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Surface electromyography activity of the rectus abdominis, internal oblique, and external oblique muscles during forced expiration in healthy adults

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ABSTRACT

We aimed to characterize rectus abdominis, internal oblique, and external oblique muscle activity in healthy adults under expiratory resistance using surface electromyography. We randomly assigned 42 healthy adult subjects to 3 groups: 30%, 20%, and 10% maximal expiratory intraoral pressure (PEmax). After measuring 100% PEmax and muscle activity during 100% PEmax, the activity and maximum voluntary contraction of each muscle during the assigned experimental condition were measured. At 100% PEmax, the external oblique ($p < 0.01$) and internal oblique ($p < 0.01$) showed significantly elevated activity compared with the rectus abdominis muscle. Furthermore, at 20% and 30% PEmax, the external oblique ($p < 0.05$ and < 0.01, respectively) and the internal oblique ($p < 0.05$ and < 0.01, respectively) showed significantly elevated activity compared with the rectus abdominis muscle. At 10% PEmax, no significant differences were observed in muscle activity.

Although we observed no significant difference between 10% and 20% PEmax, activity during 30% PEmax was significantly greater than during 20% PEmax (external oblique: $p < 0.05$; internal oblique: $p < 0.01$). The abdominal oblique muscles are the most active during forced expiration. Moreover, 30% PEmax is the minimum intensity required to achieve significant, albeit very slight, muscle activity during expiratory resistance.

1. Introduction

As the elderly population increases in Japan, respiratory complications arising preoperatively, postoperatively, or during protracted convalescence have become problematic. For example, aspiration pneumonia is associated with reduced swallowing and cough capacity (Ebihara and Ebihara, 2011; Ebihara et al., 2012; Widdicombe et al., 2011; Pitts et al., 2013). Furthermore, cough capacity is reportedly related to expiratory capacity (Pitts et al., 2009; Kim et al., 2009; Kim and Sapienza, 2005; Chiara et al., 2006). Several studies have reported that in patients with cerebrovascular or Parkinson's disease, aspiration pneumonia is associated with decreased expiratory muscle strength (Pitts et al., 2009; Chiara et al., 2006; Pollock et al., 2013). These findings suggest that expiratory muscle training may prevent the development of aspiration pneumonia secondary to various conditions in elderly patients.

Conventional expiratory muscle training has been performed by using incentive spirometers such as threshold PEP (Weiner et al., 2003a; Mota et al., 2007; Battaglia et al., 2009). However, many studies have shown no improvement in expiratory flow rate or respiratory function, both of which are related to expiratory muscle strength (Chiara et al., 2006; Weiner et al., 2003a, 2003b; Mota et al., 2007; Ambrosino et al., 1984). Considering the possible association between expiratory flow rate and respiratory tract infections, including aspiration pneumonia, conventional expiratory muscle training is thought to be insufficient. A thorough understanding of the muscle activation patterns of the rectus abdominis, internal oblique, external oblique, and the transversus abdominis muscles during forced expiration is necessary to determine the issues with conventional expiratory muscle training. To the best of our knowledge, no studies have clearly demonstrated these issues.

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The purpose of the present study was to characterize the activities of the rectus abdominis, internal oblique, and external oblique muscles in healthy adults under expiratory resistance to expose the issues with conventional expiratory muscle training and the results of this study support with the development of new trainings.

2. Methods

2.1. Participants

The subjects were 42 healthy adults with no respiratory, cardiovascular, or musculoskeletal disease. Informed written consent was obtained from all the subjects. The study was conducted at Osaka Prefecture University and Kyoto Tachibana University and approved by the ethical review board of Kyoto Tachibana University (approval No. 14-1).

2.2. Expiratory resistance settings and subject assignment

The subjects were assigned to 1 of 3 experimental groups for observation of abdominal muscle function under the following different maximal expiratory intraoral pressures (PEmax): 30% PEmax, which is equivalent to respiratory muscle training using Threshold PEP (Sasaki, 2007); 20% PEmax, which is equivalent to pursed-lip breathing; and 10% PEmax. The 20% PEmax and 10% PEmax conditions were established based on the intraoral pressure during pursed-lip breathing evaluated in a previous pilot study.

The subjects were assigned to each group by using a random number table and were instructed to perform forced expiration under 2 conditions as follows: the assigned experimental condition and 100% PEmax. Electromyograms were obtained under these conditions.

2.3. Maximal intraoral pressure and expiratory resistance measurements

The patients were placed in a sitting position, and PEmax was measured by using a spirometer (AS-507; Minato Medical Science Co., Ltd., Osaka, Japan). During measurement, the trunk of the seated subjects was separated and isolated from the chair backrest to inhibit abdominal muscular activity associated with longitudinal inclination of the trunk. In addition, the subjects placed both elbows on a table in front of them to prevent trunk flexion. Measurements of PEmax began from full lung capacity. Maximal expiration was performed for 5 s, 3 times in total, and the highest value was designated as PEmax. Values for the experimental conditions (30%, 20%, and 10% PEmax) were calculated accordingly.

2.4. Target muscles for surface electromyography and electrode placement

Surface electromyography was performed on the right rectus abdominis, external oblique, and internal oblique muscles. The musculus transversus abdominis was excluded because it cannot be evaluated using surface electrodes. The electrodes were placed bilaterally, with the subject in a supine position at 3 and 15 cm para-midline of the umbilicus for the rectus abdominis and external oblique muscles, respectively. The electrodes for measuring the internal oblique muscle were positioned bilaterally at the midpoint of a straight line between the umbilicus and anterior superior iliac spine. The earth electrode was installed on the iliac crest. The positive and negative electrode centers were 2 cm apart (Sanchez-Zuriaga et al., 2009) (Fig. 1).

2.5. Surface electromyographic measurement

A spirometer capable of measuring intraoral pressure fluctuations in real time was used to reproduce forced expiration during

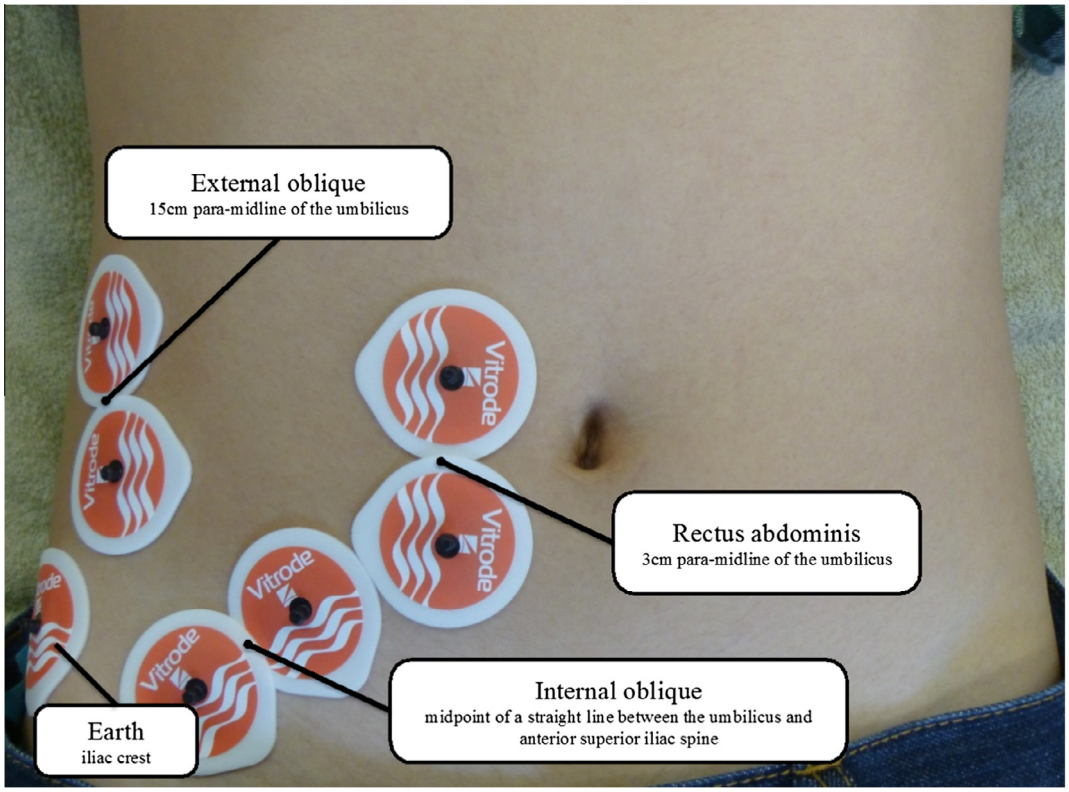

Fig. 1. Electrode placement. The figure was based on the article by Sanchez-Zuriaga et al. (2009).