The Effects of Strength Training of Pelvis Elevator Muscles on Exhalation Capacity in Healthy Men

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Abstract. The effects on expiratory muscle strength and exhalation capacity of increased pelvis elevator muscles strength caused by strength training are not known. Twenty-six male students were randomized to either a training group or a control group. The training group had pelvis elevator muscles strength training twice daily for 4 weeks. At the beginning and end of the study, pelvis elevator muscle strength, maximum expiratory muscle strength (PEmax), and peak cough flow (PCF) were measured, and pulmonary function testing (forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1.0), peak expiratory flow rate (PFR)) was performed. In the training group, significant increases were seen in pelvis elevator muscles strength, PEmax, and FEV1.0; no changes were seen in FVC, PFR, or PCF. No significant correlation was seen between change in pelvis elevator muscles strength and changes in exhalation capacity parameters in the training group. Strength training of the pelvis elevator muscles increases respiratory muscle strength, which would suggest that such training could increase exhalation capacity. However, the increase in pelvis elevator muscles strength that occurred as a result of training could not fully account for the changes in respiratory muscle strength or other parameters of exhalation capacity noted after training.

Key words: Pelvis elevator muscles training, Exhalation capacity, Maximal expiratory pressure

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INTRODUCTION

Difficulty in expectoration caused by neuromuscular and pulmonary diseases, particularly chronic obstructive pulmonary disease (COPD), increases the risk of pulmonary infection due to the accumulation of airway secretions1–5). In patients with respiratory or neuromuscular disease, it is important to maintain exhalation capacity. Exhalation capacity affects coughing, which is a key mechanism for protecting the airways6). The effectiveness of mucus clearance depends largely on peak cough flow (PCF). Weak expiratory muscles result in a decrease in PCF, which reduces cough effectiveness6). Decreased respiratory muscle strength in COPD patients affects not only the inspiratory muscles, but also the expiratory muscles7). In patients with neuromuscular diseases, advanced stages of disease are associated with decreased strength of the muscles used for exhalation, as well as a decrease in vital capacity8, 9). In patients with such diseases, it is important to prevent decreases in expiratory muscle strength.

The quadratus lumborum muscle runs from the ilium to the transverse processes of the 1st to 4th lumbar vertebrae and the 12th rib. The primary action of this muscle is to elevate the pelvis; however, it is thought that the muscle’s anatomical
location allows it to have the counter-effect of depressing the chest. Training the pelvis elevator muscles may thus accelerate airway expiratory flow and increase exhalation capacity.

To examine the effects of pelvis elevator muscles strengthening on exhalation capacity, healthy male subjects had pelvis elevator muscles strength training for a prescribed period of time; changes in exhalation capacity before and after training were then evaluated.

**METHODS**

**Subjects**

The subjects consisted of 26 healthy male students who were given a thorough explanation of the study, both orally and in writing, and who then signed the consent form. Male subjects were selected because neuromuscular diseases, such as muscular dystrophy, myotonic dystrophy, spinal progressive muscular atrophy, and amyotrophic lateral sclerosis, occur only or predominantly in males. The 26 participants were randomized to a training group (n=20) or a control group (n=6), based on the predetermined sample size for the training group. The baseline characteristics of the two groups are shown in Table 1. There were no significant differences between the groups with respect to age or body type.

**Study protocol**

Pelvis elevator muscles training involved maintaining the maximum isometric effort needed to elevate the pelvis against manual resistance for 6 s. This was repeated 10 times each on the left and right sides. No breath-holding was done during training. Subjects had training sessions twice daily, once in the morning and once in the afternoon, for 4 consecutive weeks. The control group received no training during this period. A written questionnaire was used to confirm that the exercise and smoking habits of subjects did not change during the trial. At the beginning and end of the study, pelvis elevator muscle strength, expiratory muscle strength, and PCF were measured, and pulmonary function testing was done.

**Measurements**

A Cybex Norm isokinetic machine (Cybex International, MA, USA) was used to measure pelvis elevator muscles strength (Fig. 1). Measurements were done with the subject lying supine on the flat seat of the machine. One ankle of the subject was connected to the lever arm of the machine using a GF-29 ankle orthosis (OG GIKEN, Okayama, Japan), and the muscular force generated by the pelvis elevator muscles was transmitted to the power head of the device via the lever arm. The distance from the power head to the lever arm was standardized at 0.5 m, and the absolute muscular strength was determined using the equation, torque = force × length, to derive the equation, force = torque/0.5. The subjects were asked to grasp the left and right sides of the seat with both hands and exert their maximum effort to elevate the pelvis for the purposes of measurement. The subjects performed forced pelvic elevations 3 times each on the left and right sides; the mean of the maximum measured values for the 2 sides was used as a representative value.

Expiratory muscle strength was measured using a Vitalo Power KH-101 respiratory muscle dynamometer (Chest, Tokyo, Japan). Measurements were performed as previously described by Black and Hyatt10). Specifically, while sitting and wearing a nose clip, the subject was fitted with a mouthpiece and, at total lung capacity, maximal expiratory effort was sustained for ≥1 s. This method was used to measure mouth pressure 3 times, and the maximum value was used to determine maximal expiratory pressure (PEmax). Pulmonary function tests were done using an Autospirometry System 7 spirometer (Minato Medical Science, Osaka, Japan). While sitting and wearing a nose clip, the subject was fitted with a mouthpiece and asked to exhale as rapidly as possible from maximum inspiration to maximum expiration. Measurements were taken at least twice and up to 4 times if necessary to obtain stable measurements. The parameters that were measured included forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1.0), and peak expiratory flow rate (PFR); the best values were used for the analysis. PCF was determined using the same spirometer used for spirometry. A facemask (size, medium adult; King Systems, IN, USA) was connected so that the mouthpiece of the spirometer did not leak. With the subject sitting, the mouth and nose were covered with the facemask so that no leaks were present, and the subject was asked to produce a strong, forced cough after maximum inspiration. Measurements were
obtained at least twice and up to 4 times if necessary to obtain stable measurements. Good reproducibility was noted for the PCF measurement obtained using the spirometer in our investigation, with an intraclass correlation coefficient of 0.74 for a single measurement and 0.85 for 2 measurements\(^11\).

### Statistical analysis
Mann-Whitney’s U tests were used to compare the 2 groups pre- and post-trial. Wilcoxon signed-ranks tests were used to compare the pre- and post-trial measurements of the 2 groups. Changes from pre- to post-trial were compared between the groups using 2-way repeated measures analysis of variance (ANOVA). The relationship between changes in the pelvis elevator muscles strength (post-trial value – pre-trial value) and changes in the exhalation capacity parameters (post-trial value – pre-trial value) in the training group were examined using Pearson’s product-moment correlation test. Values of p<0.05 were considered statistically significant.

### RESULTS
Pre- to post-trial changes in the parameters that were measured are shown in Table 2. Pre-trial, there were no differences in any of the parameters between the 2 groups. Repeated-measures ANOVA showed no interaction between the training and control groups with respect to pelvis elevator muscles strength, PE\(_{\text{max}}\), pulmonary function, or PCF. Group comparisons showed no significant changes for any post-trial measurements. However, compared with the pre-trial values, higher values of pelvis elevator muscles strength (from 452.20 ±

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### Table 1. Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>Training group (n=20)</th>
<th>Control group (n=6)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>26.1 ± 6.6</td>
<td>26.0 ± 6.1</td>
<td>0.790</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.8 ± 6.2</td>
<td>172.3 ± 5.8</td>
<td>0.836</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.0 ± 7.9</td>
<td>66.2 ± 5.3</td>
<td>0.656</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>22.0 ± 2.3</td>
<td>22.3 ± 1.3</td>
<td>0.533</td>
</tr>
</tbody>
</table>

Data are presented as mean ± standard deviation (SD). BMI, body mass index.

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141.63 N to 568.00 ± 142.57 N; p<0.01), PE\textsubscript{max} (from 143.08 ± 39.58 cmH\textsubscript{2}O to 171.34 ± 46.31 cmH\textsubscript{2}O; p<0.01), and FEV\textsubscript{1.0} (from 3.81 ± 0.50 L to 3.93 ± 0.52 L; p<0.05) were noted post-trial in the training group. In the training group, no differences were seen in the pre- and post-trial FVC, PFR, and PCF values. Moreover, no significant correlation was seen between change in pelvis elevator muscles strength and changes in exhalation capacity parameters in the training group (Table 3).

**DISCUSSION**

This study found that: 1) although strength training of the pelvis elevator muscles increased expiratory muscle strength and FEV\textsubscript{1.0}, PFR and PCF were unaffected; and 2) the degree of pelvis elevator muscles strength increase could not account for the increase in PE\textsubscript{max} or FEV\textsubscript{1.0} seen with training. Furthermore, the degree of the increase in pelvis elevator muscles strength did not explain the changes seen in individual PFR and PCF values, which did not show any overall changes with training.

First, the increase in expiratory muscle strength resulting from strength training of the pelvis elevator muscles suggests that, as has been hypothesized, the quadratus lumborum muscle plays an important role as an expiratory muscle. Abdominal muscles have previously been shown to act strongly during forced expiration and coughing, indicating that these muscles have a primary role in coughing\textsuperscript{7, 12–14}. However, the quadratus lumborum muscle connects a portion of the ilium to the 12th rib, which indicates that, by depressing the chest, it contributes to the increase in mouth pressure that is noted during expiratory effort. Second, strength training of the pelvis elevator muscles increased at least 1 parameter (FEV\textsubscript{1.0}) in pulmonary function testing and PCF measurements. Numerous reports have indicated that training with an expiratory muscle training device, which uses a valve to resist expiration from the mouth, does not affect performance in pulmonary function tests\textsuperscript{7, 15–17}. Although the mechanism remains unclear, the training used in this study had an effect that was different from training with an expiratory muscle training device; our results suggest that the training used in this study increases exhalation capacity. Third, although training increased exhalation capacity as measured by FEV\textsubscript{1.0}, neither the PFR nor the PCF changed. FEV\textsubscript{1.0} represents the total expiratory volume during the first 1 s of the maximal expiratory flow-volume curve, a convex curve the peak of which is PFR. Mean flow rate is lower than PFR. PCF is even higher than PFR\textsuperscript{3}. The increase in expiratory muscle strength appeared to contribute only to FEV\textsubscript{1.0}, during which the flow

<table>
<thead>
<tr>
<th>Table 2. Pre- and post-trial changes in each measurement parameter</th>
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<tbody>
<tr>
<td>Training group (n=20)</td>
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<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Pelvis elevator muscles strength (N)</td>
</tr>
<tr>
<td>pre 452.20 ± 141.63</td>
</tr>
<tr>
<td>post 568.00 ± 142.57\textsuperscript{##}</td>
</tr>
<tr>
<td>PE\textsubscript{max} (cmH\textsubscript{2}O)</td>
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<tr>
<td>pre 143.08 ± 39.58</td>
</tr>
<tr>
<td>post 171.34 ± 46.31\textsuperscript{##}</td>
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<tr>
<td>FVC (L)</td>
</tr>
<tr>
<td>pre 4.42 ± 0.58</td>
</tr>
<tr>
<td>post 4.47 ± 0.52</td>
</tr>
<tr>
<td>FEV\textsubscript{1.0} (L)</td>
</tr>
<tr>
<td>pre 3.81 ± 0.50</td>
</tr>
<tr>
<td>post 3.93 ± 0.52\textsuperscript{##}</td>
</tr>
<tr>
<td>PFR (L/s)</td>
</tr>
<tr>
<td>pre 9.63 ± 1.19</td>
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<tr>
<td>post 9.83 ± 1.30</td>
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<tr>
<td>PCF (L/s)</td>
</tr>
<tr>
<td>pre 9.02 ± 1.24</td>
</tr>
<tr>
<td>post 9.23 ± 1.23</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD. PE\textsubscript{max}, maximal expiratory pressure. FVC, forced vital capacity. FEV\textsubscript{1.0}, forced expiratory volume in 1 s. PFR, peak expiratory flow rate. PCF, peak cough flow.
\textsuperscript{##}p<0.01 comparing post-trial with pre-trial.
rate is relatively low. Parameters with higher flow rates, such as PFR and PCF, were unaffected. A possible explanation for this finding is the fact that training required isometric contraction, making dynamic shortening of the pelvis elevator muscles difficult. As a result, the effects of training did not extend to higher expiratory flow rates.

Regarding the second finding, there appears to be individual differences with respect to the effect that changes in pelvis elevator muscles strength had on the increase in expiratory muscle strength, FEV\textsubscript{1.0}, and expiratory flow rate. The respiratory pattern at rest varies between individuals and the amount and quality of the various respiratory muscles’ actions differ. Similarly, the proportions of the different expiratory muscles related to the various parameters, all of which were exertional, also varied; the quality of the muscles’ actions may also have varied between individuals. This likely explains why, in our study, the changes in strength of the pelvis elevator muscles were not directly reflected in changes in exhalation capacity. A second explanation for the fact that changes in muscular strength did not account for PCF changes in particular subjects is the complex mechanism of coughing. With a normal cough, an initial inspiratory phase is followed by a compression phase in which the expiratory muscles contract with the glottis closed to increase intrathoracic pressure. During the expiratory phase, the glottis opens rapidly, and air in the airways is forced out\cite{10, 11, 12}. During an effective cough, the expiratory flow rate increases and secretions in the airway are moved towards the buccal cavity\cite{13, 14, 15}. Alone, isometric training of the pelvis elevator muscles is unlikely to improve cough force, since in addition to expiratory muscle strength, factors that determine cough effectiveness include: the ability to instantaneously increase intrathoracic pressure\cite{16, 17}; contraction of the expiratory muscles to increase this pressure\cite{18, 19}; timing of glottis opening\cite{20}; and bulbar function\cite{21, 22, 23}.

**CLINICAL IMPLICATIONS**

Expiratory muscle training using a training device for patients with COPD has been found to increase expiratory muscle strength, endurance, and exercise performance\cite{24}. In children with neuromuscular diseases, improvements in respiratory load perception have been reported with inspiratory and expiratory muscle training\cite{25}. A study dealing with the effects of expiratory muscle training on cough efficacy in patients with multiple sclerosis found a significant improvement in cough efficacy with such training\cite{26}. In patients with neuromuscular disease, the PCF is usually 160–270 L/min, and a decrease to 160 L/min can result in viral illnesses\cite{27}. In boys with Duchenne muscular dystrophy with a PCF <160 L/min, coughing is insufficient for mucus clearance\cite{28}. PCF values ≥160 L/min in patients with neuromuscular disease who exhibit respiratory failure are a predictor of successful extubation and decannulation\cite{29}. In patients with advanced COPD or neuromuscular disease, when respiratory function decreases severely, non-invasive ventilation or mechanically assisted coughing is used for sputum expectoration\cite{30, 31, 32, 33}. In patients whose disease has not yet progressed to a relatively advanced stage, physical therapists now introduce huffing and manually assisted coughing\cite{34, 35, 36, 37}. Furthermore, preventing the weakening of expiratory muscles may be effective\cite{38}. In this study, the training of the pelvis elevator muscles increased respiratory muscle strength, and our results suggest that this may have increased exhalation capacity. Thus, the training program used in this study is clinically significant.

**REFERENCES**


2) Hasani A, Pavia D, Agnew JE, et al.: Regional lung


