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

HIDEO KANECO

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

INTRODUCTION

Lung function is an important predictor of cardiovascular, respiratory, and all-cause mortality1). Previous studies demonstrated that reduction in forced expiratory volume in 1 s (FEV1), which is partly interpreted as progression of chronic obstructive pulmonary disease, is associated with morbidity and mortality1). In addition, low forced vital capacity (FVC) without airway limitation, showing a restrictive lung pattern, is a significant predictor of mortality in the general population2). A restrictive pattern is relatively common and highly prevalent in older adults; it is associated with functional impairment, various comorbid conditions, and mortality3).

Physical inactivity, one of the leading risk factors of mortality4), is positively associated with reduced FEV1 and FVC in older adults5, 6). Moreover, less physical activity is associated with decreased respiratory muscle strength7) and poor physical performance8) 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 measures9). 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 adults10). 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-
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 65 years and older from community-based organizations in Okawa, Japan. Participants with cardiopulmonary diseases, rheumatic diseases, neurological diseases, airflow limitation, body mass index >30 kg/m², 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 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-Iufh-02), and all the participants gave their written informed consent.

FVC and FEV₁ 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. 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. Airflow limitation and restrictive pattern were defined as FEV₁/FVC<LLN and as FEV₁/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. 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 and 30-s chair stand (30s-CS) test. 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 and non-locomotive activities with a validated algorithm. 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 expressed 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, FEV₁, 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 FEV₁) 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...
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, FEV1, 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 FEV1.

**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 FEV1 are positively associated with physical activity. However, these associations are not consistent with our results. No significant predictors for FVC and FEV1 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, this study demonstrated that respiratory impairment (FEV1 and MIP<LLN) was associated with impaired physical performance, but not high sedentary time. 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. On the other hand, FVC and FEV1 are associated with handgrip strength in older adults, rather than physical performance. Considering that most previous findings show no significant associations of FVC and FEV1 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 and thoracic spinal mobility is related with lung volumes, 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...
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 differentially 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.

**Funding**

This work was supported by JSPS KAKENHI Grant number JP17K01792.

**Conflicts of interest**

The author declares no conflicts of interest.

**REFERENCES**

1. Baughman P, Marott JL, Lange P, et al.: Combined effect of lung function level and decline increases morbidity and mortality risks. Eur J Epidemiol, 2012, 27: 933–943. [Medline] [CrossRef]
2. Guerra S, Sherrill DL, Venker C, et al.: Morbidity and mortality associated with the restrictive spirometric pattern: a longitudinal study. Thorax, 2010, 65: 499–504. [Medline] [CrossRef]
3. Scarlata S, Costanzo L, Giua R, et al.: Diagnosis and prognostic value of restrictive ventilatory disorders in the elderly: a systematic review of the literature. Exp Gerontol, 2012, 47: 281–289. [Medline] [CrossRef]
4. World Health Organization: Global health risks: mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization, 2009.
5. Burchfiel CM, Enright PL, Sharp DS, et al.: Factors associated with variations in pulmonary function among elderly Japanese-American men. Chest, 1997, 112: 87–97. [Medline] [CrossRef]
6. O’Donovan G, Hamer M: The association between leisure-time physical activity and lung function in older adults: The English longitudinal study of ageing. Prev Med, 2018, 106: 145–149. [Medline] [CrossRef]
7. Summerhill EM, Angov N, Garber C, et al.: Respiratory muscle strength in the physically active elderly. Lung, 2007, 185: 315–320. [Medline] [CrossRef]
8. Giua R, Pedone C, Scarlata S, et al.: Relationship between respiratory muscle strength and physical performance in elderly hospitalized patients. Rejuvenation Res, 2014, 17: 366–371. [Medline] [CrossRef]
9. Dyrdstad SM, Hansen BH, Holme IM, et al.: Comparison of self-reported versus accelerometer-measured physical activity. Med Sci Sports Exerc, 2014, 46: 99–106. [Medline] [CrossRef]
10. Vaz Fragoso CA, Beavers DP, Hankinson JL, et al. Lifestyle Interventions Independence for Elders Study Investigators: Respiratory impairment and dyspnea and their associations with physical inactivity and mobility in sedentary community-dwelling older persons. J Am Geriatr Soc, 2014, 62: 622–628. [Medline] [CrossRef]
11. Miller MR, Hankinson J, Brusasco V, et al. ATS/ERS Task Force: Standardisation of spirometry. Eur Respir J, 2005, 26: 319–338. [Medline] [CrossRef]
12. Kubota M, Kobayashi H, Quanjer PH, et al. Clinical Pulmonary Functions Committee of the Japanese Respiratory Society: Reference values for spirometry, including vital capacity, in Japanese adults calculated with the LMS method and compared with previous values. Respir Investig, 2014, 52: 242–250. [Medline] [CrossRef]
13. American Thoracic Society/European Respiratory Society: ATS/ERS Statement on respiratory muscle testing. Am J Respir Crit Care Med, 2002, 166: 518–624. [Medline] [CrossRef]
14. 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] [CrossRef]
15. Jones CJ, Rikli RE, Beam WC: A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. Res Q Exerc Sport, 1999, 70: 113–119. [Medline] [CrossRef]
16. Ohkawara K, Oshima Y, Hikihara Y, et al.: Real-time estimation of daily physical activity intensity by a triaxial accelerometer and a gravity-removal classification algorithm. Br J Nutr, 2011, 105: 1681–1691. [Medline] [CrossRef]
17. Rosenberg DE, Bellettiere J, Gardiner PA, et al.: Independent associations between sedentary behaviors and mental, cognitive, physical, and functional health among older adults in retirement communities. J Gerontol A Biol Sci Med Sci, 2016, 71: 78–83. [Medline] [CrossRef]
18. Santos DA, Silva AM, Baptista F, et al.: Sedentary behavior and physical activity are independently related to functional fitness in older adults. Exp Gerontol, 2012, 47: 908–912. [Medline] [CrossRef]
19. Sillanpää E, Stenroth L, Bjälsma AY, et al.: Associations between muscle strength, spirometric pulmonary function and mobility in healthy older adults. Age (Dordr), 2014, 36: 9667. [Medline] [CrossRef]
20. Henehan NR, Baker G, Thomas K, et al.: What is the effect of prolonged sitting and physical activity on thoracic spine mobility? An observational study of young adults in a UK university setting. BMJ Open, 2018, 8: e019371. [Medline] [CrossRef]
21. Mellin G, Harjula R: Lung function in relation to thoracic spinal mobility and kyphosis. Scand J Rehabil Med, 1987, 47: 908–912. [Medline] [CrossRef]
22. Calabrer VB, Lisón JF, Rosado-Calatayud P, et al.: Factors associated with the 6-minute walk test in nursing home residents and community-dwelling older adults. J Phys Ther Sci, 2015, 27: 3571–3578. [Medline] [CrossRef]
23. Shin HI, Kim DK, Seo KM, et al.: Relation between respiratory muscle strength and skeletal muscle mass and hand grip strength in the healthy elderly. Ann Rehabil Med, 2017, 41: 686–692. [Medline] [CrossRef]
24. Evans JA, Whitefall WA: The assessment of maximal respiratory mouth pressures in adults. Respir Care, 2009, 54: 1348–1359. [Medline] [CrossRef]
25. Culham EG, Jimenez HA, King CE: Thoracic kyphosis, rib mobility, and lung volumes in normal women and women with osteoporosis. Spine, 1994, 19: 1250–1255. [Medline] [CrossRef]
26. Moon JH, Kong MH, Kim HJ: Implication of sarcopenia and sarcopenic obesity on lung function in healthy elderly: using Korean national health and nutrition examination survey. J Korean Med Sci, 2015, 30: 1682–1688. [Medline] [CrossRef]
27) Ohara DG, Pegorari MS, Oliveira Dos Santos NL, et al.: Respiratory muscle strength as a discriminator of sarcopenia in community-dwelling elderly: a cross-sectional study. J Nutr Health Aging, 2018, 22: 952–958. [Medline] [CrossRef]

28) Mayhew AJ, Amog K, Phillips S, et al.: The prevalence of sarcopenia in community-dwelling older adults, an exploration of differences between studies and within definitions: a systematic review and meta-analyses. Age Ageing, 2019, 48: 48–56. [Medline] [CrossRef]

29) Matthews CE, Ainsworth BE, Thompson RW, et al.: Sources of variance in daily physical activity levels as measured by an accelerometer. Med Sci Sports Exerc, 2002, 34: 1376–1381. [Medline] [CrossRef]

30) Trost SG, McIver KL, Pate RR: Conducting accelerometer-based activity assessments in field-based research. Med Sci Sports Exerc, 2005, 37: S531–S543. [Medline] [CrossRef]