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Original Paper

Relationships between Respiratory Function, Bone Density, and Abdominal Muscle Thickness in Community-dwelling Elderly Women

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Key words: the elderly, peak expiratory flow rate, ultrasound, bone density, abdominal muscle thickness

Abstract

Respiratory function declines with aging, and respiratory muscle dysfunction may indicate respiratory sarcopenia. Expiratory flow expels foreign substances from the trachea, minimizing the risk of aspiration pneumonia. On the other hand, low bone mineral density of the femoral neck could be a risk factor for mortality in elderly women. However, the underlying mechanism of the mortality associated with low bone mineral density remains unclear. The aim of this study was to examine the relationships between respiratory function, bone density, and abdominal muscle thickness in elderly women. Forty-two community-dwelling elderly women participated in this study. Respiratory function, calcaneus bone density, and abdominal muscle thickness were measured using a spirometer, ultrasound bone densitometer, and B-mode ultrasound, respectively. The relationship between respiratory function and the other obtained values were investigated using Spearman's correlation coefficient. The peak expiratory flow rate showed a significant positive correlation with calcaneus density and external oblique muscle thickness. Calcaneus bone loss and abdominal external oblique muscle atrophy, in accordance with low peak expiratory flow rate, were observed in community-dwelling elderly women. In the elderly women who have decreased bone density, there may be little spare ability to expectorate an aspiratory substance by fast expiration.

1. Introduction

The fifth leading cause of mortality in Japan is pneumonia[1)]. Respiratory function declines with age[2)], and respiratory muscle dysfunction may indicate respiratory sarcopenia in community-dwelling elderly people[3)]. Sarcopenia is characterized by the age-related decline of skeletal muscle plus low muscle strength and/or physical performance. Previous studies have shown that physical activities, such as aerobics, endurance

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exercise, and resistance training, could delay muscle mass loss[4-6]. Expiratory flow expels foreign substances from the trachea, minimizing the risk of aspiration pneumonia[7]. Thus, it is important to consider the forced expiratory muscles of elderly individuals to prevent the incidence of aspiration pneumonia.

On the other hand, research has shown that low bone mineral density of the femoral neck could be a risk factor for mortality in elderly women[8,9]. Low bone mineral density of the lumbar spine and femur and prevalent vertebral fractures pose a risk for future immobilization (prolonged bedrest at home, lying in bed or using a wheelchair for locomotion at nursing homes) in postmenopausal women[10]. However, the underlying mechanism of the mortality associated with low bone mineral density remains unclear[8,9]. Therefore, it is important to evaluate the physical characteristics of elderly women with bone density loss.

Previous studies have shown significant positive correlations between respiratory functions (forced expiratory volume in 1 second [$FEV_{1.0}$], peak expiratory flow rate [PEFR]) and bone mineral density in women (aged > 45years)[11-13]. The decline in muscle size with increased age results from decreased physical activity and correlations between PEFR and individual muscle thickness were different among abdominal muscles[14-16]. Thus, to determine the decline in expiratory flow production, individual muscle size evaluation of the abdominal muscles as primal forced expiratory muscles should be performed. Therefore, the aim of this study was to examine the relationships between respiratory function, bone density, and abdominal muscle thickness in elderly women.

2. Methods

2.1 Design and participants

This study used a cross-sectional design. Forty-two community-dwelling elderly women able to perform activities of daily living involving walking independently with or without walking aids participated in this study. Participants were recruited from the Outpatient Rehabilitation Center of the Shukumo Clinic in Okayama, Japan. Exclusion criteria included the following: inability to follow instructions related to cognitive dysfunction; history of orthopedic surgery in the lumbar spine; or neuromuscular disease. The Ethics Committee of the Kawasaki University of Medical Welfare approved the protocol (#19-025). Written informed consent was obtained from each subject prior to participation.

2.2 Respiratory function

Respiration function was assessed by forced vital capacity, which was measured twice using a spirometer (HI-801, Chest Co. Ltd., Tokyo, Japan). Values used in the analysis were $FEV_{1.0}$ (L) and PEFR (L/sec). The maximum value was used in the analysis. Airway obstruction was deemed to be present when the $FEV_{1.0}$% ($FEV_{1.0}$ / forced vital capacity × 100) was less than 70 %.

2.3 Bone mass

Although Dual-X-ray absorptiometry is the gold standard for bone mineral density assessment, a quantitative ultrasound of calcaneus, which is free of radiation emissions and suitable for portable field work, has been developed. A previous study demonstrated that Dual-X-ray absorptiometry and quantitative ultrasound evaluations were strongly related[17]; therefore, quantitative ultrasound of calcaneus was used to measure bone density in this study. The speed of sound of the right calcaneus (m/sec) was measured once using an ultrasound bone densitometer (CM-300, Furuno Electric Co. Ltd., Hyogo, Japan) (Figure 1). Standardization and calibration were performed before the first measurement of each survey day.

2.4 Muscle thickness

B-mode (Noblus, Hitachi Ltd., Tokyo, Japan) with a 18-5 MHz linear probe (L64) was used to perform ultrasound imaging of the right rectus abdominis, external oblique, internal oblique, and transverse abdominis muscles (Figure 2). The subjects were in the supine position to perform ultrasound imaging of the abdominal muscles at rest. The rectus abdominis muscle was measured 3 cm lateral to the umbilicus

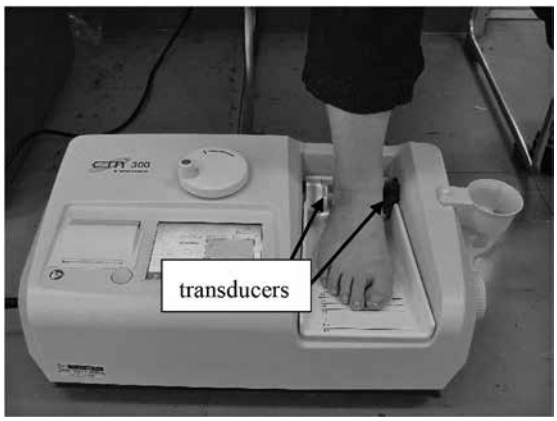

Figure 1 Measurement of speed of sound through the calcaneus

While sitting, the subject placed her right foot on the foot plate, which could be adjusted to any foot size. The calcaneus was held with a transducer on both the inside and outside of the foot. Ultrasound waves were conveyed from one transducer through the calcaneus and the other transducer, requiring only about 10 seconds to measure the speed of the sound.

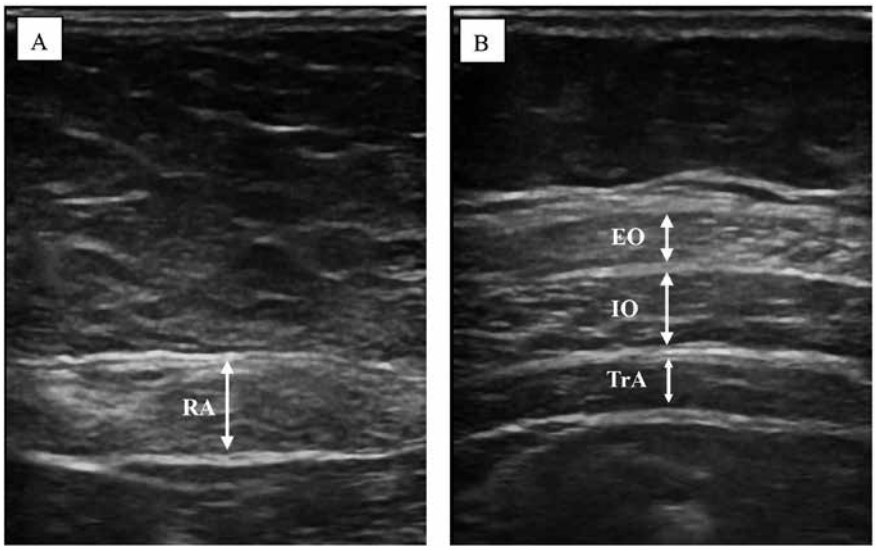

Figure 2 Abdominal muscle ultrasound images

A: The right rectus abdominis (RA) muscle; B: The right external oblique (EO), internal oblique (IO), and transverse abdominis (TrA) muscles

on the right side of the body[14]. The external oblique, internal oblique, and transverse abdominis muscles were measured 2.5 cm anterior to the midaxillary line and at the midpoint between the inferior rib and iliac crest[14]. The probe was held using the minimum pressure required to achieve a clear image. Measurement of abdominal muscle thicknesses was performed at the end of a relaxed expiration. The abdominal muscle images were collected twice. The average values of the two trials were used in the analysis (mm).

2.5 Statistical analysis

SPSS Statistics 23.0 (IBM Japan Inc., Tokyo, Japan) was used for statistical analysis. The relationship between respiratory function and the other obtained values were investigated using Spearman's correlation coefficient. The significance level was selected as $p<0.05$.

3. Results

The obtained values are listed in Table 1. All of the subjects' $FEV_{1.0}$% was within the normal range. Correlation coefficients between respiratory function and the other obtained values are listed in Table 2. Significant positive correlations were observed in the calcaneus speed of sound and muscle thickness of the external oblique muscle with the PEFR.

Table 1 Median (first-third quartile) of obtained values

Age (years)	85 (81-88)
Height (cm)	149.3 (144.9-152.5)
Weight (kg)	50.5 (46.0-55.0)
BMI (kg/m^2)	23.1 (20.9-24.9)
$FEV_{1.0}$ (L)	1.6 (1.3-1.8)
$FEV_{1.0}$% (%)	84.7 (79.7-91.7)
PEFR (L/sec)	4.0 (3.4-4.8)
Speed of sound (m/sec)	1470 (1460-1487)
Rectus abdominis (mm)	6.9 (5.2-8.2)
External oblique (mm)	4.9 (3.5-6.5)
Internal oblique (mm)	6.7 (4.7-8.5)
Transversus abdominis (mm)	2.2 (1.7-2.9)

BMI: body mass index; $FEV_{1.0}$: forced expiratory volume in 1 second; $FEV_{1.0}$%: $FEV_{1.0}$ / forced vital capacity × 100; PEFR: peak expiratory flow rate

Table 2 Correlation coefficients between respiratory function and the other obtained values

	$FEV_{1.0}$	PEFR
Age	-0.15	-0.11
Height	-0.17	0.23
Weight	0.03	0.21
BMI	0.21	<0.01
Speed of sound	0.01	0.36*
Rectus abdominis	-0.14	0.02
External oblique	-0.14	0.34*
Internal oblique	-0.03	0.24
Transversus abdominis	-0.30	0.01

BMI: body mass index; $FEV_{1.0}$: forced expiratory volume in 1 second; PEFR: peak expiratory flow rate; *: $p<0.05$

4. Discussion

In this study, the relationships between respiratory function, bone density, and abdominal muscle thickness were examined in community-dwelling elderly women. Calcaneus bone loss and external oblique muscle atrophy among the abdominal muscles, in accordance with low PEFR, were observed. Our results indicated that, in the elderly women who have decreased bone density, there may be little spare ability to expectorate an aspiratory substance by fast expiration. However, $FEV_{1.0}$ did not show a significant correlation with calcaneus bone density and abdominal muscle thickness. The $FEV_{1.0}$ was measured at 1 second at the beginning of the forced vital capacity. On the other hand, the PEFR was recorded at the moment when expiratory flow rate was the fastest during the forced vital capacity. Therefore, calcaneus bone density and external oblique muscle thickness might be associated with instantaneous and quick movement. A previous study revealed thoracic kyphosis significantly affects $FEV_{1.0}$[18]. Another study detected a significantly negative correlation between thoracic kyphosis and the femoral neck and lumbar spine bone mineral density[19]. Further study is necessary to show the relationships among $FEV_{1.0}$, calcaneus bone density, and thoracic kyphosis.

A previous study reported that muscle atrophy, in accordance with low appendicular skeletal muscle mass, was marked in the external oblique muscle among the abdominal muscles in community-dwelling elderly women[20]. Additionally, literature showed an association between appendicular skeletal muscle mass and PEFR in community-dwelling elderly people[3]. Exercise may promote healthy aging of bone and skeletal muscle[21,22]. A decrease in the frequency to perform physical activities, including movement of trunk rotation, might be associated with low PEFR, bone loss, and external oblique muscle atrophy[14,20]. However, the exact mechanism of the associations between respiratory function and bone density and abdominal muscle thickness is unclear. Previous reports have determined an association between bone density and muscle mass[23,24]; furthermore, genetic, developmental, endocrine, and lifestyle factors, such as physical activity, smoking, and poor diet have dual effects on both bone density mass and muscle in later life[25]. Several parameters should be measured to detect these associations.

This study has some limitations. First, the sample size was small. Second, only female participants were recruited; thus, the influence of gender was not detected. Third, participants' history of osteoporotic drug therapy could not be collected. Finally, a cross-sectional design might not detect cause-effect inferences. A longitudinal study would be needed to determine whether low respiratory function relates to bone density and abdominal muscle size in elderly individuals.

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