Age-Related Decline in Chest Wall Mobility: A Cross-Sectional Study Among Community-Dwelling Elderly Women

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

Objective: To investigate age-related differences in chest wall mobility and respiratory function among elderly women in different age groups.

Methods: This cross-sectional observational study was performed in Himeji City in Hyogo Prefecture and Ayabe City in Kyoto Prefecture in Japan. Inclusion criteria were female sex, age 65 years or older, community resident, and ability to ambulate independently, with or without an assistive device. Thoracic excursion at the axillary and xiphoid levels and at the level of the tenth rib was measured with 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 4 age groups.

Results: Of 251 potential participants, 132 met the inclusion criteria. Participants were divided into 4 age groups: group 1, 65 to 69 years; group 2, 70 to 74 years; group 3, 75 to 79 years; and group 4, 80 years or older. Statistically significant differences were found 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=.01). In addition, statistically significant differences were found in the FVC and FEV_1 values between groups 1 and 3 and between groups 2 and 3 (FVC: $F_{4.97}$, P=.01; FEV_1: $F_{6.17}$, P=.01).

Conclusion: Chest wall mobility at the axillary level and respiratory function decreased with age in community-dwelling women aged 65 years or older. Further longitudinal studies are required to clarify the effects of aging on chest wall mobility and respiratory function.

In recent years, chronic obstructive pulmonary disease (COPD) has become a serious problem globally.[1] Epidemiologic studies indicate that COPD, which was ranked as the sixth leading cause of death in 1990, will become the third leading cause of death by 2020 and the fourth leading cause of death by 2030.[2] The prevalence of COPD increases with age,[3-5] 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.[6] Consequently, a simple and convenient method is required for assessing respiratory function in the community. The prevalence of COPD increases with age,[3-5] but the rate of recognition and diagnosis of COPD in affected individuals remains low.

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 measuring tape has been applied in clinical practice to evaluate the effects of rehabilitation.[7] This measurement technique exhibits a high inter- and intraobserver reliability[8,9] and is a simple and economical method for assessing respiratory function.

Previous studies have found a statistically significant relationship between chest wall mobility and forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and respiratory muscle strength.[10-13] Although 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.

In the current study, we sought to evaluate the difference in chest wall mobility and respiratory function in elderly community-dwelling volunteers of different age groups. We hypothesized that if chest wall mobility could be associated with the age-related decrease in respiratory function, then measurement of chest wall mobility could be used for respiratory function screening among elderly persons within a community.

Methods

This cross-sectional observational study was carried out by Kyoto University in Himeji city in the Hyogo prefecture and Ayabe city in the Kyoto prefecture in Japan in November 2013. Participants were recruited by advertisements in the local community paper, and eligibility was determined by interview. Because about half as many men as women were eligible for the study, and because only 5 of the men were older than 80 years, we would have been unable to establish differences between the variables among groups. Therefore, the analysis included women only. Furthermore, because the purpose of the study was to address 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 disease or stroke. The inclusion criteria were female sex, age 65 years or older, community-dwelling resident, and ability to ambulate independently, with or without an assistive device.

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). Informed consent was obtained from each participant.

Pulmonary Function Tests

Spirometry was used to measure FVC and FEV_1 in all participants. 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 formulas for calculating %FVC and %FEV_1 were derived from Japanese criteria.[15] The FEV_1/FVC ratio was also calculated. All pulmonary function tests and measurements were conducted by the same trained physical therapist (D.A.).

Chest Wall Mobility

To ensure a high level of reproducibility, chest wall mobility was measured according to methods described previously.[8,9] During the measurements, the participants stood with their hands at their sides, and their chest circumference was measured with a measuring tape at maximal inhalation and maximal exhalation at 3 levels: the axillary line (axillary excursion), tip of the xiphoid process (xiphoid excursion), and the lateral lower edge of the tenth rib (tenth rib excursion). These levels were chosen because they are measured frequently in clinical practice. The standardized measurement procedure included keeping the tape aligned horizontally with the

landmark with the 0-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 participants were asked to hold maximum inspiration and expiration for at least 2 seconds, during which time the measurements were taken. All of the chest wall mobility measurements were obtained by a single trained physical therapist (S.M.).

Statistical Analysis

Participants were categorized into 4 age groups. Differences in chest wall mobility among the 4 groups were examined using an analysis of covariance adjusted for height and weight. Other variables were examined using an analysis of variance. Some of the respiratory parameters (eg, %FVC and %FEV_1) were already adjusted for age and height. When a statistically significant effect was found, differences were determined with the Bonferroni post hoc test (analysis of covariance) and the Turkey-Kramer post hoc test (analysis of variance). Statistical analyses were performed using the SPSS version 20.0 software package (SPSS Inc), with $P<.05$ considered statistically significant.

Results

Of 251 potential participants, 132 met the inclusion criteria. The women were divided into 4 groups according to age: group 1 (n=38), 65 to 69 years; group 2 (n=45), 70 to 74 years; group 3 (n=38), 75 to 79 years; and group 4 (n=11), 80 years or older. The characteristics of the participants are presented in the *Table*. Statistically 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 ($F_{4.52}$, $P=.01$), but no statistically significant differences were observed among the 4 groups in xiphoid or tenth rib excursion.

Measurements of FVC and FEV_1 indicated statistically significant differences in respiratory function between groups 1 and 3 and groups 2 and 3 (FVC: $F_{4.97}$, $P=.01$; FEV_1: $F_{6.17}$, $P=.01$). The differences across age groups in axillary excursion and FVC, using group 1 as a reference, are shown in the *Figure*. The gradual rate of decrease in thoracic excursion at the axillary level with increased age was accompanied by a marked rate of decrease in FVC.

Discussion

In the current study, the relationship among chest wall mobility, respiratory function, and age was evaluated by comparing the differences in chest wall mobility and spirometric parameters among women in 4 age groups. Statistically significant differences between groups were detected during the thoracic excursion at the axillary level and in respiratory function.

Although a sharp decline in FVC was seen with age, as indicated by the statistically significant difference between groups 2 and 3, the decline in thoracic excursion at the axillary level with age was more gradual (*Figure*). 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 anatomic and physiologic changes in the lungs and upper airways, decreased functioning of the respiratory muscles, and changes in chest wall compliance.[5,16] Accordingly, measurement of chest wall mobility should provide a straightforward assessment of chest wall compliance. We believe that the primary cause of the differences seen in axillary excursion among the age groups was the related decrease in chest wall compliance.

Several studies have demonstrated that a decrease in chest wall compliance is a structural cause of an age-related decrease in respiratory function.[5,16-18] In particular, calcification of costal cartilage and costovertebral articulations has been associated with decreased chest

Table.
Participant Characteristics by Age Group in a Study of Age-Related Decline in Chest Wall Mobility Among Community-Dwelling Elderly Women (N=132)[a]

Characteristics	Group 1 (n=38)	Group 2 (n=45)	Group 3 (n=38)	Group 4 (n=11)	P Value
Height, cm	153.0 (4.9)	152.0 (5.2)	148.8 (5)	150.5 (6.1)	<.01[b]
Weight, kg	55.4 (7.7)	53.3 (8.6)	51.2 (8.2)	48.3 (4.7)	.03[c]
Axillary excursion, cm[e]	3.4 (1.3)	3.2 (1.1)	2.8 (1.1)	2.3 (0.5)	.01[d]
Xiphoid excursion, cm[e]	5.1 (1.5)	4.9 (1.7)	4.3 (2.3)	4.1 (1.3)	.12
10th rib excursion, cm[e]	3.2 (1.4)	3.0 (1.7)	3.3 (2.8)	2.6 (1.4)	.59
FVC, L	2.23 (0.67)	2.23 (0.62)	1.81 (0.57)	1.73 (0.74)	<.01[b]
FEV_1, L	1.78 (0.52)	1.79 (0.48)	1.40 (0.48)	1.42 (0.57)	<.01[b]
%FVC	94.04 (26.97)	99.25 (27.54)	88.02 (26.36)	82.84 (32.61)	.17
$\%FEV_1$	93.84 (26.54)	101.67 (27.2)	87.82 (29.4)	90.38 (34.23)	.16
FEV_1/FVC, %	80.00 (9.07)	81.53 (9.33)	77.35 (13.21)	84.64 (10.13)	.15

[a] Data are given as mean (SD).
[b] Significant differences between groups 1 and 3 and between groups 2 and 3.
[c] Significant difference between groups 1 and 4.
[d] Significant difference between groups 1 and 4 and groups 2 and 4.
[e] Adjusted for participant height and weight using analysis of covariance; other parameters were analyzed for analysis of variance.

Abbreviations: FEV_1, forced expiratory volume in 1 second; $\%FEV_1$, FEV_1 percent predicted; FVC, forced vital capacity; %FVC, FVC percent predicted.

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. Although the pathogenesis of cartilage calcification is not fully understood, contributing factors include decreased proteoglycan synthesis[20] and diminished levels of transforming growth factor β.[21]

Although the decrease in thoracic excursion at the axillary level with age was statistically significant in the current study, no statistically significant differences in tenth rib excursion were seen. 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 is covered by 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 would be by disease-related changes. Malaguti et al[8] reported chest wall mobility at the abdominal level in patients with COPD.

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 persons. In patients with osteoporosis, 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 to 69 years have osteoporosis, and the prevalence of osteoporosis among women older than 80 years is 43.8%.[22,23] We believe that the changes in thoracic shape impede
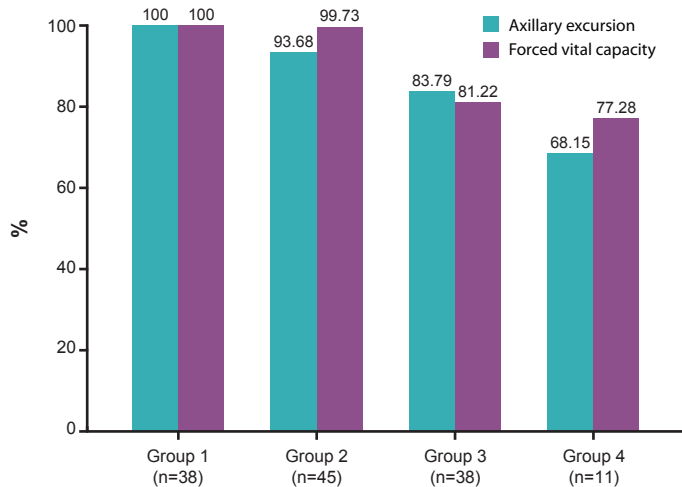
Figure.
Rate of change in the axillary excursion and forced vital capacity in each group using group 1 as the reference. Groups were determined by age, as follows: group 1, 65 to 69 years; group 2, 70 to 74 years; group 3, 75 to 79 years; and group 4, 80 years or older.

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 managed with physical therapy and osteopathic manipulative treatment. Recent studies examining the effect of chest rehabilitation in patients with COPD,[24] patients with ankylosing spondylitis,[25] and healthy patients[26] have shown a positive effect on chest wall mobility. We believe that these noninvasive interventions could become important in the prevention and management of age-related decline in chest wall mobility. Therefore, further studies are required to investigate the associations among posture, musculoskeletal alignment, and chest wall mobility in the elderly population.

Several limitations to the present study exist. First, this study was a cross-sectional observational study. Therefore, further research using a longitudinal design is needed to determine whether chest wall mobility decreases with age in a given person. It would be useful to

measure chest wall mobility in persons in the same population in the short and long term, such as at 1 year and at 5 years. Furthermore, we did not account for other factors that affect chest wall mobility, such as the prevalence of osteoporosis, vertebral alignment, and posture.

Despite these limitations, the findings of 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 different age groups. 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 4 different age groups in a population of community-dwelling elderly women and detected statistically significant age-related changes in thoracic excursion at the axillary level. Moreover, we found statistically significant age-related differences in FVC and FEV_1. These findings suggest that assessment of chest wall mobility may be a useful method for detecting age-related decreases in respiratory function among elderly patients. Further longitudinal studies are needed to clarify the effects of aging on chest wall mobility.

Acknowledgments

Author Contributions

Mr Adachi, Mr Shirooka, Ms Morino, Mr Nozaki, Ms Hirata, and Ms Yamaguchi provided substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; Mr Nishiguchi, Mr Fukutani, Mr Tashiro, and Mr Hotta drafted the article or revised it critically for important intellectual content; Ms Yamaguchi gave final approval of the version of the article to be published; and Mr Adachi agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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