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Original Article

Association of respiratory function with physical performance, physical activity, and sedentary behavior in older adults

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Abstract. [Purpose] The associations between respiratory function, physical performance, physical activity, and sedentary behavior in older adults remain to be elucidated. This study aimed to investigate the associations of lung volume and respiratory muscle strength with physical performance, physical activity, and sedentary behavior in older adults. [Participants and Methods] In 62 ambulatory community-dwelling older adults, lung volumes (forced vital capacity and forced expiratory volume in 1s), respiratory muscle strength (maximum inspiratory and expiratory muscle pressures), physical performance (Timed Up and Go test and 30 s chair stand test), physical activity (steps and locomotive and non-locomotive physical activity), and sedentary behavior (percent sedentary time) were assessed. [Results] The percent sedentary time, 30-s chair stand test performance, and non-locomotive moderate-to-vigorous physical activity were independently associated with forced vital capacity, maximum inspiratory pressure, and maximum expiratory pressure, respectively. [Conclusion] The preliminary findings suggest that lung volumes and respiratory muscle strength may be differently affected by physical performance, physical activity, and sedentary behavior in ambulatory older adults.

Key words: Respiratory function, Physical performance, Physical activity

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INTRODUCTION

Lung function is an important predictor of cardiovascular, respiratory, and all-cause mortality[1)]. Previous studies demonstrated that reduction in forced expiratory volume in 1 s (FEV_1), which is partly interpreted as progression of chronic obstructive pulmonary disease, is associated with morbidity and mortality[1)]. In addition, low forced vital capacity (FVC) without airway limitation, showing a restrictive lung pattern, is a significant predictor of mortality in the general population[2)]. A restrictive pattern is relatively common and highly prevalent in older adults; it is associated with functional impairment, various comorbid conditions, and mortality[3)].

Physical inactivity, one of the leading risk factors of mortality[4)], is positively associated with reduced FEV_1 and FVC in older adults[5, 6)]. Moreover, less physical activity is associated with decreased respiratory muscle strength[7)] and poor physical performance[8)] in older adults. However, these findings are mostly based on physical activity data from self-reported questionnaires, which could possibly lead to overestimated physical activity in older adults, compared to objective measures[9)]. To the best of my knowledge, there is only one large epidemiological study using accelerometers to assess the association between sedentary behavior and respiratory function and physical performance in older adults[10)]. This study demonstrated that reduced ventilatory capacity and respiratory muscle weakness are associated with decreased physical performance. However, associations between respiratory function and objective variables of physical activity in older adults remain to be investigated. Objective measure of physical activity and sedentary behavior may promote better understanding of the associa-

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tion of respiratory function with physical activity and sedentary behavior, helping inform strategies via physical activities for preventing age-associated change in respiratory function, in older adults.

Therefore, the purpose of this study was to conduct a preliminary investigation of the associations of lung volume and respiratory muscle strength with physical performance, physical activity, and sedentary behavior in older adults using accelerometers.

PARTICIPANTS AND METHODS

Study participants were 69 community-dwelling, ambulatory older adults aged 65years and older from community-based organizations in Okawa, Japan. Participants with cardiopulmonary diseases, rheumatic diseases, neurological diseases, airflow limitation, body mass index >30 kg/m^2, and cognitive disorders that prevented understanding measurement instructions were excluded. The remaining 62 participants (25 males and 37 females) who provided at least 4 valid days of accelerometer monitoring (≥10 hours of wear time per day) were included in the study. The sample size was calculated based on a previous study that showed a large effect size[5)] in multiple regression analysis. The sample size of 54 participants was calculated considering 9 variables, power=80%, α=0.05 and effect size f^2=0.35. This study was approved by the ethics committee of the International University of Health and Welfare (17-Ifh-02), and all the participants gave their written informed consent.

FVC and FEV_1 were measured using a hand-held portable spirometer (Spirobank, Medical International Research, Roma, Italy) in accordance with the American Thoracic Society and European Respiratory Society guidelines[11)]. The diagnostic threshold for spirometric measures was set at the lower limit of normal (LLN) defined as the fifth percentile of distribution calculated by using the Lambda-Mu-Sigma method[12)]. Airflow limitation and restrictive pattern were defined as FEV_1/FVC<LLN and as FEV_1/FVC>LLN and FVC<LLN, respectively. Measurements were performed at least three times in the sitting position, and the highest value was adopted. FVC was expressed as percentage of predicted FVC using predicted reference values.

Respiratory muscle strength was assessed by measuring the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) using a hand-held portable respiratory pressure meter with the least air leakage (MicroRPM, CareFusion, Hoechberg, Germany). MIP and MEP were measured in the sitting position starting from residual volume and total lung capacity, respectively, in accordance with the American Thoracic Society and European Respiratory Society guidelines[13)]. Measurements were repeated at least three times, and the highest value was adopted.

Physical performance was assessed using the Timed Up and Go (TUG) test[14)] and 30-s chair stand (30s-CS) test[15)]. The TUG test, which was used to assess functional balance and predict fall risk, was performed using an armless chair and a stopwatch. Participants were seated with their backs against the chair. They were instructed to stand up from the chair, walk for 3 m, turn around a cone, walk back and sit on the chair at the participants' maximal speed. TUG time was measured as the time taken in seconds. The fastest time was recorded for two trials. The 30s-CS test assessed lower body strength. Participants were instructed to sit on the middle of the chair and perform as many chair stands as possible in 30 s, after a practice trial to check proper form. The number of full stands with arms folded across the chest within 30 s was recorded.

Physical activity and sedentary behavior were assessed using a tri-axial accelerometer (Active style Pro HJA-750C; Omron Healthcare, Kyoto, Japan). The accelerometer, set at 10 s epochs, recorded steps and physical activity in metabolic equivalents. Participants were instructed to wear the accelerometer on the left or right side of their waist. Physical activity was monitored while awake for at least 7 consecutive days (except during bathing and showering). Non-wear time was defined as an interval of at least 60 consecutive minutes of zero activity. Physical activity data was classified into locomotive or non-locomotive activities with a validated algorithm[16)]. Moderate-to-vigorous physical activity (MVPA) was defined as ≥3 metabolic equivalents of locomotive and non-locomotive physical activity. Locomotive and non-locomotive MVPA were expressed as the total daily amount of MVPA (metabolic equivalents hour/day). Sedentary behavior was assessed by sedentary time, which was defined as the time of ≤1.5 metabolic equivalents of non-locomotive physical activity. Daily sedentary time was calculated and express as a percentage of total wear time (percent sedentary time).

Data are expressed as mean ± SD for continuous and categorical variables. Normal distributions of continuous variables were verified using Shapiro-Wilk test. Differences between male and female participants were assessed using unpaired t-tests or Mann-Whitney U tests. Categorical variables were compared using Fisher's exact test. Stepwise multiple linear regression analysis was used to assess the associations of respiratory function (FVC, FEV_1, MIP, and MEP) with physical performance (TUG and 30s-CS), physical activity (steps, locomotive MVPA, and non-locomotive MVPA), and sedentary behavior (percent sedentary time), adjusted for gender, age, and height (for FVC and FEV_1) as possible confounders. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, NY, USA). Statistical significance was set at p value <0.05.

RESULTS

Participant characteristics are summarized in Table 1. Nine (15%) participants had restrictive lung patterns. The average total wear time was 14.1 ± 1.4 hours/day. Male participants had significantly higher values of height, weight, FVC, MIP, MEP, steps, and locomotive MVPA, but no significant differences in the prevalence of restrictive pattern, FVC percentage

Table 1. Participant characteristics

Variables	Total (N=62)	Males (n=25)	Females (n=37)	p value
Age (years)	78 ± 6	77 ± 5	79 ± 6	0.215
Height (cm)	155 ± 8	159 ±7	150 ± 6	<0.001
Weight (kg)	54.3 ± 9.7	59.1 ± 8.6	51.0 ± 9.0	0.001
BMI (kg/m^2)	22.7 ± 3.4	23.1 ± 2.8	22.5 ± 3.7	0.511
FVC (L)	2.41 ± 0.65	2.93 ± 0.56	2.06 ± 0.45	<0.001
FVC (%predicted)	92.7 ± 17.3	94.9 ± 18.5	91.2 ± 16.6	0.581‡
FEV_1 (L)	1.83 ± 0.51	2.17 ± 0.48	1.60 ± 0.40	<0.001
FEV_1/FVC (%)	77.1 ± 8.0	73.7 ± 8.2	79.4 ± 7.2	0.008
Restrictive pattern* [n (%)]	9 (15)	5 (20)	4 (11)	0.465§
MIP (cmH_2O)	53.3 ± 26.6	65.2 ± 31.8	45.2 ± 19.0	<0.001‡
MEP (cmH_2O)	78.7 ± 34.2	101.4 ± 34.8	63.4 ± 24.1	<0.001
TUG (s)	7.3 ± 2.5	6.6 ± 1.2	7.7 ± 3.1	0.039‡
30s-CS (n)	18.3 ± 7.3	18.9 ± 4.5	17.9 ± 4.5	0.401
Steps (steps/day)	4,093 ± 2,840	5,089 ± 3,692	3,420 ± 1,852	0.049‡
Locomotive MVPA (metabolic equivalents hour/day)	1.1 ± 1.7	1.7 ± 2.4	0.6 ± 0.5	0.005‡
Non-locomotive MVPA (metabolic equivalents hour/day)	2.9 ± 1.8	3.2 ± 2.3	2.7 ± 1.3	0.931‡
Sedentary time (hour)	8.2 ± 2.0	7.9 ± 2.6	8.4 ± 1.6	0.763‡
Percentage sedentary time† (%)	57.6 ± 13.7	57.0 ± 17.7	58.9 ± 10.5	0.566‡

Values are mean ± SD or number. BMI: body mass index; FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 s; TUG: timed up and go test; 30s-CS: 30-s chair stand test; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; MVPA: moderate-to-vigorous physical activity. *Restrictive was defined as FEV_1/FVC ≥ lower limit of normal and FVC < lower limit of normal. †Proportion of total sedentary time to total wear time. ‡Mann-Whitney U test. §Fisher's exact test.

predicted, TUG, 30s-CS, steps, non-locomotive MVPA, and percent sedentary time were found between males and females (Table 1).

From the multiple regression analyses with dependent variables (FVC, FEV_1, MIP, and MEP) and independent variables (30s-CS, TUG, steps, locomotive MVPA, non-locomotive MVPA, and percent sedentary time), percent sedentary time, 30s-CS, and non-locomotive MVPA were independently associated with FVC, MIP, and MEP, respectively (Table 2). There were no variables independently associated with FEV_1.

DISCUSSION

In assessment of physical activity and sedentary behavior using objective method, novel preliminary findings that percent sedentary time, number of 30s-CS, and non-locomotive MVPA were independently associated factors for FVC, MIP, and MEP, respectively, were found in ambulatory, community-dwelling older adults without airflow limitation. The results suggest that lung volumes and respiratory muscle strength may be differently affected by physical performance, physical activity, and sedentary behavior in ambulatory older adults.

In large studies on the association between pulmonary function and physical activity using self-report questionnaires, FVC and FEV_1 are positively associated with physical activity[5, 6]. However, these associations are not consistent with our results. No significant predictors for FVC and FEV_1 are observed, but the percent sedentary time is a significant predictor for FVC. In these previous studies, the amount of time spent in sedentary behavior has not been assessed. Although there is one previous study on the associations between respiratory function and objectively-measured sedentary behavior[10], this study demonstrated that respiratory impairment (FEV_1 and MIP<LLN) was associated with impaired physical performance, but not high sedentary time. In addition, FVC was not selected for the analysis. Thus, there is no similar study to compare our results. In this respect, this is the first report of the significant association between FVC and percent sedentary time in older adults.

Recent studies showed that objectively-measured sedentary time is associated with physical performance and handgrip strength in older adults[17, 18]. On the other hand, FVC and FEV_1 are associated with handgrip strength in older adults, rather than physical performance[19]. Considering that most previous findings show no significant associations of FVC and FEV_1 with physical performance, mutual relationships between FVC, sedentary time, and handgrip strength might lead to our result of an independent association between FVC and percent sedentary time. Identifying a causal relationship for this is outside the scope of this study. However, given that thoracic spine mobility is associated with prolonged sitting in younger adults[20] and thoracic spinal mobility is related with lung volumes[21], it is possible to assume that reduced spinal mobility developed by higher sedentary time would contribute to reduced FVC. Further studies are needed to investigate the relationships between

Table 2. Results of stepwise multiple regression analyses to detect independent variables of respiratory function in community-dwelling older adults (N=62)

	β	p value	R^2	Adjusted R^2
FVC			0.65	0.63
Gender	0.43	<0.001		
Age	−0.28	0.001		
Height	0.30	0.004		
Percent sedentary time*	−0.16	0.049		
FEV_1			0.48	0.45
Gender	0.31	0.010		
Age	−0.27	0.010		
Height	0.33	0.008		
MIP			0.29	0.25
Gender	0.32	0.007		
Age	−0.30	0.012		
30s-CS	0.29	0.025		
MEP			0.42	0.39
Gender	0.48	<0.001		
Age	−0.24	0.023		
Non-locomotive MVPA	0.22	0.040		

FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 s; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; 30s-CS: 30-s chair stand test; MVPA: moderate-to-vigorous physical activity. *Proportion of total sedentary time to total wear time.

these factors in older adults.

Concerning respiratory muscle strength in older adults, previous studies showed that both MIP and MEP are associated with walking performance[8)] and physical activity[7)]. Considering that walking performance is related to lower-limb function in healthy older adults[22)], our result of the association between MIP and 30s-CS performance is partly supported by the previous findings. On the other hand, MEP was independently associated only with non-locomotive MVPA. However, in most studies on the physical activity using an objective device, physical activity has not been defined as locomotive and non-locomotive physical activity. Hence, our results of physical activity are not directly comparable to previous findings. Non-locomotive MVPA, such as washing windows, mopping, vacuuming, elderly care, and carpentry, requires more upper body function, unlike walking performance which is related to lower-limb function. A recent study demonstrated that MIP is associated with handgrip strength and skeletal muscle mass index, and MEP is exclusively associated with handgrip strength in healthy older adults[23)]. We can, therefore, speculate that MEP is more specifically related to upper-limb activities than lower-limb activities in ambulatory older adults.

In this study, 15% (9/62) of the participants had restrictive pattern. In addition, 21% (13/62) and 24% (15/62) of the participants for MIP and MEP, respectively, had lower respiratory muscle strength than the normal limits defined by Evans et al[24)]. Age-associated decline in lung volumes and respiratory muscle strength has been affected by thoracic deformity[25)] and sarcopenia[26, 27)]. Moreover, prevalence of sarcopenia in community-dwelling older adults ranging from 9.9 to 40.9% was recently reported[28)]. Since the prevalence of reduced respiratory function in our participants is within this range, many of the participants with reduced respiratory function might have sarcopenia (reduced handgrip strength, gait speed, and muscle mass). As described above, lung volumes and respiratory muscle strength may reflect multiple aspects of physical health status. Therefore, we believed that measuring lung volumes and respiratory muscle strength may be helpful in assessing physical health status and preventing the deterioration of respiratory function to prolong healthy lifestyles.

This study has some limitations. One limitation is the small population size, despite the sample size estimate based on the previous results. Therefore, our findings may not fully generalize to other populations. In addition, the amount of time spent in sedentary behavior might have been underestimated due to the limited measurement period (≥4 days)[29)], although physical activity was assessed using accelerometers according to previous studies[30)]. Finally, the cross-sectional design of this study limits causal inferences regarding the observed associations. Further larger and longitudinal studies are required to investigate the causal relationship between respiratory function and physical performance and objectively-measured physical activity and sedentary behavior in older adults.

In conclusion, percent sedentary time, 30s-CS, and non-locomotive MVPA were independently associated with FVC, MIP, and MEP, respectively, in ambulatory community-dwelling older adults without airflow limitation. These results suggest that lung volumes and respiratory muscle strength may be differently affected by physical performance, physical activity, and sedentary behavior. Measurement of respiratory function might be useful to assess physical health status and prevent deterioration of respiratory function in ambulatory older adults.

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Conflicts of interest

The author declares no conflicts of interest.

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