PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Comparison of voluntary cough function in community - dwelling elderly and its association with physical fitness

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ABSTRACT. Objective: To compare the association of cough peak flow (CPF) with aging in community-dwelling older adults and to investigate the relationship between physical fitness and CPF in these individuals. Method: Two hundred twenty two community-dwelling older adults were enrolled. CPF was assessed as a cough function parameter. Forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1.0) were assessed as respiratory function. Maximal expiratory pressure (MEP) and inspiratory pressure (MIP) were assessed as respiratory muscle strength. The 3-minute walk test (3MWT) performance was assessed as a physical fitness. Participants were divided into the following age groups: 60-64, 65-69, 70-74, 75-79 and 80-89 years. One way analysis of variance were computed for comparison between age group, sex and CPF. Multivariate regression analyses were used to investigate the association of CPF with 3MWT. Results: The value of CPF significantly decreased in the 75-79 and 80-89 years group than 60-64 years group in men and in the 80-89 years group than 65-69 years group in women. The value of CPF were 545.5, 497.2, 403.3, 354.8 and 325.4 L/min in the 60-64, 65-69, 70-74, 75-79 and 80-89-year group in men and 263.4, 278.8, 264.5, 214.0, and 193.6 L/min in the corresponding age groups in women, respectively. 3MWT ($p = 0.041$) was significantly associated with CPF. Conclusions: Cough function tends to decrease with aging in community-dwelling elderly. Physical fitness is associated with cough function.

Key words: aging, cough, older adults, 3-minute walk test, respiratory function

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Cough is a physiological reflex aimed at clearing airway secretions[1] and plays an important role in the prevention of respiratory infections. Additionally, a decline in cough function leads to aspiration pneumonia, which is an important cause of death in older people[2-6]. Thus, for older adults, maintaining cough function is of clinical importance.

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Cough peak flow (CPF) is widely used as an index of physiological function reflecting voluntary cough function. For community dwelling adults, the value of CPF was negatively correlated with aging[7]. Considering the prevalence rate of pneumonia in people, we should focus on older adult's cough function. However, a previous study just showed the mean of CPF even though the subjects were a wide range of adults aged 20-80 years[7], and how the age-related decline in CPF occur is still unclear in community dwelling older adults. In those subjects, knowing the

features of cough function may contribute to the prevention of aspiration pneumonia.

The value of CPF is lower in women than men[7,8], and it was related to thorax expansion at the tenth rib, inspiratory muscle strength and forced expiration volume in 1 second in men, and thorax expansion at the tenth rib, inspiratory reserve volume, and expiratory muscle power in women[7,9]. Additionally, physical activity level was also associated with value of CPF[8]. Some studies have reported that physical fitness is related to respiratory functions[10-12]. A limitation of expiratory flow, which can be assessed by peak expiratory flow (PEF), has been shown to be negatively correlated to walking distance during the 6-minute walk test (6MWT) [13]. PEF and CPF are parameters that reflect similar functions[14]. Considering this information, it is highly possible that physical fitness is strongly linked to CPF. To clarify this association may provide the importance of physical fitness assessment and endurance exercise to maintain cough function in community-dwelling older adults. However, to our knowledge, this association has not been investigated.

The first objective of the present study was to compare the association of CPF with aging according to sex in community-dwelling older adults. The second objective was to investigate the relationship between physical fitness and CPF in community-dwelling older adults.

Method

Study design and participants

The present study was a cross-sectional study. Sample size was determined based on independent variables (for variables with ≥10 subjects)[15] to perform multivariate regression analysis. Participants were recruited via community-based advertisements; 231 community-dwelling older adults were initially enrolled. Eligibility criteria were an age over 60 years and the ability to walk unassisted, without a walking aid. Participants were excluded if they had severe diseases, orthopedic diseases, stroke, neuromuscular diseases, or oral diseases, which prevented measurements, or if they had missing data. Of the initial 231 participants, 9 were excluded. The final analytical sample consisted of 222 (130 women and 92 men). This study was approved by the Research Ethics Committee of Kobe Gakuin University (acknowledgment number: HEB100806-1), and all participants provided informed consent according to the ethical standards set forth in the Declaration of Helsinki.

Demographic characteristics

Demographic data (age, sex, medical history, smoking history) were obtained by self-reported questionnaires. Weight (kg) and height (cm) were measured, and body mass index (BMI) was calculated (in kg/m^2).

Cough function

CPF has been confirmed to have both accuracy and reproducibility[16], and it is used as a representative parameter of cough function[7,8]. CPF was measured using a peak flow meter (Tokyo MI, Tokyo, Japan). Participants sat in an upright position and performed maximal inspiratory breathing up to total lung capacity (TLC). Then, maximal voluntary cough was performed. Measurements were performed twice, interspersed with a 30-s rest period. The higher of the two CPF values was used for statistical analyses.

Respiratory function

Forced vital capacity (FVC), FVC-predicted, Forced expiratory volume in 1 second (FEV1.0), and FEV1.0% (FEV 1.0 / FVC) were assessed using a spirometer (Autospiro AS-502, MINATO Medical Science Corporation, Osaka, Japan) according to standard guidelines[17]. All participants sat in an upright position, and performed the expiratory maneuver until residual volume (RV) was reached, and then performed the inspiratory maneuver until TLC was reached. Finally, the maximal expiratory maneuver with maximally forced effort was performed from TLC.

Respiratory muscle strength

Respiratory muscle strength was assessed using a respiratory pressure meter (MicroRPM, Vyaire Medical Inc., Mettawa, IL, USA), which is capable of measuring maximal expiratory pressure (MEP) and maximal inspiratory pressure (MIP) in cm H_2O, according to the American Thoracic Society/European Respiratory Society Statement on Respiratory Muscle Testing[18].

Expiratory muscle strength

Participants were instructed to sit in an upright position, and a nose clip was attached to their nose. First, participants were asked to perform maximal inspiratory breathing until TLC was reached. Second, maximal expiratory effort was performed for at least 3 s from TLC. Measurements were performed twice, interspersed with a 30-s rest period. The higher value of MEP was used for statistical analyses.

Inspiratory muscle strength

A 1-min break was taken after the measurement of MEP. Participants then sat in an upright position, and a nose clip was attached to their nose. First, participants were asked to perform maximal expiratory breathing until RV was reached. Second, maximal inspiratory efforts were performed for at least 3 s from the RV. Measurements were performed twice with a 30-s rest period in between. The higher value of MIP was used for statistical analyses.

Three-minute walk test

The 3-minute walk test (3MWT) was performed according to the modified method based on the guideline for the 6-minute walk test that provided by the American Tho-

Table 1. Participant characteristics

	All subjects	men	women
Age (years)	72.7±6.3	73.0±6.4	72.4±6.3
women, n, %	130, 59		
Height (cm)	156.9±9.1	165.5±6.6	150.9±4.8
Weight (kg)	56.7±10.7	63.4±10.7	51.9±7.8
Body mass index (kg/m2)	22.9±3.4	23.1±3.6	22.8±3.3
History of disease, n, %			
Hypertension	67, 30	31, 34	36, 28
Hyperlipidemia	43, 19	18, 20	25, 19
Pulmonary disease	5, 2	1, 1	4, 3
Diabetes mellitus	18, 8	9, 10	9, 7
Stroke	6, 3	4, 4	2, 2
Parkinson's Disease	1, 1	0, 0	1, 1
Forced vital capacity (L)	2.6±0.7	3.2±0.7	2.2±0.4
Forced vital capacity predicted (%)	96.5±15.3	93.4±15.2	98.7±15.1
Forced expiratory volume in 1 second (L)	2.1±0.6	2.5±0.5	1.8±0.4
Forced expiratory volume in 1 second (%)	80.3±8.2	79.4±8.4	81.0±8.0
Maximal expiratory pressure (cmH_2O)	85.5±32.7	103.0±32.1	73.1±27.2
Maximal inspiratory pressure (cmH_2O)	58.8±23.7	66.2±24.0	48.4±20.6
Cough peak flow (L/min)	316.0±165.6	412.5±190.7	247.7±99.9
3-minute walk test distance (m)	274.0±40.4	284.6±48.1	266.5±32.2

Values are expressed as mean ± standard deviation or number of participants (percentages).

racic Society[19]. We modified the walkway distance from 30 m which recommended by guideline[19] to 25 m due to facility environment limitation, thus a 25 m indoor walkway was used during the test. Participants were instructed to walk from the start line to the end of the walkway for 3 min self-regulated intensity "somewhat hard"[20]. The feedback during the 3MWT was changed from the guideline for the 6-minute walking test to suitable for 3 minutes[19]. Feedback was as follows: After the first minute, the subject was told the following (in even tones): "You have 2 min to go." When the timer showed 2 min, the subject was told "You have only 1 min left." When the timer showed 2 min and 50 s, the subject was told "You have only 10 s to go." The distance covered at the end of the 3MWT was recorded. 3MWT was used as a parameter of physical fitness[20]. One study confirmed the test-retest reliability of 3MWT in methodology[20]. The distance of 3MWT was associated with several fitness parameters[21,22]. These studies suggest that validity for physical fitness assessment of 3MWT was confirmed.

Statistical analyses

Descriptive characteristics of participants are reported as mean±standard deviation in all participants. Participants were divided into the following age groups: 60-64 years, 65-69 years, 70-74 years, 75-79 years, 80-89 years. First, one-way analysis of variance was conducted between age group and CPF, according to sex. When a statistically significant effect was found, differences were determined with the Tukey-Kramer post hoc test. Additionally, student's *t* test was conducted between sex and CPF according to age group. Next, forced-entry multivariate regression analysis was then used to investigate the association of CPF with 3MWT adjusted by age, sex, BMI and smoking history (Model 1). Then, respiratory parameters, such as FVC, FEV1.0%, MEP, and MIP, were added to Model 1 (Model 2). Multicollinearity was investigated between independent variables with variance inflation factor (VIF) > 10[23]. Statistical significance was set at $p < 0.05$; all analyses were performed using JMP version 10.0 software (SAS Institute Japan, Tokyo, Japan).

Results

Table 1 showed the demographic characteristics of the participants. Table 2 showed the value of CPF was significantly lower in the 75-79 and 80-89 years group than 60-64 years group ($p = 0.007$) in men, and additionally in the 80-89 years group than 65-69 years group in women ($p = 0.013$). The value of CPF were significantly lower in women than men in all age group (p < 0.001, p < 0.001, p < 0.001, p < 0.001 and p < 0.001 in 60-64, 65-69, 70-74, 75-79 and 80-89-year group, respectively). The value of CPF were 545.5±246.5, 497.2±185.9, 403.3±181.1, 354.8±164.8 and 325.4±124.2 L/min in the 60-64, 65-69, 70-74, 75-79 and 80-89-year group in men and 263.4±97.3, 278.8±121.8, 264.5±101.7, 214.0±67.8, and 193.6±71.3 L/min in the corresponding age groups in women, respectively (Table 2).

Table 2. Comparison of cough peak flow according to age group and sex

age group (years)	60-64	65-69	70-74	75-79	80-89	p value
All subjects						
n	27	42	72	50	31	
Mean (SD)	378.3 (220.8)	362.0 (182.2)	316.5 (151.7)	284.4 (143.6)	248.9 (115.8)	
Min-Max	90-800	60-750	90-780	60-720	80-570	
Men						
n	11	16	27	25	13	
Mean (SD)	545.5 (246.5)	497.2 (185.9)	403.3 (181.1)	354.8 (164.8)[a]	325.4 (124.2)[a]	0.007
Min-Max	120-800	65-750	95-780	90-720	120-570	
Women						
n	16	26	45	25	18	
Mean (SD)	263.4 (97.3)[c]	278.8 (121.8)[c]	264.5 (101.7)[c]	214.0 (67.8)[c]	193.6 (71.3)[b, c]	0.013
Min-Max	90-420	60-530	90-520	60-300	80-350	

Mean (SD) cough peak flow value are given in L/min.
a significant difference v.s 60-64 age group p < 0.05
b significant difference v.s 65-69 age group p < 0.05
c significant difference v.s men in same age group p < 0.05

Table 3. Factors affecting cough peak flow

	Model 1		Model 2	
Adjusted R^2	0.345		0.422	
	standard β	*p* value	standard β	*p* value
Age	-0.180	0.004	-0.063	0.338
Sex	-0.426	<0.001	-0.203	0.019
BMI	0.123	0.030	0.092	0.085
Smoking history	-0.034	0.623	0.022	0.739
3MWT	0.216	0.001	0.129	0.041
FVC			0.249	0.005
FEV1.0%			0.133	0.015
MEP			0.224	0.006
MIP			0.039	0.619

BMI, Body mass index; FVC, Forced vital capacity; FEV1.0%, Forced expiratory volume in 1 second %; MEP, Maximal expiratory pressure; MIP, Maximal inspiratory pressure; 3MWT, 3-minute walk test.

Table 3 shows the results of multivariate regression analyses. The value of CPF was independently associated with 3MWT (Model 1; standard beta = 0.216, p = 0.001, Model 2; standard beta = 0.129, p = 0.041) in both models, with an adjusted R^2 of 0.345 (Model 1) and 0.422 (Model 2). There were no significant associations between independent variables (VIF $\leq$ 10) in all models.

Discussion

The first objective of the present study was to compare the association of CPF with aging according to sex in community-dwelling older adults. The value of CPF was lower in the 75-79 and 80-89 years group than 60-64 years group in men, and additionally in the 80-89 years group than 65-69 years group in women. The value of CPF was significantly lower in women than men in all age groups. The second objective was to investigate the relationship between physical fitness and CPF in community-dwelling older adults. The results of multivariate regression models showed that 3MWT distance was significantly associated with the value of CPF in community-dwelling older adults.

The value of CPF was significantly lower in older age group in both sexes. Our findings are partly consistent with a previous study showing that CPF correlated negatively with age[7]; however, that study found this correlation only

in women[7], whereas we found this relationship between the value of CPF and age in women as well as in men. This discrepancy may be explained by the difference in the age groups between the studies. In the previous report, the mean age was 50.1±19.8 years in men and 51.4±18.4 years in women, which was about 20 years younger than subjects in our study (73.0±6.4 years for men and 72.4±6.3 years for women). Importantly, many studies have shown that respiratory function gradually decreases with aging[24-27]. One study showed that FVC, FEV1.0, and MIP in the 70-79-year group were significantly lower than those in the 50-59-year group in men, and that FVC, FEV1.0, MIP, and MEP in the 70-79-year group were significantly lower than those in the 50-59-year group in women[27]. Additionally, the value of CPF in the older group (50-80 years) was lower than in the younger group (20-49 years)[28]. Taken these other results and our own results into account, the tendency for a decline in CPF with ageing seems to be similar to that for other respiratory functions.

The value of CPF was significantly lower in women than men in all age groups. Our finding consist with a previous reports that value of CPF was lower in women than in men[7,8,28]. Men demonstrated greater height and body weight than women. Height and weight affect respiratory function[29] and respiratory muscle[26], and CPF increased as height increased[28]. Thus, difference of CPF between sexes can be explained by physique, and this relationship is similar to other respiratory functions.

Multivariate regression analysis also showed that the 3MWT distance was significantly associated with the value of CPF without adjustment for respiratory function and respiratory muscle strength (Model 1), and after adjustment for confounders (Model 2). This result indicates that physical fitness is associated with cough function in community-dwelling older adults. Physical fitness is closely related to respiratory function, such as FVC, FEV1.0, MEP, and MIP in older adults[10-12], and is related to expiratory flow limitation in patients with chronic obstructive pulmonary disease (COPD)[13]. Additionally, physical activity level, which is strongly related to physical fitness[30], was affected by CPF in community-dwelling elderly individuals[8]. Our findings may partly agree with these previous studies that physical fitness is related to respiratory function. Expiratory flow limitation measured by PEF which similar to CPF[14] was related to physical fitness[13]. Thus expiratory flow limitation might be one factor that associated cough function with physical fitness in community dwelling older adults. One study suggested that expiratory muscle training was an effective program to improve cough function[31]. However, in that study, a special respiratory training device was used, which is somewhat difficult to apply in practice. On the other hand, our approach was simple and applicable to older adults. Therefore, the results of the present study may help to provide exercise therapy aiming to maintain effective cough function in the elderly.

The value of CPF were 412.5±190.7 L/min and 247.7 ±99.9 L/min in men and women respectively. Previous study shown that value of CPF were 550.0±165.3 L/min and 373.8±102.4 L/min in over 20 aged men and women[7], 434.3±111.1 L/min and 309.2±61.3 L/min in over 60 aged men and women[8], and 329.8±105.9 L/min in over 60 aged men residents of a nursing home[9], respectively. There is a general agreement that our results of the value of CPF lower than previous study of over 20 age adults[7]. Although a slight difference were found the results of the value of CPF of men in present study similar to other studies of older people[8], on the other hand, the value of CPF in women was lower than previous study[8]. These differences can be explained by differences in characteristics such as race, physique, respiratory function and respiratory muscle strength. For the variation of CPF, the Coefficient of variation (CV) (calculated by dividing the standard deviation by the average) of CPF in present study were 0.462 and 0.403 in men and women, respectively. Previous studies have shown that the CV of CPF were 0.301 and 0.274 in over 20 aged men and women[7], 0.256 and 0.198 in over 60 aged men and women[8] and 0.321 in over 60 aged men residents of a nursing home[9], respectively. The CV of CPF were higher than previous reports, however the tendency that men had high value of CV than women was similar. Our study is a same line with the previous studies.

There are several limitations to the current study. First, the present study was a cross-sectional investigation of participants who were recruited via community-based advertisements; thus, the causal relationship is unclear. Second, a selection bias may have occurred because subjects voluntarily participated in our study. Third, involuntary cough function, which is important for prevention of aspiration pneumonia, was not measured in the present study. Future investigations are needed to investigate whether physical fitness and respiratory parameters are associated with involuntary cough.

Conclusion

Cough function tends to decrease with age in women and men in community-dwelling elderly. Physical fitness was associated with cough function. The present study may provide insights into the most appropriate exercise prescription to maintain cough function and to prevent pneumonia effectively in older adults.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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