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Original Article

Effects of fast expiration exercises without pressure on the respiratory muscle strength of healthy subjects

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Abstract. [Purpose] The aim of this investigation was to determine the effects of 4 weeks of fast expiration exercises performed without pressure on respiratory muscle strength. [Subjects and Methods] Respiratory muscle strength of the training group that performed fast expiration exercises (n=12) was compared with that of a control group that performed no exercises (n=12). The fast expiration exercises were performed using a peak expiratory flow meter device and consisted of 20 fast expiration exercises performed 3 times per week for 4 weeks. Maximal expiratory and inspiratory pressures were evaluated as respiratory muscle strength using a spirometer pre- and post-intervention. [Results] There were significant increases in maximal expiratory pressure from 76.9 ± 29.1 to 96.1 ± 37.5 cmH_2O and maximal inspiratory pressure from 80.8 ± 36.6 to 95.3 ± 37.6 cmH_2O in the training group, but there was no significant difference in respiratory muscle strength between pre- and post-intervention in the control group. [Conclusion] Fast expiration exercises may be beneficial for increasing respiratory muscle strength. The findings of this study should be considered when prescribing a variation of the expiratory muscle strength training, as part of a pulmonary rehabilitation program.

Key words: Expiratory muscle strength training, Maximal expiratory pressure, Maximal inspiratory pressure

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INTRODUCTION

Cough serves as an important airway defense mechanism. The effectiveness of cough is dependent on the capacity of the respiratory muscles to increase intrathoracic pressure which generates the requisite cough expiratory flows and airstream velocities[1)]. The contraction of the expiratory muscles increases the intrathoracic pressure, diminishes lung volume, and facilitates expiratory flow. For cough to be effective, the flow caused by the expiratory muscles should be high.

Expiratory muscle strength training (EMST) programs are known to increase the force output of expiratory muscles[2)]. In general, EMST performed using pressure threshold devices strengthens the expiratory muscles by increasing the expiratory load during breathing exercises[3–23)]. The mechanism that creates the expiratory load in pressure threshold devices is a spring-loaded relief valve housed inside the device. The valve blocks the flow of air until sufficient expiratory pressure is produced; then the valve opens, and air begins to flow through the device. The physiologic load on the expiratory muscles can be increased or decreased depending on the device setting. Overload, the basis of strength training, can be accomplished with pressure threshold devices. A few previous studies have described how to blow during EMST[11, 16, 20)]. In these previous studies, subjects were instructed to exhale as hard as possible using a pressure threshold devices[11)], to breathe rapidly with maximal effort[16)], and to blow as forcefully as possible[20)]. If motor units are activated in a task-specific manner, the expiratory muscle activity will differ with the task. However, little is known about the effects of the expiratory flow speed during EMST. Our aim was to study the effects of 4 weeks of fast expiration (FE) exercises performed without a pressure threshold on respiratory muscle strength.

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SUBJECTS AND METHODS

Twenty-six healthy volunteers participated in this trial. The subjects were physiotherapy students attending the Kawasaki University of Medical Welfare. The protocol for the present study was approved by the Ethics Committee of the Kawasaki University of Medical Welfare. Written informed consent was obtained and the rights of the subjects were protected. 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 an acute upper respiratory infection; none of the subjects had participated in a sports activity for more than 3 hours a week in the past year. All of the subjects' pulmonary function measures of percentage of the predicted vital capacity (%VC: vital capacity/predicted vital capacity) and the forced expiratory volume in one second (%FEV_1: forced expiratory volume in one second/forced vital capacity). The values were calculated from measurements made by a multi-functional spirometer (HI-801; Chest Co., Ltd., Tokyo, Japan) and were within the normal range. All the subjects were asked to report any significant changes in their levels of physical activity during their participation in the study.

This study was a prospective cohort study. Measurements of respiratory muscle strength were performed before and after a 4-week intervention. The subjects were randomly assigned to the training (n=14) and control groups (n=12). Practice measurements were performed on all subjects on the day before the baseline in order to avoid possible training and learning effects.

Maximal expiratory and inspiratory pressures (PE_{max} and PI_{max}) at the mouth are most commonly used as noninvasive measurements of respiratory muscle strength[3–23]. PE_{max} and PI_{max} were measured three times using a multi-functional spirometer with an optional respiratory pressure unit. Pulmonary function and respiratory muscle strength were measured using the same spirometer. Subjects sat and wore nose clips during the measurements. PE_{max} was measured using expiration from total lung capacity. For measurement of PE_{max}, the subjects were instructed to inspire fully to total lung capacity, and then to forcefully exhale against an occluded mouthpiece for 3 s. PI_{max} was measured from the residual volume. For measuring PI_{max}, the investigator instructed the subjects to exhale fully to residual volume, then to forcefully inspire against an occluded mouthpiece for 3 s. One-minute rests were taken between the measurements. All the data were collected by the same investigator. The maximum value of the three trials was used in the analysis. Percent changes from pre-intervention respiratory muscle strength were calculated as [(post − pre) / pre respiratory muscle strength × 100] (%).

The FE exercises were performed using a peak expiratory flow meter device (Assess, Full range; Philips Respironics G.K., Tokyo, Japan) for feedback of the performance, and consisted of 20 FE exercises at the subject's own pace to avoid "hard" effort, equivalent to a rating of 15 on the Borg scale[24]. The time duration required for completion of the 20 FE exercises was 3 minutes. The breath that subjects blew into a mouthpiece of the device exited from an opening on the opposite side of the mouthpiece and another vent which was located above an internal piston. The piston moved against a spring during expiration and moved the needle, avoiding the creation of expiratory load. The training was performed 3 times a week for 1 month under the supervision of an investigator. During training, the investigator instructed the subjects to inspire fully to total lung capacity, and then to blow through the mouthpiece as fast as possible. The subjects were told to pay attention to the speed of instantaneous expiration not the volume, and the investigator also instructed that it was not necessary to exhale to residual volume.

SPSS Statistics 23.0 was used for the statistical analysis. Differences in baseline characteristics of the subjects and respiratory muscle strengths between the groups were analyzed using the unpaired t-test. Differences in respiratory muscle strength between pre- and post-intervantion were analyzed using the paired t-test. Values were considered statistically significant at values of $p<0.05$.

RESULTS

Two subjects of the training group withdrew from the study because they had an acute upper respiratory infection during the intervention period. Therefore, the results of the remaining 24 subjects were analyzed.

There were no significant differences between the two groups in terms of age, height, weight, %VC, and %FEV_1 at the beginning of the study (Table 1).

Before the trial period, there were no differences in PE_{max} or PI_{max} between the two groups. At the end of intervention, a significant increase in the PE_{max} and PI_{max} was found in the training group, but not in the control group (Table 2).

DISCUSSION

To our knowledge, this is the first study to show the effects of 4 weeks of FE exercises without pressure on the respiratory muscle strength of healthy subjects. As both VC and FEV_1 were within the normal range, the subjects had normal pulmonary function. The results of this study show that there were significant increases in PE_{max} and PI_{max} at the end of the intervention period in the training group. These results indicate the efficacy of FE exercises in increasing the respiratory muscle strength of healthy individuals.

The increase in PE_{max} between pre- and post-intervention was 30% in the training group. This reflects an increase in

Table 1. Characteristics of the subjects

Characteristics	Training group (n=12)	Control group (n=12)
Age (years)	20.5 ± 0.7	20.7 ± 0.5
Male/Female (n)	6/6	6/6
Height (cm)	161.6 ± 7.6	165.6 ± 10.1
Weight (kg)	54.9 ± 10.5	54.3 ± 7.5
%VC	102.5 ± 12.9	104.1 ± 12.8
$\%FEV_1$	97.2 ± 16.8	98.7 ± 8.8

%VC: vital capacity/predicted vital capacity. $\%FEV_1$: forced expiratory volume in one second/forced vital capacity

Table 2. Mean ± standard deviation of respiratory muscle strength and percent change

		Pre (cmH_2O)	Post (cmH_2O)	Percent change (%)
Training group	PE_{max}	76.9 ± 29.1	96.1 ± 37.5 *	30.0 ± 38.4
	PI_{max}	80.8 ± 36.6	95.3 ± 37.6 *	23.9 ± 29.7
Control group	PE_{max}	68.1 ± 18.3	74.1 ± 19.9	10.8 ± 19.6
	PI_{max}	77.6 ± 31.7	79.5 ± 31.5	4.9 ± 15.8

*$p<0.05$. PE_{max}: maximal expiratory pressure, PI_{max}: maximal inspiratory pressure

expiratory force generating capacity and is comparable to previously reported PE_{max} increases of 27–41% in healthy young adults participating in a 4-week EMST program using pressure threshold devices[11, 22]. These previous studies used the protocol of 5 cycles of 5 expirations through pressure threshold devices, with 75% of PE_{max}[11, 22]. Baker et al.[11] studied the effects of a training frequency of 5 days per week after 4- and 8-week training periods. Anand et al.[22] reported the effects of training frequencies of 3 and 5 days per week after a 4-week training period. The major finding of this study was that 20 FE exercises performed for 3 days per week in a 4-week intervention without expiratory pressure strengthened the expiratory muscles with an effect comparable to EMST which expiratory load.

The training period used in many previous EMST studies was 4 weeks[3, 11, 16, 18–22]. A limb strength training study that demonstrated a significant improvement in strength within 4 weeks indicated that the primary mechanisms influencing muscle strength change during the first 4 weeks of training are neural adaptations[25, 26]. It is possible that strength training causes changes within the nervous system that allow a trainee to more fully activate prime movers in specific movements, and to better coordinate the activation of all relevant muscles; therefore, changes within the nervous system may allow force to be developed more rapidly[26]. These neural adaptations occur as a result of the ability of the central nervous system to respond to changes in functional demands. Hence, in this study, the primary mechanism that influenced a respiratory muscle strength change during the 4 weeks of training may have been neural adaptation. Beyond 4 weeks of training, there is evidence that other mechanisms, such as peripheral or structural changes, may be responsible for improvements in strength. Further studies are necessary to clarify the effects of longer periods of FE exercises.

A few previous studies have indicated that EMST significantly increases inspiratory muscle strength[6, 8], but other studies have reported no significant increase in inspiratory muscle strength after EMST[13, 16]. In this study, FE exercises significantly increased not only expiratory but also inspiratory muscle strength. Increases in activity of the expiratory muscles may expand the diaphragm at residual volume, and improve the length-tension characteristics for generation of pressure required to produce a subsequent inspiration[27, 28]. Our results indicate that FE exercises could increase both expiratory and inspiratory muscle strength. However, there is ambiguity over whether the expiratory muscle activity increased while measuring respiratory muscle strength, because the expiratory muscle activity was not measured in the present study.

The present study had some limitations. First, the sample size was small. Second, all the subjects were healthy young adults. Further studies, using larger and broader samples of asymptomatic individuals with weakness of respiratory muscle strength (e.g. spinal cord injury, chronic obstructive pulmonary disease, multiple sclerosis, amyotrophic lateral sclerosis, and Parkison's disease) are needed to determine whether FE exercises increase respiratory muscle strength. Third, a direct comparison of the effects on the respiratory muscle strength between a group performing FE exercises without pressure and a group performing general EMST using a pressure threshold device was not performed. Accordingly, the effects of FE exercises in combination with a pressure threshold device should be quantified. Finally, the evaluation of the effect was limited to respiratory muscle strength. Influences of the exercise on pulmonary function, exercise capability, and feeling of breathing effort during exercise should also be investigated.

Our results indicate that 20 FE exercises, performed for 3 days per week in a 4-week intervention using a peak flow meter without a threshold pressure load, strengthened not only expiratory but also inspiratory muscle strength. Thus, FE exercises may be beneficial for respiratory muscle strength. The findings of this study should be considered when prescribing a variation of the EMST as part of a pulmonary rehabilitation program.

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