Ramstrand, N., Thuesen, A. H., Nielsen, D. B., & Rusaw, D. (2010). Effects of an unstable shoe construction on balance in women aged over 50 years. *Clinical Biomechanics (Bristol, Avon), 25*, 455–460.

Shakoor, N., Lidtke, R. H., Wimmer, M. A., Mikolaitis, R. A., Foucher, K. C., Thorp, L. E., ... Block, J. A. (2013). Improvement in knee loading after use of specialized footwear for knee osteoarthritis: Results of a six-month pilot investigation. *Arthritis and Rheumatism, 65*(5), 1282–1289.

Silveira, P., van de Langenberg, R., van Het Reve, E., Daniel, F., Casati, F., de Bruin, E. D. (2013). Tablet-based strength-balance training to motivate and improve adherence to exercise in independently living older people: A phase II preclinical exploratory trial. *Journal of Medical Internet Research, 15*(8), e159. doi:10.2196/jmir.2579

Singh, S. J., Morgan, M. D., Scott, S., Walters, D., & Hardman, A. E. (1992). Development of a shuttle walking test of disability in patients with chronic airways obstruction. *Thorax, 47*, 1019–1024.

Spagnuolo, D. L., Jürgensen, S. P., Iwama, A. M., & Dourado, V. Z. (2010). Walking for the assessment of balance in healthy subjects older than 40 years. *Gerontology, 56*, 467–473.

Tencer, A. F., Koepsell, T. D., Wolf, M. E., Frankenfeld, C. L., Buchner, D. M., Kukull, W. A., ... Tautvydas, M. (2004). Biomechanical properties of shoes and risk of falls in older adults. *Journal of the American Geriatrics Society,* 52, 1840–1846.

Tojo, N., Suga, H., & Kambe, M. (2005). Lung function testing – the official guideline of the Japanese Respiratory Society. *Rinsho Byori, 53*(1), 77–81.

Win, T., Jackson, A., Groves, A. M., Sharples, L. D., Charman, S. C., & Laroche, C. M. (2006). Comparison of shuttle walk with measured peak oxygen consumption in patients with operable lung cancer. *Thorax, 61*(1), 57–60.

Title:

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

Authors:

Daiki Adachi RPT BS[1)] (adachi.daiki.53z@st.kyoto-u.ac.jp)

Minoru Yamada PhD[2)] (m-yamada@human.tsukuba.ac.jp)

Shu Nishiguchi RPT MSc[1)] (nishiguchi.shu.82s@st.kyoto-u.ac.jp)

Naoto Fukutani RPT MSc[1)] (fukutani.naoto.36x@st.kyoto-u.ac.jp)

Takayuki Hotta RPT BS[1)] (hotta.takayuki.36r@st.kyoto-u.ac.jp)

Yuto Tashiro RPT BS[1)] (tashiro.yuto.53c@st.kyoto-u.ac.jp)

Saori Morino RPT BS[1)] (morino.saori.48r@st.kyoto-u.ac.jp)

Hidehiko Shirooka RPT BS[1)] (shirooka.hidehiko.88s@st.kyoto-u.ac.jp)

Yuma Nozaki RPT BS[1)] (nozaki.yuma.44x@st.kyoto-u.ac.jp)

Hinako Hirata RPT BS[1)] (hirata.hinako.25s@st.kyoto-u.ac.jp)

Moe Yamaguchi RPT BS[1)] (yamaguchi.moe.75a@st.kyoto-u.ac.jp)

Tomoki Aoyama MD PhD[1)] (aoyama.tomoki.4e@kyoto-u.ac.jp)

Affiliation:

[1)]Department of Physical Therapy, Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan.

[2)]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tokyo, Japan.

Authors who aided in data collection or analysis and interpretation of data: D.A, H.S, Y.N, M.Y, H.H.

Authors who drafted the article or revised it critically for important intellectual content: S.N, N.F, Y.T, S.M, T.H.

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.

Reference

1. Vestbo J, Hurd SS, Agustí AG, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. *Am J Respir Crit Care Med.* 2013;187(4):347-365.

2. Lopez AD, Shibuya K, Rao C, et al. Chronic obstructive pulmonary disease: current burden and future projections. *Eur Respir J.* 2006;27(2):397-412.

3. van den Boom G, van Schayck CP, van Mollen MP, et al. Active detection of chronic obstructive pulmonary disease and asthma in the general population. Results and economic consequences of the DIMCA program. *Am J Respir Crit Care Med.* 1998;158(6):1730-1738.

4. Lalley PM. The aging respiratory system--pulmonary structure, function and neural control. *Respir Physiol Neurobiol.* 2013;187(3):199-210.

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

the aging process on respiratory function. *Gerontology*. 2009;55(5):505-510.

6. Meyer KC. Aging. *Proc Am Thorac Soc*. 2005;2(5):433-439.

7. Kakizaki F, Shibuya M, Yamazaki T, Yamada M, Suzuki H, Homma I. Preliminary report on the effects of respiratory muscle stretch gymnastics on chest wall mobility in patients with chronic obstructive pulmonary disease. *Respir Care*. 1999;44(4):409-414.

8. Lanza Fde C, de Camargo AA, Archija LR, Selman JP, Malaguti C, Dal Corso S. Chest wall mobility is related to respiratory muscle strength and lung volumes in healthy subjects. *Respir Care*. 2013;58(12):2107-2112.

9. Kaneko H, Horie J. Breathing movements of the chest and abdominal wall in healthy subjects. *Respir Care*. 2012;57(9):1442-1451.

10. Ozgocmen S, Cimen OB, Ardicoglu O. Relationship between chest expansion and respiratory muscle strength in patients with primary fibromyalgia. *Clin Rheumatol*. 2002;21(1):19-22.

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