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Jacobs Journal of Physiotherapy and Exercise

Research Article

Correlation between Peak Expiratory Flow and Abdominal Muscle Thickness in Elderly Subjects

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Received: 12-10-2015

Accepted: 12-18-2015

Published: 01-13-2016

Abstract

Introduction

High expiratory flow plays an important role in expelling foreign substances and excessive mucus from the lungs and airways in order to minimize the risk of infection. Activity of the abdominal muscles is important for the generation of high expiratory flow. This muscle group includes the rectus abdominis (RA), external oblique (EO), internal oblique (IO), and transverse abdominis (TrA). However, little is known about the contribution of each abdominal muscle to forced expiration.

Objective

The aim of the present study was to determine whether abdominal muscle thickness at rest is correlated with peak expiratory flow (PEF) in elderly subjects.

Methods

The present study examined whether PEF was associated with the thickness of specific abdominal muscles in 24 elderly women who could walk independently. Muscle thickness was measured at rest in the supine position. The thicknesses of the right RA, EO, IO, and TrA were measured using B-mode ultrasound at the end of a relaxed expiration in the supine position. PEF was obtained using a peak flow meter in the sitting position. The correlation between normalized PEF and normalized abdominal muscle thickness was determined using Pearson's correlation coefficient.

Results

Correlation coefficients when comparing PEF and the RA, EO, IO, and TrA were 0.434 (P = 0.034), 0.323 (P = 0.124), 0.539 (P = 0.007), and 0.470 (P = 0.021), respectively.

Conclusion

Our results indicate that the muscle thickness of the IO correlates most with fast forced expiration production in the elderly subjects, TrA and RA have intermediate correlations, while EO is the least correlated. Thus, the action of the IO and TrA in

increasing IAP, as well as the action of the RA on the rib cage, might be more highly associated with PEF than the action of the EO on the rib cage in elderly subjects.

Keywords: Ultrasound Imaging; Rectus Abdominis; External Oblique; Internal Oblique; Transverse Abdominis; Muscle Thickness; Expiration

Abbreviations

EO: External Oblique;
IAP: Intra-Abdominal Pressure;
IO: Internal Oblique;
PEF: Peak Expiratory Flow;
RA: Rectus Abdominis;
TrA: Transverse Abdominis

Introduction

High expiratory flow plays an important role in expelling foreign substances and excessive mucus from the lungs and airways in order to minimize the risk of infection [1]. The abdominals play an important role in forced expiration. A number of studies have shown that abdominal muscle volume decreases with aging [2-6]. Therefore, data regarding the specific abdominal muscles that produce high expiratory flow in elderly subjects would be useful to physical therapists.

The abdominal muscles include the rectus abdominis (RA), external oblique (EO), internal oblique (IO), and transversus abdominis (TrA), and each abdominal muscle contributes in the production of high expiratory flow. The action of the RA produces a caudal displacement of the sternum and a decrease in the anteroposterior diameter of the rib cage [7]. The EO causes a caudal displacement and a decrease in the transverse diameter of the rib cage [7]. The activities of the TrA and IO are related to changes in intra-abdominal pressure (IAP) [8-10]. However, little is known about the contribution of each abdominal muscle to forced expiration. Expiratory muscle strength training programs use a pressure threshold device and respiratory maneuvers [11]. If there is differing involvement of individual abdominal muscles with forced expiration, non-respiratory exercises could be tailored to strengthen the muscle that associates most strongly with forced expiration. Although it is not possible to make a direct force measurement of individual abdominal muscles, muscle size during a relaxed state may provide an indirect measure of force-generating capacity [12,13]. A recent study found that the thickness of the EO had the highest correlation with PEF amongst the abdominal muscles in healthy young subjects [14]. To our knowledge, there are no studies investigating the association between abdominal muscle thickness and PEF in elderly subjects. Therefore, the present study examined an elderly population to determine whether abdominal muscle thickness at rest is correlated with PEF.

Methods

Subjects

Thirty elderly women, who were able to walk independently, volunteered to participate in the present study. Subjects were recruited from the Outpatient Rehabilitation of the Shukumo Clinic in Okayama, Japan. Subjects were excluded if they presented with a history of chronic or acute cardiac, pulmonary, or neuromuscular disease; had a history of smoking; or had no acute upper respiratory infection. The protocol for the present study was approved by the Ethics Committee of the Kawasaki University of Medical Welfare. In addition, approval for the present study was obtained from the director of the Shukumo Clinic. Written informed consent was obtained and the rights of the subjects were protected.

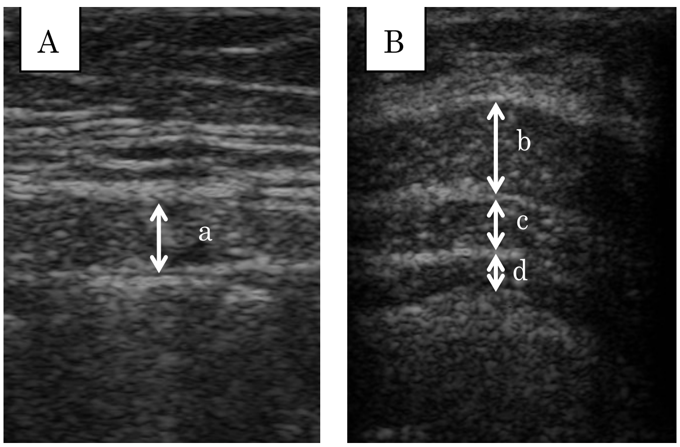
PEF measurements

One investigator was responsible for collecting patient PEF values. PEF was measured using a peak flow meter (Assess, Full range; Philips Respironics G.K. Tokyo, Japan). Subjects were seated and wore nose clips while testing for PEF. PEF was measured relative to the total lung capacity. When measuring PEF, the investigator instructed subjects to inspire fully to total lung capacity, then to exhale through a mouthpiece as forcefully as possible. Subjects were allowed to practice until they could perform the task consistently, and measurements were repeated three times. The maximum value of the three repetitions was used for analysis (L/min). Predicted values of PEF in healthy Japanese subjects were calculated as (– 191.3 + 6.15 × age – 0.08472 × age {years}^{2} + 0.0000981 × age {years}^{3} + 3.32 × height {cm}) (L/min) [15]. This formula has a normal range of ± 71 L/s. To examine only the subjects who had normal PEF, 6 subjects who obtained PEF outside of the predicted range of PEF ± 71 L/s were excluded. The absolute PEF was normalized to the predicted PEF (absolute PEF/predicted PEF × 100) and used for the statistical analysis (%).

Ultrasound measurements

A second investigator was responsible for collecting ultrasound images. B-mode ultrasound (JA6; Medicare co. Ltd. Kanagawa, Japan) with a 12-MHz transducer was used to obtain thickness of the right RA, EO, IO, and TrA. To perform ultrasound imaging of the abdominal muscles at rest, the subject was placed in the supine position. The RA was measured 4 cm lateral to the umbilicus on the right side of the body (Figure 1A) [6]. The EO, IO, and TrA were measured 2.5 cm anterior to the midaxillary line and at the midpoint between the inferior rib and iliac crest (Figure 1B) [16]. Previous work indicates that inward pressure caused by the transducer during ultrasound imaging decreases the thickness of the abdominal muscles [17]. A large quantity of gel was interposed between the transducer and the skin, and the transducer was tilted upward and downward to place the transducer in a plane in which the ultrasound wave was approximately perpendicular to the muscle fascia of the abdominal muscles using the minimum pressure required to achieve a clear image. The thickness of the abdominal muscles increases during expiration [18], thus measurement of abdominal muscle thickness was performed at the end of a relaxed expiration. Two repeated images were obtained for each abdominal muscle. The average value of from the two images was normalized relative to weight (muscle thickness/weight) and used for statistical analysis (mm/kg).

Figure 1. Example ultrasound images of the abdominal muscles. A: ultrasound image of the rectus abdominis (a). B: ultrasound image of the external oblique (b), internal oblique (c), and transversus abdominis (d).



Statistical analyses

SPSS Statistics 22.0 was used for statistical analysis. The correlation between normalized abdominal muscle thickness and normalized PEF was determined using Pearson's correlation coefficient. Values were considered statistically significant at $P < 0.05$. We also used G-Power software (Franz Faul, Univesitat Kiel, Germany) to calculate the statistical power of the sample.

Results

The mean 24 subject age, height, and weight were 82.6 ± 6.2 years, 149.0 ± 7.2 cm, and 49.2 ± 8.6 kg, respectively.

The absolute and predicted PEF were 275.5 ± 46.2 and 286.1 ± 48.8 L/min, respectively. Normalized PEF was 97.1 ± 18.6 %. The thicknesses of individual abdominal muscles, and the results of correlation analysis, are listed in Table 1.

Table 1. Normalized abdominal muscle thicknesses and their correlations with normalized peak expiratory flow.

Muscles	Muscle thickness (mm) [a]	Normalized muscle thickness (mm/kg) [a]	Correlation coefficient	Power
Rectus abdominis	7.3 ± 1.4	0.15 ± 0.03	0.434*	0.584
External oblique	4.5 ± 1.2	0.09 ± 0.03	0.323	0.344
Internal oblique	7.2 ± 1.7	0.15 ± 0.05	0.539**	0.806
Transversus abdominis	2.9 ± 0.9	0.06 ± 0.02	0.470*	0.665

n = 24. [a:] Values are expressed as mean ± standard deviation.
* $P < 0.05$
** $P < 0.01$

Discussion

To our knowledge, this is the first study to show relationships between abdominal muscle thickness at rest and PEF in elderly subjects. As both vital capacity and forced expiratory volume in one second were not measured, there may be concerns as to whether the subjects had normal pulmonary function. However, as their PEF was within the expected range for healthy Japanese subjects (predicted PEF ± 71 L/s) [15], we can speculate the subjects have normal pulmonary function.

In the present study, the muscle thickness of the IO correlates most with fast forced expiration production. The TrA and RA have an intermediate correlation, while the EO has the least. The action of the IO and TrA in increasing IAP, as well as the action of the RA on the rib cage, might be associated with PEF. A previous study found that EO muscle thickness was more highly associated with PEF than the RA, IO, and TrA thicknesses in young subjects [14]. The difference in our results compared to the previous study may result from structural alterations in the chest wall with age. Previous studies have shown that aging decreases chest wall compliance [19,20]. The stiffening of the chest wall is most probably related to calcification and other structural changes within the rib cage and its joints (e.g., calcification of costal cartilage and costovertebral joints, and the narrowing of intervertebral disk spaces) [21]. Rizatto and Marazzini [20] reported the relative contribution of the chest wall and abdomen-diaphragm to the changes in lung volume identified between elderly and young subjects. The authors identified that the contribution of the abdomen-diaphragm in elderly subjects is greater, relatively, than in younger subjects. Thus, for the production of fast forced expiration production in the elderly, it might be more efficient to use the action of the IO and TrA and their subsequent increase in IAP, rather than utilize their action on the chest wall. As the stiffening of the chest wall was not measured in this study, the association between chest wall compliance and the relative contribution of the chest wall and abdomen-diaphragm to the changes in subject lung volume is unclear. Changes in the shape of the rib cage also occur as a result of age-related osteoporosis, resulting in vertebral fractures, and leading to increased dorsal kyphosis and anteroposterior diameter in elderly individuals [21]. Though the anteroposterior diameter of the rib cage increases with age [22], it is unclear whether this structural alteration effects the action of the RA when decreasing the anteroposterior diameter of the rib cage. Previous studies reported that during fast forced expiration, rib-cage deformation consisted of a rounding of the lower rib cage with the transverse diameter decreasing more rapidly than the lower anteroposterior diameter in normal adult subjects [23,24]. Because PEF occurs during the early phase of fast forced expiration, these previous results suggest the action of the EO may decrease the transverse diameter of the rib cage during fast forced expiration in young individuals. However, little is known about the chest wall shape during fast forced expiration in elderly individuals. Further studies are required to consider the relative contribution to PEF of the rib-cage deformation of the transverse and anteroposterior diameters in elderly subjects.

A previous study reported that the RA, EO, IO muscles were significantly thinner in a walking independent elderly group than in a younger group [5,6]. Factors implicated in the etiology of the gradual decline in muscle mass and quality with increaed age include decreased physical activity, malnutrition, increased cytokine activity, oxidative stress, and abnormalities in growth hormone and sex steroid axes [25]. The primary intervention for this decline – progressive resistance training – has been shown to slow down or reverse these changes [25]. The present study also indicated that training for both the RA and IO might be effective in preventing the decrease of PEF seen with aging. Previous research demonstrated that sit-ups provide a good challenge for the RA, but not for the IO [26]. Asymmetrical exercises, such as the isometric side bridge, strengthen oblique activity with little effect on the RA [26]. Yoon et al. [27] reported that the activities of the TrA and IO are significantly greater during an abdominal curl-up with slow expiration than an identical move but with quiet inspiration. Ishida and Watanabe [28] showed that activities of the abdominal muscles (RA, EO, and IO) increased when maximum expiration was held in the side bridge exercise when compared with resting expiration. These results indicate that training with non-respiratory maneuvers such as the curl-up and side bridge exercises (with expiration) might effectively strengthen the RA and IO, thus increasing PEF in elderly subjects.

The present study has some limitations. Firstly, the sample size is small. Secondly, all subjects were female. Further studies, using a larger and broader sample, are needed to determine whether abdominal muscle thickness and PEF are correlated in male subjects. Finally, a cross-sectional design might not allow for cause-effect inferences. A longitudinal study would be needed to define whether the production of fast forced expiration is associated with abdominal muscle thickness in elderly individuals.

Conclusions

Our results indicate that the muscle thickness of the IO correlates the most with fast forced expiration production. The TrA and RA have intermediate correlations, while the EO is the least correlated. Thus, the action of the IO and TrA in increasing IAP, as well as the action of the RA on the rib cage, might be more highly associated with PEF than the action of the EO on the rib cage in elderly subjects.

Funding

This work was supported by JSPS KAKENHI Grant Number 15K16383.

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