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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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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 (FEV1), was assessed
by spirometry, and FVC percent predicted (%FVC), FEV\textsubscript{1} percent predicted (%FEV\textsubscript{1}), and FEV\textsubscript{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\textsubscript{1} values between Groups 1 and 3 and between Groups 2 and 3 (FVC, F = 4.97, P = 0.01; FEV\textsubscript{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. 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 FEV₁ were measured using a Spiro Sift SP-370 spirometer (Fukuda Denshi Co., Ltd, Tokyo, Japan). The FVC percent predicted (%FVC) and FEV₁ percent predicted (%FEV₁) 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 %FEV₁ were derived from Japanese criteria.¹⁵ The FEV₁/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 %FEV₁, 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 FEV₁ measurements indicated significant differences in respiratory function between Groups 1 and 3 and Groups 2 and 3 (FVC: $F = 4.97$, $P = 0.01$; FEV₁, $F = 6.17$, $P = 0.01$).

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.\textsuperscript{6,16-18} In particular, calcification of costal cartilage and costovertebral articulations has been associated with decreased chest wall compliance.\textsuperscript{17} The calcification of costal cartilage generally progresses with age,\textsuperscript{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\textsuperscript{20} and diminished levels of transforming growth factor beta (TGF-\(\beta\)).\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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\%.\textsuperscript{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\textsuperscript{24} or ankylosing spondylitis,\textsuperscript{25} but also in healthy individuals,\textsuperscript{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.

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Reference


5. Britto RR, Zampa CC, de Oliveira TA, Prado LF, Parreira VF. Effects of


11. Cimen OB, Ulubas B, Sahin G, Calikoglu M, Bagis S, Erdogan C. Pulmonary function tests, respiratory muscle strength, and endurance of