Advance Publication
Journal of Atherosclerosis and Thrombosis
Accepted for publication: October 31, 2014
Published online: December 20, 2014

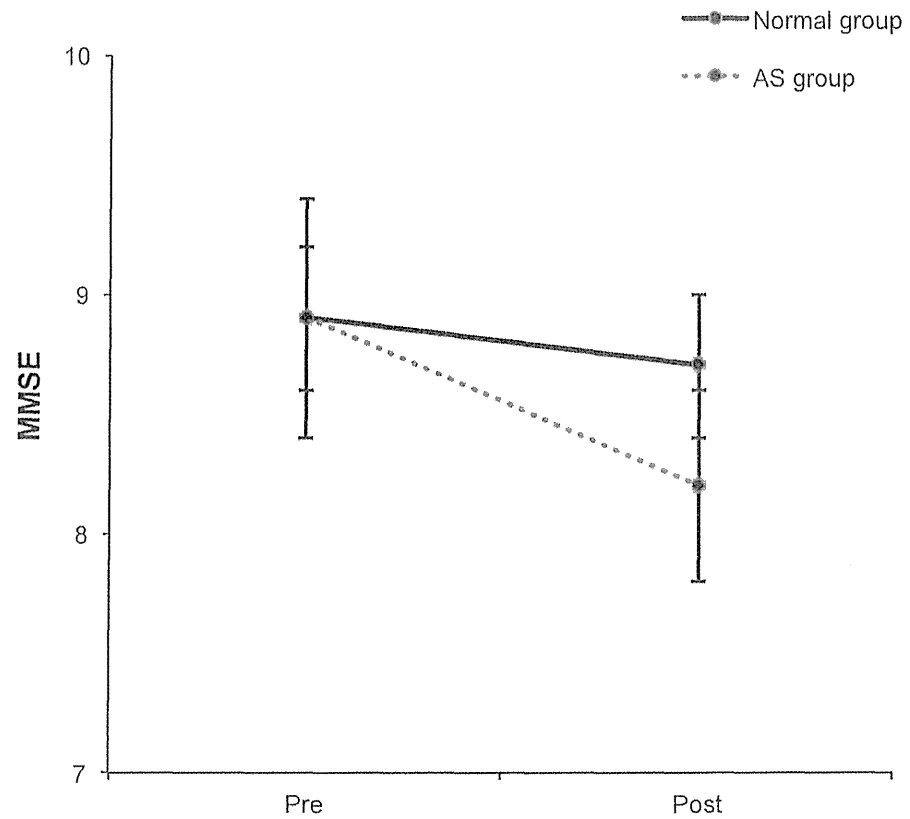

Fig. 3. Two-way analysis of variance showing the differences in the changes in the post-MMSE (language) scores between the normal and AS groups. These findings indicate that the elderly subjects in the AS group experienced greater cognitive decline than those in the control group ($F = 4.32$, $p = 0.04$).

ity of arterial stiffness longitudinally predicts cognitive decline. For example, one study targeting people older than 80 years of age in nursing homes showed results similar to the current findings[13]. The mean baseline MMSE score of these subjects was 23.7 ± 4.9, which is lower than that observed in the current study. Another study, in which the subjects were older patients in the hospital with complaints of memory loss, also reported that arterial stiffness has a strong predictive ability for cognitive decline[14]. Furthermore, Yamamoto *et al.* performed a similar analysis in community-dwelling elderly patients; however, the mean age was higher than that noted in our study[18]. Notably, we found that arterial stiffness predicts cognitive decline in community-dwelling elderly subjects with a comparably preserved cognitive function, even after adjusting for age, gender, BMI and the baseline cognitive function. In addition, we observed the scores for the attention-and-calculation and language domains of the MMSE to be significantly decreased in the AS group. It has been reported that these MMSE domains are not affected by impairment of the hippocampus[26]. Therefore, we assume that the cognitive dysfunction resulting from arterial stiffness is not attributed to dysfunction of the hippocampus. However, other studies have reported that measurements of arterial stiffness do not predict performance for the global cognitive function, as measured according to the MMSE[15-17]. There are various possible reasons for this discrepancy: 1) the mean age of the subjects was 57.1 years and the participants were relatively high functioning (ceiling effect of the MMSE)[15]; 2) many participants dropped out from the follow-up survey and selection bias may have affected the results for the change in the cognitive function[16]; 3) memory tasks that are more demanding for the executive function and attention may be more sensitive to cerebrovascular alterations due to aging and the MMSE may be too insensitive to accurately detect cognitive changes[17, 27]. As a result, further studies are needed to establish evidence clarify-

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ing the association between arterial stiffness and the cognitive function.

The most important clinical implication of our findings is that one of the most easily measured and non-invasive parameters, especially in community-dwelling elderly individuals, arterial stiffness, predicted cognitive decline after one year. These results imply that maintaining the arterial function may prevent or delay the onset of dementia in the community-dwelling elderly. Additionally, it may be possible to identify individuals at risk of dementia by evaluating the degree of arterial stiffness. Interventional and longitudinal studies examining improvements in arterial stiffness with the aim of preventing cognitive decline are required to establish effective strategies for inhibiting the onset of dementia.

This study is associated with several limitations. First, because we were unable to perform neuroimaging assessments, it was not possible to make a specific diagnosis of dementia subtypes. In addition, we only performed MMSE as a cognitive test, and the cognitive function was not fully investigated. There may be asymptomatic brain lesions and specific cognitive domains that exhibit a strong relationship with arterial stiffness. Second, the age at baseline in the AS group was significantly higher than that observed in the normal group. Although we tried to minimize the impact of this difference by adjusting for age, the effect may have been insufficient. Third, the small number of subjects may also have affected the results, and more samples are needed to confirm the results of this study. Finally, many studies have investigated the relationship between arterial stiffness and the cognitive function; therefore, this study may not have adequate novelty. Nevertheless, we regard our findings as providing evidence that strengthens the close relationship between arterial stiffness and cognitive decline.

Conclusions

This study showed that arterial stiffness predicts cognitive decline in Japanese community-dwelling elderly subjects regardless of the initial level of the global cognitive function. These findings indicate the potential of improving arterial stiffness in order to prevent or delay of the onset of dementia in the elderly.

Conflicts of Interest

None.

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Title:

Age-related decline in chest wall mobility: A cross-sectional study among community-dwelling elderly women belonging to different age groups

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Authors who provided the final approval of the version of the article to be published: M.Y, T.A.

Disclosure of interest

The authors declare no conflicts of interest related to the manuscript.

Age-related decline in chest wall mobility: A cross-sectional study among community-dwelling elderly women belonging to different age groups

Abstract

Context: Chest wall mobility is significantly related to respiratory function; however, the effect of aging on chest wall mobility, and at which level this mobility is the most affected remains unclear.

Objective: To investigate differences in chest wall mobility and respiratory function by comparison among different age groups.

Method: This cross-sectional observational study included 132 community-dwelling elderly women over the age of 65 years. These women were divided into four groups according to their age: Group 1, 65–69 years; Group 2, 70–74 years; Group 3, 75–79 years; and >Group 4, 80 years. Thoracic excursion at the axillary and xiphoid levels and at the level of the tenth rib was measured with a measuring tape. Respiratory function, including forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1), was assessed by spirometry, and FVC percent predicted (%FVC), FEV_1 percent predicted (%FEV_1), and FEV_1/FVC were calculated. Chest wall mobility and respiratory function were compared among the four groups.

Results: There were significant differences in thoracic excursion at the axillary level between Groups 1 and 4 and between Groups 2 and 4 when adjusted for height and weight ($F = 4.52$, $P = 0.01$). In addition, there were significant differences in the FVC and FEV_1 values between Groups 1 and 3 and between Groups 2 and 3 (FVC, $F = 4.97$, $P = 0.01$; FEV_1, $F = 6.17$, $P = 0.01$).

Conclusion: Chest wall mobility at the axillary level and respiratory function decreased with age in community-dwelling elderly women. Further longitudinal studies are required to clarify the effects of aging on chest wall mobility and respiratory function.

Introduction

In recent years, chronic obstructive pulmonary disease (COPD) has become a serious global threat.[1] Epidemiological studies indicate that COPD, which was ranked as the sixth leading cause of death in 1990, will become the fourth leading cause of death by 2030 and will be the third leading cause of death.[2] The prevalence of COPD increases with age, but the rate of recognition and diagnosis of COPD in affected individuals remains low. Therefore, many people in the community who are living with COPD have not been diagnosed and are not undergoing treatment.[3] Consequently, a simple and convenient method is required for assessing respiratory function in the community.

In addition to the worldwide threat of COPD, studies have indicated that human respiratory function decreases with age, and that this is an irreversible process related to the physiology of aging.[4-6]

Chest wall mobility is closely related to respiratory function. Similar to the lungs, the chest wall is an elastic structure that follows the displacement of the lungs. Measurement of chest wall mobility at different levels using a measuring tape has been applied in clinical practice to evaluate the effects of rehabilitation.[7] This measurement technique exhibits a high inter- and intra-observer reliability[12,13] and is a simple and economical method for assessing respiratory function.

Previous studies have found a significant relationship between chest wall mobility and forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and respiratory muscle strength.[8-11] While spirometry requires specialized equipment and techniques, measurement of chest wall mobility can be performed with relative ease in a variety of settings, allowing for screening of respiratory health within the community. We hypothesized that if chest wall mobility could be associated with the age-related decrease in respiratory function, measurement of chest wall mobility could be used for the screening of the respiratory function among elderly individuals within the community.

In this study, we evaluated the difference in chest wall mobility and respiratory function among age groups in community-dwelling elderly women.

Methods

This was a cross-sectional observational study that was carried out in Himeji city, Hyogo prefecture and Ayabe city, Kyoto prefecture, Japan, by Kyoto University, in November 2013. Volunteers were recruited by advertisements in the local community paper. We obtained informed consent from each person who was included in the study. Eligibility was determined by interview, and the inclusion criteria were female gender, age ≥65 years, community resident, and ability to ambulate independently, with or without an assistive device. Because we found only about half as many men as women who were eligible for the study, and because only 5 of the men were older than 80 years, we would have been unable to establish difference between the variables among groups. Therefore, the analysis included women only. Since the purpose of the study was to address only age-dependent changes in chest wall mobility, we excluded individuals with COPD, as well as those with severe cognitive impairment; severe cardiac, pulmonary, or musculoskeletal disorders; and comorbidities associated with greater risk of falls, such as Parkinson's disease or stroke. The study was conducted in accordance with the guidelines of the Declaration of

Helsinki, and the study protocol was reviewed and approved by the Ethics Committee of the Kyoto University Graduate School of Medicine (E-1850).

Pulmonary function tests

All volunteers underwent evaluation by spirometry. FVC and FEV_1 were measured using a Spiro Sift SP-370 spirometer (Fukuda Denshi Co., Ltd, Tokyo, Japan). The FVC percent predicted (%FVC) and FEV_1 percent predicted (%FEV_1) were calculated and corrected for height and age. Spirometry was carried out according to the guidelines of the Japanese Respiratory Society,[14] and the formulae for calculating %FVC and %FEV_1 were derived from Japanese criteria.[15] The FEV_1/FVC ratio was also calculated. All measurements were performed by the same trained physical therapist.

Chest wall mobility

Chest wall mobility was measured according to methods described previously to ensure a high level of reproducibility.[12,13] During the measurements, the volunteers stood with their hands at their sides, and the chest circumference was measured with a measuring tape at maximal inhalation and maximal exhalation at three levels: the axillary line (axillary excursion), tip of the xiphoid process (xiphoid excursion), and lateral lower edge of rib 10 (tenth rib excursion). These levels were chosen for inclusion in the study, because they are measured frequently in clinical practice. The standardized measurement procedure included keeping the tape aligned horizontally with the landmark, with the zero-point fixed at the midline, while the other end of the tape was allowed to move. The tape was snug but not tight, to ensure that the soft tissue contour remained unchanged. Measurements were performed twice at maximum inspiration and twice at maximum expiration at all levels, and volunteers were asked to hold maximum inspiration and expiration for at least 2 seconds, during which the measurements were taken. All of the measurements were performed by a single trained physical therapist, who was not the same therapist that measured respiratory function.

Statistical analysis

Volunteers were categorized into four age groups: Group 1, 65–69 years (n =

38); Group 2, 70–74 years (n = 45); Group 3, 75–79 years (n = 38), and Group 4, >80 years (n = 11).

Differences in chest wall mobility among the four groups were examined using analysis of covariance (ANCOVA) adjusted for height and weight. Other variables were examined using analysis of variance (ANOVA). Some of the respiratory parameters, i.e., %FVC and $\%FEV_1$, were already adjusted for age and height. When a significant effect was found, differences were determined with the Bonferroni post-hoc test (ANCOVA) and Turkey-Kramer's post-hoc test (ANOVA). Statistical analyses were performed using the SPSS version 20.0 software package (SPSS, Chicago, IL, USA), with $P < 0.05$ accepted as significant.

Results

The characteristics of the participants are shown in Table 1. Significant differences in chest wall excursion at the axillary level were detected between Groups 1 and 4 and between Groups 2 and 4 when adjusted for height and weight ($F = 4.52$, $P = 0.01$), but there were no significant differences among the four groups in xiphoid or tenth rib excursion.

FVC and FEV_1 measurements indicated significant differences in respiratory function between Groups 1 and 3 and Groups 2 and 3 (FVC: $F = 4.97$, $P = 0.01$; FEV_1, $F = 6.17$, $P = 0.01$).

The differences across age groups in axillary excursion and FVC, using Group 1 as a reference, are shown in Figure 1. As suggested by this graph, the gradual rate of decrease in thoracic excursion at the axillary level with increased age was accompanied by a marked rate of decrease in the FVC value.

Discussion

In the current study, the relationship between chest wall mobility, respiratory function, and age was evaluated by comparing the differences in chest wall mobility and spirometric parameters among women in four age groups. Significant differences between groups were detected during the thoracic excursion at the axillary level and in the respiratory function.

While there was a sharp decline in FVC with age, as indicated by the significant difference between Groups 2 and 3, the decline in thoracic excursion at the axillary level with age was more gradual (Figure 1). These results suggest that the decrease in chest wall mobility preceded the decrease in FVC. Previous studies have shown that the age-related decrease in FVC is associated with many factors, including anatomical and physiological changes in the lungs and upper airways, decreased functioning of the respiratory muscles, and changes in chest wall compliance.[6,16] Accordingly, measurement of chest wall mobility should provide a straightforward assessment of chest wall compliance, and we believe that the primary cause of the differences in axillary excursion among age groups that are reflected in our results is the related decrease in the chest wall compliance. Several prior studies have demonstrated that the decrease in chest wall compliance is a structural cause of the age-related decreases in respiratory function.[6,16-18] In particular, calcification of costal cartilage and costovertebral articulations has been associated with decreased chest wall compliance.[17] The calcification of costal cartilage generally progresses with age,[19] and in the current study, the axillary excursion gradually declined with age. Though the pathogenesis of cartilage calcification is not fully understood, contributing factors include decreased proteoglycan synthesis[20] and diminished levels of transforming growth factor beta (TGF-β).[21]

While thoracic excursion at the axillary level was significantly decreased with age in the current study, there were no significant differences in tenth rib excursion. It was thought that axillary excursion was more profoundly affected by changes in chest wall compliance than tenth rib excursion because the tenth rib does not have a sternal articulation and the anterior portion of the tenth rib level is covered with abdominal muscles. Therefore, thoracic excursion at the level of the tenth rib would not be as markedly affected by age-related changes in chest wall compliance as it may be by disease-related changes, and the contrary result in COPD patients that was reported by Malaguti et al.[12] can be explained by the difference in study populations between the previous study and our study.

The shape of the thorax also affects chest wall compliance. Janssens et al.[17] reported that age-related osteoporosis resulted in changes in the shape of the thorax in elderly individuals. In osteoporosis patients, spinal intervertebral disk spaces are narrowed and vertebral fractures occur more frequently.[22] The prevalence of osteoporosis increases with age. In Japan, 13.5% of women aged 60–69 years have osteoporosis, and the prevalence of osteoporosis among women over 80 years of age is 43.8%.[22,23] We believe that the changes in thoracic shape impede optimal kinetics, including the pump-handle and bucket-handle rib motions, and contribute to reduced chest wall compliance. Decline in chest wall mobility caused by structural change can be effectively treated by physical therapy and osteopathic manipulative treatment. Recent studies that have considered the effect of chest rehabilitation, not only in patients with in COPD[24] or ankylosing spondylitis,[25] but also in healthy individuals,[26] have shown a positive effect on chest wall mobility. We hypothesize that these noninvasive interventions could become important in the prevention and treatment of age-related declines in chest wall mobility. Therefore, further studies are required to investigate the association between posture, musculoskeletal alignment, and chest wall mobility in the elderly population.

There were several limitations to the present study. First, this study was a cross-sectional design and not a longitudinal observational study. Therefore, we need further research to determine whether chest wall mobility decreases with age in the same individual. It would be useful to measure chest wall mobility in individuals in the same population in the short and long term, such as at one year later or at 5 years. Furthermore, we did not account for other factors that may affect chest wall mobility, such as the prevalence of osteoporosis, vertebral alignment, and posture of each subject. Despite these limitations, the findings from the present study provide valuable information, and may encourage the measurement of thoracic excursion as a means of determining standard values for chest wall mobility in each age group. Moreover, the efficacy of pulmonary rehabilitation programs should be more firmly established by incorporating measurements of chest wall mobility.

Conclusion

We investigated differences in chest wall mobility and respiratory function among four different age groups in a population of community-dwelling elderly women and detected significant age-related changes in thoracic excursion at the axillary level. Moreover, we found significant age-related differences in FVC and FEV_1. The findings suggest that assessment of chest wall mobility may be a useful method for detecting age-related decreases in respiratory function among the elderly. Further longitudinal studies should be undertaken to clarify the effects of aging on chest wall mobility.

Acknowledgements

We would like to thank the students of Human Health Sciences at Kyoto University for their help with data collection.