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Relationship between Expiratory Activity of the Lateral Abdominal Muscle and Exercise Tolerance in Chronic Obstructive Pulmonary Disease

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Abstract. [Purpose] The purpose of this study was to investigate the relationship between the expiratory activity of the lateral abdominal muscle during quiet breathing and exercise tolerance in COPD patients. [Subjects] The participants were 15 moderate and severe male COPD patients (FEV_1 = 42.5 ± 15.9% predicted) and 15 sex- and age-matched healthy subjects. [Methods] The expiratory activity of the lateral abdominal muscle and exercise tolerance were measured. The expiratory activity was estimated from the thickness difference (Tdif) of the lateral abdominal muscle during quiet breathing using ultrasonography. Exercise tolerance was assessed by the incremental shuttle walking test (ISWT). Pearson's correlation coefficient was used to study the correlation between Tdif and the distance walked in ISWT, and FEV_1. [Results] Tdif was higher in COPD patients than in healthy subjects, and a moderate significant negative correlation was found between Tdif and the distance walked. However, there was no significant correlation between Tdif and FEV_1. [Conclusion] The results indicate that exercise intolerance may be more important factors than airflow limitation in expiratory muscle activity during quiet breathing in advanced COPD patients.
Key words: Expiratory activity, Chronic obstructive pulmonary disease, Exercise tolerance

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INTRODUCTION

In advanced COPD, activity of the transversus abdominis muscle is observed during the phase of expiration[1)], in addition to increased activity of thoracic inspiratory muscles, including the parasternal intercostal muscles and scalenus muscles[2–4)]. This is considered to be due to increased airway resistance, reduced dynamic compliance, and dynamic pulmonary hyperinflation due to COPD. It is also regarded as compensatory activity for the diaphragm which is shortened by pulmonary hyperinflation and becomes fatigable. However, the activity of expiratory muscles promotes dynamic pulmonary hyperinflation by causing intrinsic positive end-expiratory pressure ventilation. Considering that dynamic pulmonary hyperinflation is an important contributing factor to exercise intolerance, excessive activity of expiratory muscles in COPD is undesirable.

There have been few studies of expiratory muscle activity in COPD patients, and no study has examined the relationship between respiratory muscle activity and exercise tolerance. Ninane et al.[1] associated expiratory activity of the transversus abdominis muscle in COPD patients with the severity of airflow obstruction. However, it is also reported that there are COPD patients who do not present expiratory muscle activity despite the presence of severe airflow obstruction[5]. Currently, other factors that determine whether or not a COPD patient recruits expiratory muscles at rest are pointed out[6].

One of the reasons why the literature is limited would be because historically the evaluation of expiratory muscle activity required invasive methods using wire electrodes and balloon catheters. Recently, however, non-invasive evaluation of the transversus abdominis muscle by ultrasonography has been reported[7, 8]. This method has mainly been used for the evaluation of the motor function of abdominal muscles in patients with low back pain, but its utility in the evaluation of expiratory activity has also been verified[9]. Therefore, this study aimed to evaluate expiratory activity of the lateral abdominal muscles non-invasively using ultrasonography, to clarify whether expiratory activity of the lateral abdominal muscles of patients with moderate to severe COPD during quiet breathing is related to exercise tolerance.

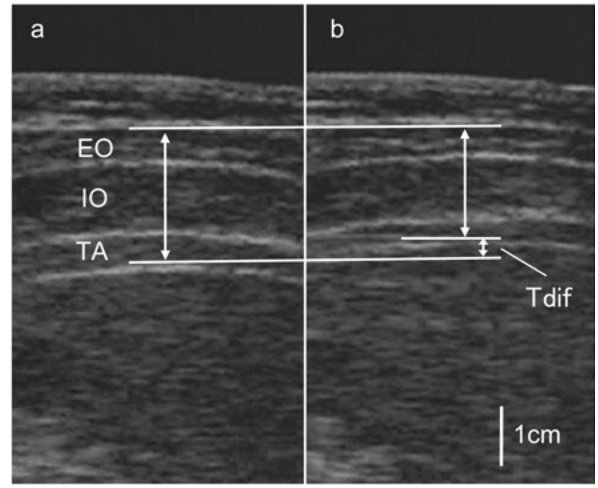

Fig. 1. Ultrasonographic image of the lateral abdominal muscles at the end of expiration (a) and the end of inspiration (b) in a representative subject. EO, external oblique; IO, internal oblique; TA, transversus abdominis; Tdif, thickness difference of the lateral abdominal muscle during quiet breathing calculated as the thickness at the end of expiration minus the thickness at the end of inspiration and was expressed as a percentage of thickness at the end of inspiration.

METHODS

We studied 30 male subjects, of whom 15 had COPD and 15 were age-matched healthy subjects. The study was approved by the ethical committee of the International University of Health and Welfare, and informed consent was obtained from the subjects following an explanation of the content of the study. The inclusion criteria for COPD in this study were as follows: $FEV_1 < 80\%$ predicted; FEV_1/FVC ratio of < 70% and stable disease for at least one month. Exclusion criteria were as follows: cardiovascular disease; dysfunctions of lower extremities; and low back pain that interfered with participation in the study. Healthy subjects were recruited by advertisement. Inclusion criteria were $FEV_1 > 80\%$ and FEV_1/FVC ratio of > 70% of the predicted value. The exclusion criteria were the same as those for the COPD patients.

Spirometry measurements were performed to determine FEV_1, FEV_1/FVC, and VC with a spirometer AS-302 (Minato Medical Science Co. Ltd, Tokyo, Japan) according to American Thoracic Society standards[10].

A B mode ultrasonograph SM-206 with a 3.5-MHz linear probe (Seikousha Co. Ltd, Tokyo, Japan) was used to measure the thickness difference (Tdif) of the lateral abdominal muscle during quiet breathing. Tdif was calculated as thickness at the end of expiration minus thickness at the end of inspiration and was expressed as a percentage of the thickness at the end of inspiration (Fig. 1).

Subjects sat in an upright sitting position on a chair with a nearly-vertical backrest. The back of the subject was kept on the backrest during the measurement. The probe was placed at the midpoint between the costal border and iliac crest on the right anterior axillary line. Then, ultrasonographic images of the external oblique muscle, internal oblique muscle, and transversus abdominis muscle were obtained[12]. The ultrasonographic image was recorded for 30 seconds when breathing was stable. Static images at the end of inspiration and the end of expiration fog 3 breaths were extracted from the ultrasonographic images recorded on a digital video. The images at the end of inspiration and the end of expiration were respectively defined as the minimum and maximum values of the lateral abdominal muscle. Scion Image (http://www.scioncorp.com/) was used for image analysis to measure the distance between the outer surface of the external oblique and the inner surface of the transversus abdominis muscles which was defined as the thickness of the lateral abdominal muscles. Muscle thickness was measured in millimeters, and the mean of the 3 breaths was used as the representative value. Measurement was performed by the same investigator.

The ISWT was performed as described by Singh et al.[11]. Subjects unfamiliar with the ISWT completed two tests, which were separated by more than 30 min of rest. Following the ISWT, the reason for termination and the distance walked was recorded.

Results are given as means ± SD. Comparison between COPD patients and healthy subjects was done using the unpaired Student's t test. To determine a normal range for Tdif, the 95% confidence upper bound of Tdif in healthy subjects was calculated. Correlations between Tdif and the distance walked, and FEV_1 were calculated using Pearson's correlation coefficient. Values of $p < 0.05$ were accepted as significant.

Table 1. Characteristics of subjects

	healthy (n=15)	COPD (n=15)
Age (yr)	71.9 ± 5.2	71.9 ± 7.3
Height (m)	1.61 ± 0.06	1.64 ± 0.05
Weight (kg)	54.8 ± 8.0	53.1 ± 11.2
BMI (kg/m^2)	21.2 ± 2.6	19.7 ± 3.2
FEV_1 (L)	2.38 ± 0.37	1.12 ± 0.44*
FEV_1 (% predicted)	93.1 ± 13.4	42.5 ± 15.9*
FEV_1/FVC (%)	77.4 ± 4.9	45.7 ± 12.9*
VC (% predicted)	100.7 ± 15.1	81.5 ± 18.8*

Values are expressed as mean ± SD. *: p<0.05.

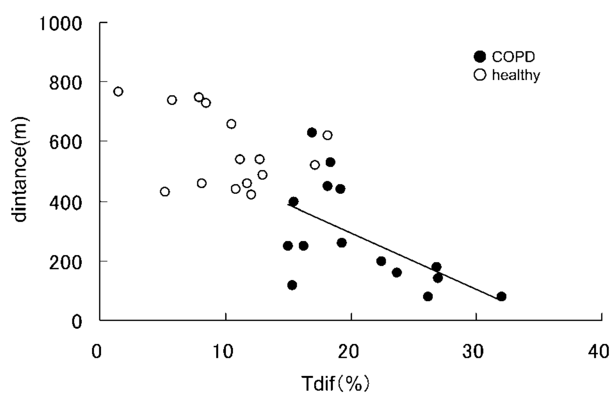

Fig. 2. Correlation between Tdif and the distance walked. In the COPD patients, the distance walked in ISWT was significantly negatively correlated with Tdif, but it was not significantly correlated in healthy subjects.

RESULTS

Pulmonary function and anthropometric data in the COPD patients and healthy subjects are listed in Table 1. The age, height, weight, and BMI were similar in the two groups. FEV_1, FEV_1/FVC, and VC were statistically lower in the COPD patients than in the healthy subjects.

Tdif was 20.7 ± 5.4%, and 10.2 ± 4.4% in the COPD patients and healthy subjects, respectively, and was significantly different between the two groups. In healthy subjects, the 95% confidence upper bound of Tdif was 12.7%, and Tdif of all COPD patients were higher than it.

The distance walked was 278 ± 172 m and 571 ± 129 m in the COPD patients and healthy subjects, respectively, and was significantly lower in the COPD patients than in the healthy subjects.

Figure 2 shows the correlations between Tdif and the distance walked in the COPD patients and healthy subjects. In the COPD patients, there was a significant negative correlation between Tdif and the distance walked ($r = -0.58$, $p < 0.05$), but for the healthy subjects there was no significant relationship. Tdif and FEV_1 were correlated in neither the COPD patients nor the healthy subjects.

DISCUSSION

The expiratory activity of the lateral abdominal muscles of patients with moderate to severe COPD during quiet breathing was evaluated by ultrasonography, and its relationships with exercise tolerance and pulmonary function were examined. The results show Tdif of the COPD patients was higher than that of healthy subjects, and a significant negative correlation was observed between Tdif and the distance walked in the COPD patients, although a significant correlation was not observed between Tdif and FEV_1. These results suggest the possibility that expiratory muscle activity of COPD patients may be associated with exercise tolerance.

In this study, we used ultrasonography for the evaluation of expiration activity of the lateral abdominal muscles. Preceding studies have reported the reliability of lateral abdominal muscle thickness measurements by ultrasonography[12, 13] and its utility in the evaluation of expiratory activity[9]. Tdif of the lateral abdominal muscles, which was used as an index of expiratory activity, is also detectable in healthy subjects. This is due to passive extension of the lateral abdominal muscles by downward movement of the diaphragm during inspiration. Thus, evaluation of expiratory activity of COPD patients requires comparison with healthy subjects. In this study, in a comparison of COPD patients and healthy subjects, Tdif of all the COPD patients were higher than the upper bound of the 95% confidence interval of healthy subjects. Therefore, it can be said that expiratory activity was enhanced in all the COPD patients. However, since Tdif is not a value directly measured, such as an electromyogram, it is difficult to determine whether Tdif values of COPD patients which are closer to those of healthy subjects reflect definite expiratory activity.

A significant negative correlation was observed between Tdif and the distance walked in the COPD patients. This result supports the hypothesis of this study that expiratory activity of the lateral abdominal muscles promotes dynamic pulmonary hyperinflation, resulting in exercise intolerance. Contrarily, it can also be considered that exercise intolerance may further aggravate dyspnea, and increases expiratory activity. Seeking a causal relationship between expiratory activity and exercise tolerance was beyond the scope of this study. In any case, expiratory activity of the lateral abdominal muscles of COPD patients during quiet breathing would not be desirable. Besides, no significant correlation was observed between Tdif and FEV_1. This agrees with results of Yan et al.[6], and shows that the expiratory activity of the lateral abdominal muscles of COPD patients does not simply reflect airway obstruction.

In COPD patients with exercise intolerance, aggressive exercise therapy tends to be difficult. Based on the results of this study, we considered that expiratory activity of lateral abdominal muscles of COPD patients with exercise intolerance is likely to be higher and that exercise tolerance may be improved by reducing the expiratory activity. This is also inferred from studies which have reported that exercise tolerance was improved by respiratory muscle training[14] and respiratory muscle rest by noninvasive ventilation[15]. In these cases, dyspnea would have been alleviated by strengthening respiratory muscles and allowing them some rest, and Tdif, an index for expiratory activity, would have been lowered. Tdif becomes lower when the thickness at the end of inspiration increases or the thickness at the end of expiration decreases. Relaxation and breathing exercises may contribute to lowering Tdif. In other words, the ability to control breathing pattern would contributes to the improvement of exercise tolerance. Further study is required to clarify this.

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