups in age, TUG score, handgrip strength,
196 FVC (lit.), FVC (%-predicted), FEV₁ (lit.), and FEV₁ (%-predicted) ($p < 0.05$).

197 In the multivariate logistic regression analysis, variables that remained in the
198 final step of the regression model were considered to be significantly correlated with a
199 higher SWT result. In men, these were 10-m walk time ($p = 0.001$), and FEV₁ ($p <$
200 0.001), whereas in women, age ($p < 0.001$) was the only significantly correlated
201 variable (Table 2).

202

203 Discussion

204 We analyzed the association between SWT results and age, body composition,
205 motor function, lung function, and cardiovascular function in community-dwelling
206 elderly people. We found that younger age, higher FEV₁, and shorter 10-m walk time
207 were associated with higher SWT results in men, and that younger age associated with
208 higher SWT results in women. To date, there are few studies of the relationship between
209 lung function and SWT results in community-dwelling elderly people. The results of the
210 present study suggest that maintaining better lung function and walk speed is the key to
211 preserving endurance in community-dwelling elderly men.

212 It has been previously shown that a decrease in FEV₁ increases dyspnea during
213 exercise and results in decreased walk speed and endurance in patients with airflow
214 limitation [13, 30, 31]. We considered that in community-dwelling elderly populations,

215 a lower capacity for lung function would increase subjects' dyspnea during the SWT
216 test, resulting in decreased walk speed and SWT results. According to the American
217 College of Chest Physicians guidelines [32], it is still unclear which lung function is
218 improved by pulmonary rehabilitation in airflow limitation patients. Moreover, there are
219 only a few studies that report that pulmonary rehabilitation improves lung function
220 among community-dwelling elderly people. Therefore, we consider that pulmonary
221 exercises, such as improving thorax and respiratory muscle mobility, and employing
222 breathing techniques, may sustain better lung function and preserve endurance
223 performance in this demographic. Further investigation, such as measuring dyspnea
224 following the SWT, is needed to prove this hypothesis. In addition, we demonstrated an
225 association between lung function and endurance exclusively among men. This may be
226 attributed to the difference in smoking history between men and women in our study. As
227 shown in Table 1, compared to women, men had a significantly higher pack-years index
228 and significantly lower FEV₁. Smoking is one of the strongest risk factors for
229 respiratory disease [33]. Our results in community-dwelling elderly men indicate that
230 smoking may decrease lung function, resulting in lower SWT results. To better
231 understand the association between lung function and endurance in
232 community-dwelling elderly women, further research should be conducted in another
233 population that includes women with a history of smoking.

234 We have shown that age associates with SWT results in women. Reports indicate
235 that age can adversely affect a person's cardiovascular function and endurance level [34,
236 35]. Moreover, it is possible to separate factors that affect endurance according to

237 utilization theory and presentation theory [36]. Utilization theory acts on the premise
238 that endurance is determined by the oxygen (O₂)-consuming parties, while presentation
239 theory states that it is determined by the O₂-supplying party. Saltin et al. showed that
240 endurance is more markedly affected by O₂ presentation than by utilization [36]. In the
241 present study, lung function, considered to be a presentation theory component, affected
242 endurance performance more so than SMI, cardiovascular function, and motor function,
243 which are components of the utilization theory. We also considered that our findings,
244 with regard to age, may be associated with low cardiac function, which could
245 potentially yield decreased SWT results. It would have been beneficial to additionally
246 measure cardiovascular function parameters, such as stroke volume and pulse.

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

258

259 **Conclusion**

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

269

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